City of Marion

Coastal Climate Change Adaptation Study

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Integrated Coasts

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Final document endorsed at the City of Marion General Council Meeting 27 November 2018

Contents

Executive Summary

The purpose of this scoping study was to review the entire coastline of City of Marion in its physical, historical, and strategic contexts, from which to create a foundation to build a coastal climate change monitoring and adaptation plan. The study has quantified what is already known about the Marion coastline, analysed the implications of these findings for current and future times, and also identified what further data is required to more definitively assess the likely impacts of coastal climate change over the course of this century.

This scoping study forms the foundation of a formal coastal planning process developed by Integrated Coasts. This adaptation planning approach builds on best practice methodology identified by the *National Climate Change Adaptation Research Facility* via *CoastAdapt,* as well as the *Coastal Adaptation Decision Support Pathways Project* developed by the South Australian Local Government Association and the *Coastal Hazard Wheel* framework developed by the United Nations Environment Program. The coastal scoping methodology utilised in this study and the recommendations of this report have been reviewed and endorsed by the Coastal Management Branch at Department of Environment and Water (DEW).

Background

The development of a Coastal Management Plan has been identified in the City of Marion Business Plan 2016-2019 as part of the broader goal for "a healthy and climate resilient urban environment". Early scoping of coastal issues identified the need for this plan to focus on gaining further local understanding of coastal climate change.

Council's overall approach to climate change adaptation is framed by the *Resilient South Climate Change Adaptation Plan.* This plan provides a general framework to understand climate change adaptation needs and priorities across Adelaide's southern region. The City of Marion is currently working with a broad range of government, community and industry partners to implement the plan across four regional foundation projects. A climate change policy has also been adopted by the City of Marion to support integration of climate change principles into local council operations.

Several studies and plans have already been completed by the City of Marion that provide direction for future coastal management planning. In particular, the *Hallett Cove Coastal Management Study 2012* (HCCMS) provides a thorough review of the coastal processes for the Hallett Cove Beach region.

Coastal adaptation context

The primary coastal climate change hazards taken into consideration as part of this study are sea level rise, associated erosion, and possible changes to rainfall patterns.

Conversely, the receiving environments considered in this study, upon which these hazards may impact, are: public assets, private assets, public safety. The impact upon coastal ecosystems is also considered but in a more general sense as to the potential for an ecosystem as a whole to become 'disrupted' over time from rising sea levels and associated erosion[1].

South Australian Coast Protection Board policy provides the statutory context in which coastal planning and adaptation is undertaken in this State. Coast Protection Board has set sea level rise

[1] The concept of 'ecosystem disruption' is found within the Coastal Hazard Wheel methodology that has been recently released by United Nations Environment Program.

policy levels at 0.3m, indicatively by 2050, and 1.00m indicatively by 2100. In this study, the longer-term context of 2100 has been utilised because long-term thinking is required in the context of urban infrastructure where decisions have long-lasting effects.

For the purposes of this study the 7km coastline was segmented into five study cells in accordance with underlying geological types: *Marino Cliffs, Hallett Cliffs, Hallett Beach, Field River, and Southern Cliffs.* First, a desktop study was conducted to establish the historical and statutory contexts, and then a coastal tour was undertaken on foot and from the air. Preliminary risk assessments, using standard risk methodologies based upon *National Emergency Risk Assessment Guidelines* and *CoastAdapt* are provided in this report for the purpose of identifying and categorising coastal risks and adaptation issues.

Summary Findings (Parts 2-4)

When considered in global context where many coastal locations are under considerable threat from inundation or erosion, City of Marion should be considered a 'good news' story. Within the next 100 years, inundation is unlikely to be a major problem for City of Marion. In the geological review where cliff vulnerability was considered using classifications such as 'highly vulnerable' and 'highly resistant', the cliffs assessed in this study fall between these two extremes. The main issue to consider is that projected sea level rise will change the nature of the existing relationship between the ocean and the landforms. The scenario modelling in this study demonstrates where this relationship will change the most, and more importantly, where the fabric of the shoreline is likely to be most vulnerable to that change. In some locations, the base of the cliffs was assessed as being more resistant to erosion, but the tops of the cliffs were assessed as being more friable. The study emphasized the importance of effectively managing storm water runoff in these locations. Ongoing and careful monitoring will identify the early warning signs of any change, and therefore costs to manage these can be kept to a minimum.

More specifically, within the ***Marino Cliffs*** section, significant infrastructure is situated close to cliff escarpments (Marine Parade and Marino Rocks carpark). The study identified one area where further investigation is required. Minor over-topping has occurred on The Esplanade at the northern border of the Council. Increased sea level will exacerbate the potential for further inundation.

The geological review in the context of sea level scenario modelling identified two locations within the ***Hallett Cliffs*** cell which require further investigation (Westcliff area and The Esplanade). The proximity of public and private assets to the tops of the cliffs elevate the need for further study. Improving storm water control in locations where cliff tops are categorised as more friable is recommended.

Within the ***Hallett Cove Beach*** cell Hallett Cove Coastal Management Study (2012) was positive regarding the prospects of the dune system to the west of the Hallett Cove Conservation Park. The scenario modelling in this study tends to support this view. However, storm water has recently begun to erode gullies through the dunes, and although the entrance of sea water into these is unlikely, these dunes would erode quite quickly if this did occur. In the south of this study cell, erosion will continue to threaten the embankment at the base of Heron Way Reserve. The Heron Way Foreshore Masterplan that is currently being developed should consider the scenario modelling from this study and ensure that proposals are carefully designed to cater for projected sea level rises over the coming century. For example, any proposal for a tidal pool should be considered first as an opportunity to manage potential coastal impacts in this region over the coming century.

The ***Field River*** area is unlikely to be susceptible to major inundation over the course of this century. However, historical photographic analysis has demonstrated that the sand spit to the south of the river and the dune to the north of the river have been extensively eroded away. Rising sea levels is likely to continue to erode these away. Private and public infrastructure situated behind these dunes are likely to come under threat over time.

The ***Southern Cliffs*** area to the south of Field River is the least susceptible of all the study sections to coastal processes. Most infrastructure is well set-back from the cliff escarpments. Urban generated storm water does drain through these cliffs at one location and action is recommended to manage the impact of the flow.

Recommendations (Part 5)

This project has established the necessary baseline from which to build a coastal management and adaptation program. The scoping study has now been completed and risks and vulnerabilities assessed. The key recommendations are as follows:

Implement a monitoring strategy as the core of the coastal adaptation and management program. While the science that underpins projections of sea level rise should be regarded as sound, nobody knows when these rises will occur, nor the exact magnitude. Effective monitoring will give the impetus for necessary responses over time, and these responses will be built around accurate historical data, not just based on projected data. The key ingredients of a monitoring program include:

- Using the high definition 3D model as the basis for the program. Data can be recaptured at appropriate intervals and changes assessed.
- Annual and bi-annual inspections of the coastline, and post-storm inspections to ensure that vulnerable locations are monitored for change so that remedial or protective action can be implemented early at low cost, rather than later at sometimes very high cost.
- Involve the community in a citizen science program where people volunteer to take photographs, report, and monitor as required.

Other tasks and strategies include:

- Conduct further investigation to the areas identified in the geological review (3 areas)
- Review and rectify storm water flows in cliff environments, starting with those cliff top locations identified in the geological review as 'friable'.
- Review, design and install protection items to Field River, Heron Way Reserve, and The Esplanade, Marino
- Ensure any changes to planning policy also take into consideration the need to manage stormwater and potential loss of land in the coastal frontline. Increasing urban density and site coverage in coastal areas along with projected increases in rainfall intensity will exaserbate current erosion issues.

Introduction

0.1 Model of Coastal Adaptation

Over the last few years, Integrated Coasts has been a key architect in developing and utilising the Local Government Association's *Coastal Adaptation Decision Pathways* tool[2]. The tool has been successfully used in major coastal adaptation studies for eight settlements around Gulf St Vincent. Based on experiences gained in these studies, and having researched emerging coastal adaptation practice, Integrated Coasts has adopted an amended approach based on three principles.

1. Coastal adaptation takes place in localities.

In comparison to other climate change hazards, sea-level-rise, and associated erosion, is unique. For example, a uniform increase of temperature of 1-2 degrees will uniformly affect a region such as the Fleurieu Peninsula. In contrast, a uniform increase of sea level of 0.5m is likely to produce a vast array of impacts, even within a ten-minute walk along the coast. The reason for the difference in the way that the hazards are experienced is that the impact of sea level rise (and associated erosion) is dependent like no other on the thresholds and tipping points that the geological layout presents at each location. Furthermore, the fabric of the geology, the bathometry of the sea-floor, and the orientation of the coast to wind and wave exposure, all act as modifiers in the way in which sea level rise and associated erosion are experienced. Therefore, coastal adaptation must take place in a fine-grained way that takes the unique nature of sea level rise impact into account. This principle does not infer regional responses are not warranted, but rather that the methodology we employ must be fine-grained and local.

Integrated Coasts has developed a low-cost scoping methodology that will:

- Partition the coastline in accordance with geological features (using standardised nomenclature),
- Scope these partitions and provide preliminary general assessment of risks and vulnerabilities, but also identify 'hotspots' for particular assessment,
- Identify what data is required to more accurately assess vulnerability and adaptation options.

2. Coastal adaptation is on ongoing process.

An approach known as 'pathways adaptation' is the preferred way to undertake coastal adaptation. A pathways approach recognises three main ingredients: uncertainty, time, and triggers or thresholds. All of these ingredients are inherent features of coastal adaptation. A 'pathways' approach also infers the use of 'scenario planning' that identifies plausible futures from which to identify key thresholds and triggers, and then to consider alternative pathways when these are breached. The methodology also infers that monitoring of thresholds will be a main part of the adaptation plan, and not just a minor step in an adaptation study. Finally, a pathways approach infers the creation of a baseline. In ten, twenty or fifty years, on what basis will a determination be made about the rate of erosion, unless we a baseline for comparison?

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[2]Balston, J.M., Kellett, Western, M, J., Wells, G. Li, S., Gray. (2012). *Climate change decision support framework and software for coastal Councils*, Local Government Association of South Australia, Adelaide, SA, and Western/ Kellett (2014) *Dealing with sea level rise on coastal assets*, PPT tool.

The *Coastal Scope* tool recognises that coastal adaptation is a process that will take place over decades, and even centuries, and therefore:

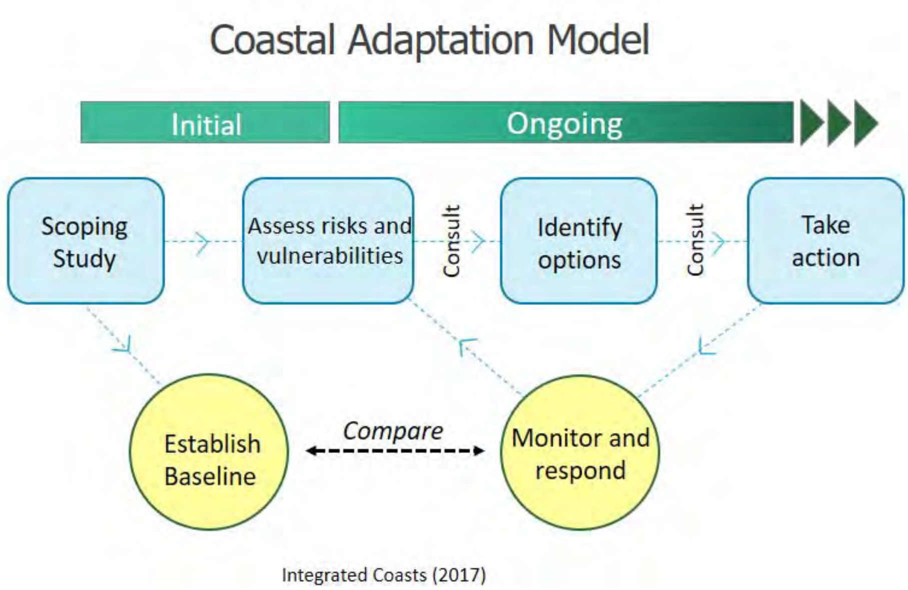
- establishes a current baseline (within a digital environment),
- utilises scenario planning using best available science to envisage plausible futures,
- recognises that monitoring will be a main feature of the coastal adaptation program both to take into account changes in the science, but also changes in the coastal zone.

3. **Coastal adaptation should be initially 'data-driven'.**

Community engagement is best sought once the physical context of adaptation has been established as outlined in (2) above. The first steps in any coastal adaptation process should be to identify the physical baseline, then to conduct scenario analysis to identify plausible futures, and then to communicate these realities to the community. This principle ensures that community engagement is based on informed decision-making, and that community expectations are managed as much as possible within physical realities. If all stakeholders have a shared understanding of the local context then it is more likely they will work together to arrive at common solutions. Therefore, this scoping study does not include any consultation with the community, but rather focusses on identifying and analysing existing data, or makes recommendations and takes steps to acquire data deemed necessary to more fully describe the physical coastal adaptation issues.

These three principles are effectively illustrated in the diagram below.

Figure 1: Coastal adaptation model (Integrated Coasts)



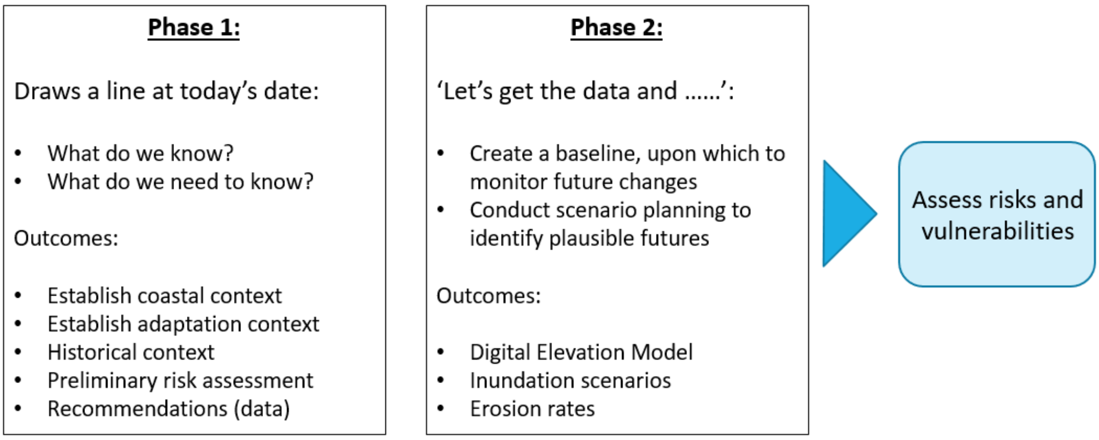
0.2 Coastal Scoping Tool

Taking into account the coastal adaptation strategy outlined above, the scoping study is the first stage in the strategy. The *Coastal Scope®* tool is designed to:

1. Identify the coastal climate adaptation context,
2. Formulate the framework and scope for coastal adaptation study,
3. Conduct a coastal tour to identify the key coastal issues in the region,
4. Provide preliminary assessment of key adaptation issues,
5. Provide the basis for the Council to obtain further funding for specialist areas of study.

The scoping study is conducted in two main phases that culminates with an assessment of risks and vulnerabilities (Figure 2):

Figure 2: The two phases of the scoping study



Specific steps

1. Partition the coastline in accordance with geological layout and sedimentary cells

CoastAdapt has divided the Australian coastline into primary and secondary sediment cells.

This study will further segment the coastline into tertiary cells according to geological layout.

Partitioning the coastline will:

- Create manageable study areas with similar characteristics
- Create regions with similar characteristics for risk assessment procedures
- Form the foundation of a future monitoring program

2. Establish the coastal adaptation context

This section of work is a formalised process within the Coastal Scoping tool designed to 'bring everything into one place' in a standardised manner that is applicable to all Local Councils. This section often draws on existing studies but also requires research within archives held either at Council or within the Department of Environment and Water (Coastal Branch).

This section of work is a thematic study around five contexts:

2.1 Coastal processes

Impacts experienced in the coastal zone are a product of how actions of the sea (tides, wave action, sediment movements and storms) combine over time with the physical features of a coastal area (geology and vegetation). Identifying these general features in the coastal region of the Marion Council is the first step in framing the study.

A review of the larger rainfall catchment areas will also be briefly analysed in the context of their impact within the coastal zone (and any associated studies).

2.2 Climate adaptation context

Changes in coastline profiles have been occurring slowly for thousands of years and human society has always had to adapt to those changes. However, over the last century, the rate of change in sea level and associated erosion has escalated, and that rate of change is projected to further escalate by the end of this century. These trends suggest that significant adaptation will be required within the coastal zone. This section of the study draws on a number of online resources and studies and explains the context in which coastal adaptation will take place.

The Climate Change in Australia[3] website provides updated climate projections for the Onkaparinga region. Periodic reference should be made to this website as part of an ongoing monitoring program to ensure that projections remain current within the Council.

2.3 Strategic context

Within the contexts described above, humans reside, work and recreate. Governments are responsible to manage how humans operate in the context of the natural environment (land use planning and assessment) and are responsible for the safety and well-being of people. Reviewing the strategic context in which City of Marion operates will provide the context for the way in which any changes (adaptation) is to be empowered over time.

2.4 Historical Context

The historical context provides a window into the past. Previous storm events provide a context for understanding current processes and risks. Photographs and community stories provide a context to understand how the coast has changed in the recent past and this will assist in framing the future. A review of approvals for protection works will enunciate the reasons for those works. A historical study may uncover areas in which Council may be vulnerable in a legal sense.

2.5 Technical Context (studies and plans)

Previous studies provide a context to understand what coastal adaptation work has been undertaken, what actions have been taken, and what recommendations other consultants have made.

3. Conduct scenario analysis

[3] climatechangeinaustralia.gov.au

3.1 Initiate the digital model

City of Marion has obtained a suitable digital model captured and prepared by Aerometrex in February 2018. This project will check the accuracy of the model using survey data grounded to the State Government's permanent survey markers.

3.2 Conduct scenario analysis

Conduct scenario analysis to model the existing and future oceanic impact upon cliffs and dunes in a digital environment. This type of analysis is designed as a 'first pass' analysis to: frame the adaptation issues, assist in general risk assessment, identify areas that may require further study and analysis, and feed directly into the planning of a monitoring program (see below). Scenario analysis will assist City of Marion to:

- Identify areas that are not likely to be impacted for 30+ years
- Identify areas that are not currently impacted, but may soon be impacted
- Identify areas that are already impacted (there is likely to be some correlation to the works and reviews conducted at 2.5).

Scenario mapping will be provided for 1 in 100 ARI storm surge scenarios for current, 2050 and 2100 time frames. Scenario mapping will also be created for the high tide regime that is likely to be occurring currently every month or two, and then these will be modelled taking into account sea level rise projections for 2050 and 2100.

3.3 Identify areas of additional study

The outputs of the scenario analysis identify areas where further study is required. In this project, extra study was completed to:

- Identify the nature and height of the storm surge of 9th May 2016 in the Field River area and The Esplanade, Marino.
- Engage a geologist to evaluate the nature of the fabric of the cliffs in the Marino and Hallett Cove regions (Cell 1,2).
- Identify locations and nature of storm water outlets in relation to the coastal environment.

4. Coastal Tour

At this point of the project, a thematic review of the entire Marion coastline within the following categories will have been concluded (Part 2). The purpose of undertaking the contextual review is to 'draw a line in the sand' at today's date and declare, 'this is what we know'.

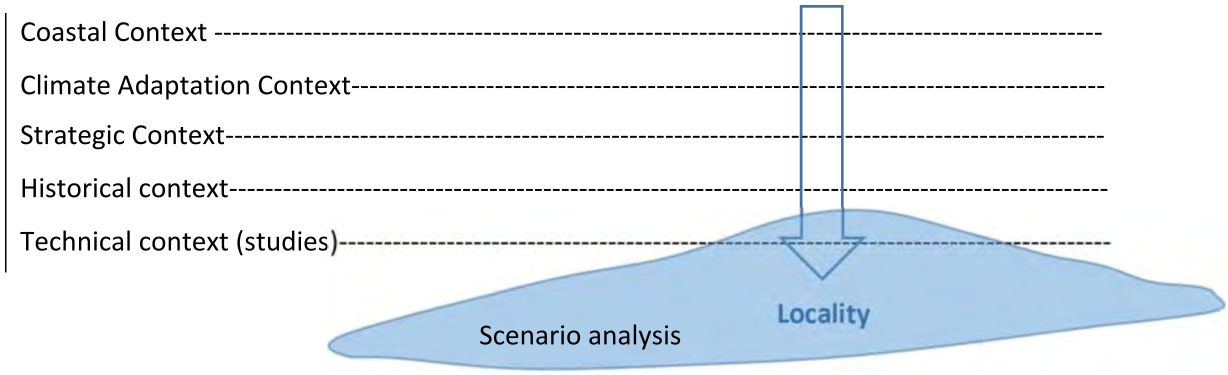
- Coastal context
- Adaptation context
- Strategic context
- Historical context
- Technical context (studies)

Scenario analysis will also have been concluded that has identified areas of the coastline with various impact ratings (Part 3). Geological and storm water reviews would have been completed, as well as historical storm surge analysis.

The coastal tour is the point of the project where attention is focussed 'vertically' at particular locations within the coastline. This methodology is congruent with Integrated Coasts' view that coastal study adaptation is a 'bottom up' process, and not a regional process. Because the features of the coastline may vary significantly within a few minutes walking distance, so too does coastal vulnerability vary. This local nature of adaptation is the reason that coastal study requires partitioning in accordance with geological type.

The positioning of this section in the flow of work is illustrated conceptually in Figure 3.

Figure 3: Conceptual illustration



4.1 Purpose of the 'tour'

The concept of the 'tour' implies both a physical tour and inspection of the coastline, and a tour within the high resolution digital model that was captured in February 2018 using photogrammetry technology.

The reason to retain the word 'tour' is to emphasize the shift to a review of localities in preparation for the risk assessment.

The overall purpose of the tour is to synthesize all of the previous study into localities. For example, having identified coastal localities in the scenario planning as a category 1 (under immediate impact), we are likely to find that these areas have already had attention from Council (as seen in the technical reports), or these may show up in the historical section (as problem areas), or already have had protection works installed. Alternatively, incident reporting within Council may have a record of coastal matters relating to some of these higher impact areas.

In particular the purpose of the tour is to identify:

- All coastal protection structures
- Storm water outlets (in relation to catchment areas)
- Locations where erosion has been evident
- Locations where inundation may have occurred
- The condition of dunes and cliffs (the escarpment)
- Nature of vegetation cover

The output from the tour is contained within 'templates' for each location along the coastline and included in Part 4 of this report.

Step 5: Conduct risk assessment

This section of work considers the findings of Steps 1 - 4, identifies specific data and/or knowledge gaps, and provides a 'second pass' assessment of key vulnerabilities and risks. An inherent hazard rating is assigned to each coastal cell according to geological layout using the methodology explained in Coastal Hazards Wheel[4] (CHW). In addition to that process, risk assessment procedures similar to the City of Marion's Risk Management Framework are utilised to further quantify / qualify risk. The risk assessment was completed in partnership with Integrated Coasts and Marion Council and workshop was conducted at City of Marion on 13th June 2018 with key personnel from various work groups from City of Marion.

The completed risk assessment tables and risk ratings are located in Part 4 of this report.

Step 6: Propose Recommendations:

The final step in the coastal scoping project is to make recommendations where further general or specific work is required. Specific recommendations are made at the conclusion of each of the coastal cells and general recommendations are made in Part 5 of this report.

0.3 Background to this project

The Southern Adelaide region (Holdfast Bay, Mitcham, Marion and Onkaparinga Councils) have cooperated together to produce the Resilient South Climate Change Adaptation Plan (2014). Resilient South, as a regional climate adaptation planning process, has utilised 'higher-level' integrated vulnerability assessments that has provided a general framework to understand climate change adaptation needs and priorities in the region.

Figure 4: Southern Adelaide regional area

Source: Resilient South – climate change adaptation plan

[4] United Nations Environmental Programme (2016) Managing climate change hazards in coastal areas

Future coastal adaptation planning will require a more fine-grained approach because coastal impacts are felt at a very local level, whereas other climate change impacts are felt more regionally.

Due to the particular localised nature of coastal adaptation, it is recommended that a 'bottom up', finegrained approach is utilised in coastal adapation, rather than a regional 'top down' approach. This localised approach does not infer that coastal adaptation should not be conducted as a regional enterprise. Regional approaches may seek to encourage uniform coastal adaptation study methods to provide consistency.

0.4 Hallett Cove Management Plan

One of the purposes of *Coastal Scope* is to identify previous studies and management plans to ensure that future adaptation work is built on the foundation of past work. However, in this project, the Hallett Cove Management Plan[5] should be brought forward as the centre piece of any adaptation work. Although the focus of the study is limited to the Hallett Cove Beach area, this study has drawn together a vast array of previous studies that identify the coastal processes that will apply to the entire Marion Council coastline. Therefore, this scoping study will rely on that study where it speaks about coastal processes.

The Hallett Cove Coastal Management Study (HCCMS) canvases coastal adaptation options for addressing climate change impacts in the Hallett Cove Beach region and recommends that,

> A detailed coastal management strategy/plan needs to be finalised and adopted by the City of Marion, identifying the preferred management approaches for each coastal cell and identifying triggers/timelines for implementation. Funding requirements should be identified and included in Council's long-term financial plan.…The plan and identified future risks should apply across all areas of Council operations (p. 79).

The Hallett Cove Coastal Management Study (HCCMS) also recommends as a high priority that a programme and methodology for monitoring coastal change is adopted to determine changes over time. HCCMS views monitoring as,

> …essential for assessing the impacts of sea level rise and the rate of retreat of the back-beach escarpment and to identify the need for implementation of elements of the coastal management strategy. It is recommended that long-term beach profiles be established in discussion with the Coast Protection Board (CPB) to ensure future monitoring builds on the beach profiling and photographic record they have already established. An additional monitoring program should be developed jointly with the CPB and the community to formally collect and collate data of the beach changes. A likely strategy could include approximately two beach cross-sections (surveyed) and these be augmented with more regular annotated photographs of the beach state or specific areas of interest, building a longer-term database of the area.
>
> HCMP also notes the need for bathymetric modelling of the coastline and recommends that the assistance of CPB be sought to complete this work.

[5] Lord, D 2012, Coastal Management Study – Hallett Cove SA, Coastal Environmental Pty Ltd

0.5 Future study areas.

The purpose of this project is to conduct a preliminary scoping study and therefore the scope and range of the project is to be contained as much as possible. The focus of the study is to identify and document any significant coastal climate change risks in the City of Marion with the view to identifying future adaptation pathways relevant for consideration as part of council operations.

It acknowledged that coastal climate change may have hazards affecting other coastal systems such as terrestrial and marine ecology and changes in coastal culture and heritage, and further study is likely to be required subsequent to this scoping study

1. Partition the coastline according to geological layout

The United Nations Environment Program (UNEP) has developed a simple coastal hazard classification system that is accessible to different coastal management levels, scientists, and policy-makers. The Coastal Hazard Wheel (CHW) system uses a simple standardized universal coastal language and is therefore well-suited as a general information and decision-support system that can be supplemented with other available methods and models when considered appropriate[6].

The CHW method begins by assigning geological layout categories to sections of the coastline. In locations where the characteristics of the coastline change frequently, classifications may change every few hundred metres, whereas in places where the coastal type extends for many kilometres a single classification may apply. The geological layout categories used in the system include: *sedimentary plain, barrier, delta/low estuary island, sloping soft rock coast, flat hard rock coast, sloping hard rock coast, coral island, tidal inlet/sand spit/ river mouth.*

To facilitate the scoping study the City of Marion coastline is broken into study segments that reflect these geological assignments (Fig. 3). See also Figure 7 for assessment of geological features (p.13).

Figure 5: Geological context and sectioning of the coastline for study purposes

[6] Rosendahl Appelquist, L. Balstrøm, T., & Halsnæs, K. (2016). Managing climate change hazards in coastal areas: The Coastal Hazard Wheel decision-support system. United Nations Environment Programme, p. 1

2. Establish the adaptation context

2.1 Coastal Context

Impacts experienced in the coastal zone are a product of how actions of the sea (tides, wave action, sediment movements and storms) combine over time with the physical features of a coastal area (geology and vegetation). Identifying these features in the coastal zone of the Marion Council is the first step in framing the study:

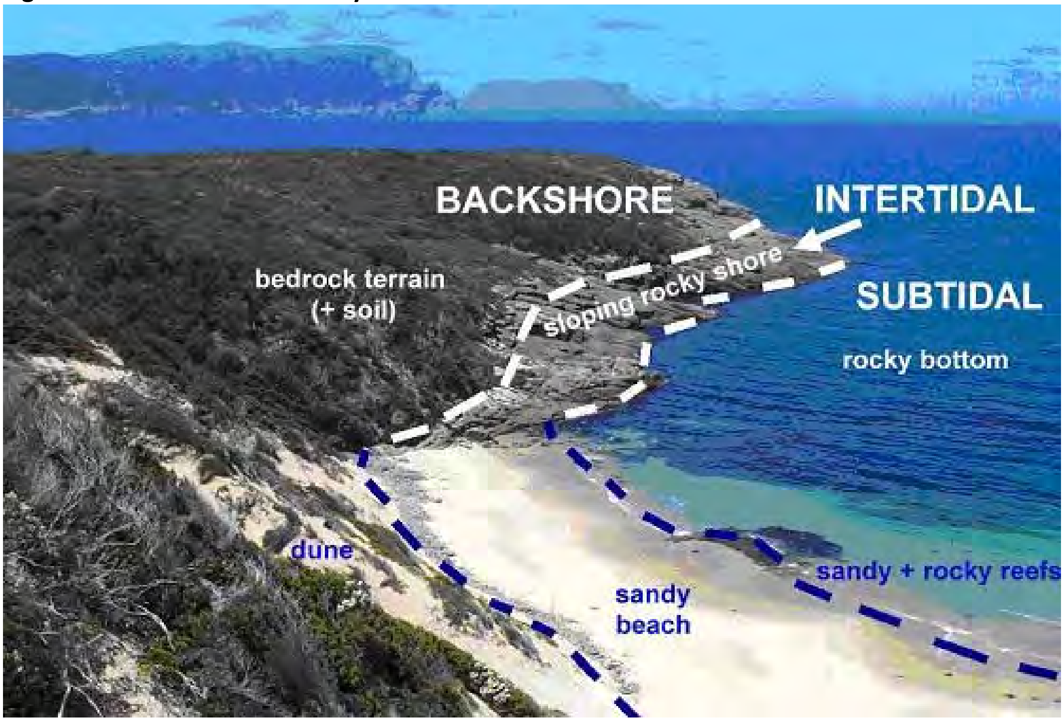
- Geology
- Wave exposure
- Tidal range
- Sediment balance
- Vegetation
- Stormwater outflow

This section of the study uses assessment categories from the United Nations Environment Programme's, Managing Climate Change Hazards in Coastal Areas, but omits 'storm profile' (as this relates to tropical regions) and includes 'stormwater outflow'[7].

2.1.1 Geology

In simple terms, the geomorphology of coasts is classified in three main parallel zones (Figure 6). The intertidal zone in the centre consists of the area between low and high-water marks. The backshore is typically characterised as up to 500m to the land side of the intertidal zone[8].

Figure 6: Coastal classification system

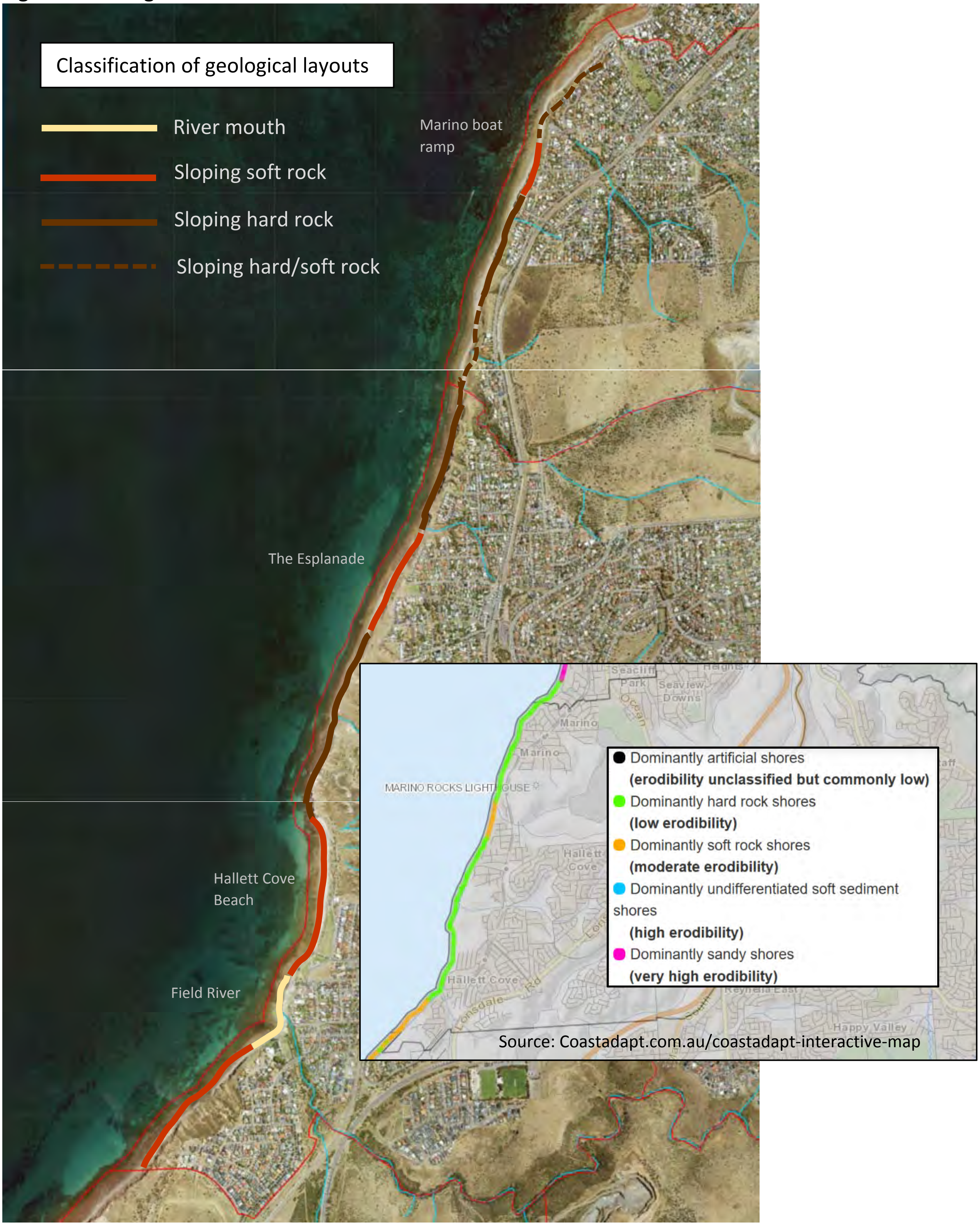


Source: Geoscience Australia, Ozcoasts

[7] One of UNEP's aims in developing CHW was to provide a universal language around coastal adaptation, and therefore this study intentionally adopts introductory text from the CHW manual.
[8] http://www.ozcoasts.gov.au/coastal/introduction.jsp

In more comprehensive studies, these three coastal zones are all assigned a category, and sometimes also sub-categories. In this study, a simple classification is assigned based on Coastal Hazard Wheel methodology (Figure 7). Assignments of classes have been made using Google Earth, site visits, and comparison with other resources such as Smartline (inset) as depicted in CoastAdapt.

Figure 7: Geological classifications



Source: location.sa.gov.au/viewer

Preliminary assessment (first pass)

To facilitate study within geological layout types, the Marion Coastline has been partitioned (Figure 5) in accordance with geological layout according to the classification in Figure 7. The Marion coastline is predominantly a combination of 'sloping hard-rock shores' and 'sloping soft-rock shores'. The Field River area is assigned as 'river mouth'. Hallett Cove Beach does not fall into 'sedimentary plain' classification, and is thus also assigned 'sloping soft-rock shores'.

Generally, the elevated geology of the Marion Council coastline has features that make it less vulnerable to inundation. The Field River area is the exception as a river mouth. The extensive areas of cliff categorised as *sloping hard rock shores* suggest that large sections of the coastline may not be subject to erosion. Areas categorised as *sloping soft rock shores* such as Hallett Cove Beach are more likely to be vulnerable to erosion.

The HCCMS has effectively described the geological circumstances for Cells 3-5 of the coastline and provided an assessment of how landforms might perform over time in relation to climate change impacts (Appendix 1, pp 10-13). A broad geological description of the Marion coastline is provided in Coastal Landscapes of South Australia (Bourman *et al.* 2016) and a detailed description of the Hallett Cove areas described by the Field Geology Club of South Australia & Giesecke (1999).

Geological Assessment (second pass)

As part of the 'second pass' assessment technical input was sought from experts in coastal geology and coastal geomorphology to further quantify regions along the City of Marion Council coastline deemed to require more intensive review. Dr Graziela Miot da Silva completed the main research and review of Cell 1, Marino Cliffs, and Cell 2, Hallett Cliffs. Dr Robert Bourman, who has interacted with the South Australian coastline for his entire career, conducted a peer review of Dr Miot da Silva's work to ensure that in the context of a second pass risk assessment that the review was robust. Their work is contained within a specific geological template in Part 4, and a brief overview of their methodology and general findings are included here.Geological review[9]

Previous studies of cliff vulnerability have indicated that age (via degree of consolidation) and rock type both have a high association with cliff recession rates (Sunamura, 2005). This is the focus of the present work, and it does not include also important geotechnical properties and/or other aspects that could interfere with rock mechanical strength such as presence of joints and faults, degrees of weathering, presence of groundwater etc. In this report, the cliff vulnerability classification proposed includes classes such as "highly vulnerable" to erosion/collapse which would be commonly associated with recent (Holocene) unconsolidated and easily erodible material such as aeolian deposits, and "highly resistant" which is associated with basement rocks such as igneous basalts and granites which have a very low long-term recession rate (Sunamura, 2005). The cliffs assessed in this study fall between these two extremes, they are composed by sedimentary to meta-sedimentary rocks ranging from Pleistocene to Neoproterozoic ages, and although these rocks are not readily erodible such as an unconsolidated sand dune, the presence of rock platforms indicate that cliffs have eroded and retreated in the past ~7000 years since sea level reached its present elevation.

The geological formations and associated rock types composing the coastal cliffs between Marino and Hallett Cove were identified via the South Australian Resources Information Gateway (SARIG)

[9] This portion of the report provided by Dr Graziela Miot da Silva and Dr Robert Bourman.

online portal. This information was complemented with an extensive literature review of the area in addition to field inspection in some cases. Cliff morphology was also assessed according to Emery and Kuhn (1982) as an indicative of the relative importance of marine erosion versus subaerial processes such as weathering (and potential erosion by stormwater flow). The presence/absence of talus deposits, shingle beach and width of adjacent rock platform were analysed during fieldwork and via digital terrain model[10].

[10] Emery, K.O., and Kuhn, G.G., 1982. Sea cliffs: their processes, profiles, and classification. Geological Society of America Bulletin, 93:644–654; Sunamura T., 2005. Cliffs, Lithology Versus Erosion Rates. In: Schwartz M.L. (eds) Encyclopedia of Coastal Science. Encyclopedia of Earth Science Series. Springer, Dordrecht.

2.1.2 Wave Exposure

Synopsis[11]:

The wave exposure is the prime energy source in the nearshore environment and a highly important parameter in the consideration of coastal geomorphology[12]. Although some incoming wave energy is reflected by the shoreline, most energy is transformed to generate nearshore currents and sediment transport and is therefore a key driver of geomorphological change. The height of the wave, defined as the difference between the wave crest and wave trough is the generally applied measure for assessing incoming wave energy. Coastal environments with high wave heights have higher energy intensity compared to coasts with lower wave heights because wave energy increases as the square of the height of the wave.

The main type of waves affecting a coastal system are 'gravity waves generated by wind stress on the ocean'. Gravity waves are generally composed of both sea waves and swell waves. 'Sea waves are formed under direct influence of the wind on the ocean surface and have peaked crests and broad troughs'. Sea waves are often complex with 'multiple superimposed sets of different wave sizes and whitecaps can be present during high wind speeds'. Swell waves develop when the wind ceases and when waves travel outside the area where the wind is blowing. Whether a coast is primarily affected by sea or swell waves is largely determined by coastline geography and the general climatic conditions of a region.

The CHW applies a wave environment perspective and distinguishes between *exposed*, *moderately exposed* and *protected* coastlines based on the wave height. The simplified way of estimating the wave exposure makes use of information on the general wave climate, the waterbody size (fetch length) and the wind conditions (Table 1).

Table 1: Wave exposure classification

General wave climate	Waterbody size (fetch length)	Specific coastal conditions	CHW classification
Swell wave climate (West coast swell, East coast swell, Trade/ monsoon influences)	Any	Extreme swell (West coast swell south of 30°S)	Exposed
		Swell	Moderately exposed
		Backbarrier, inner waters, inner estuary, fjord	Protected
Non-swell wave climate (Storm wave, Tropical cyclone influences, Sheltered area)	> 100 km	Stronger on-shore winds	Exposed
		Weak on-shore winds	Moderately exposed
	10 - 100 km	Stronger on-shore winds	Moderately exposed
		Weak on-shore winds	Protected
	< 10 km	Any	Protected

Source: Coastal Hazard Wheel

[11] UNEP, 2016, Coastal Hazard Wheel Manual pp. 7
[12] CHW uses the term 'Coastal morpho-dynamics' (i.e. the dynamics of beach morphology) refers to the study of the interaction and adjustment of the seafloor topography and fluid hydrodynamic processes, seafloor morphologies and sequences of change dynamics involving the motion of sediment (Coastal Hazard Wheel Manual).

First pass assessment

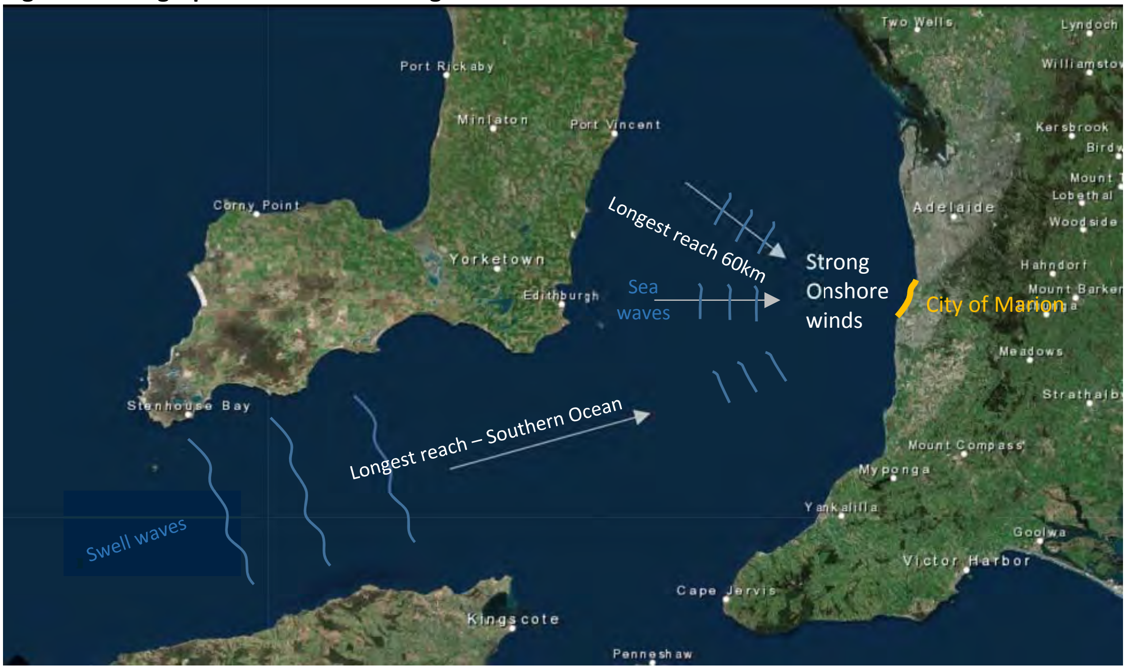
The alignment of City of Marion shoreline tends more to the north-east/ south-west in contrast to Onkaparinga and Adelaide metropolitan shoreline which tends to orientate north-south. Kangaroo Island provides significant protection from the Southern Ocean (Figure 8). The Marion Council region experiences strong on-shore winds from the north-west, west, and south-west. Winds from the north-west and west travel over the shallower waters of the Gulf and for distances less than 100kms. Using the CHW criteria in Table 1, Marion coastline is assessed in relation to wave exposure as:

	Fetch length	Specific Coastal conditions	CHW classification
Swell wave climate	Any	The region does receive swell waves, but Kangaroo Island moderates the exposure	Moderate exposure
Non-swell wave climate (ie sea waves)	Moderately exposed	Fetch length in all directions apart from SW is less than 100kms.	Moderate exposure

Drawing upon numerous sources, the Hallett Cove Coastal Management Study (HCCMS) has thoroughly evaluated the coastal processes in Gulf St Vincent as they impact upon the Marion coastline and should be relied upon in the final coastal adaptation plan (pp 17-26).

Swell waves are generated in the Southern Ocean, but after passing through Investigator Strait, and having 'refracted, diffracted and attenuated due to bottom friction', wave heights are much reduced as they approach the shoreline of Marion coastline. Swell waves that propagate to the Marion coastline region have 12-16 second periods, heights below 1m, and directions close to 260˚.
Sea waves within Gulf St Vincent are generally of short wave period and quite steep, frequently with white caps and approach the shore from the direction of the wind, mostly west-south-west winds, but can roll in at range 250˚ - 310˚. Combine with south-west swells, the net wind-wave direction is northward. Wind waves are generally lower than swell waves but have been recorded at 2.6m in Gulf St Vincent[13].

Figure 8: Geographical and meteorological features of Gulf St Vincent



Source: Map from location.sa.gov.au

[13] See Lord, D (2012) Hallett Cove Coastal Management Study p 22

Storm surge components are not readily estimated as the different driving mechanisms may not occur in any single event and they are independent of wave conditions. Estimates of storm surge at particular locations are based on historical occurrence and calculated from tide height + storm surge height + wave effects (wave setup and wave runup). For design purposes, Coast Protection Board uses 1 in 100 average return interval methodology and has set sea-flood risk levels for the Marion Coastline region as detailed in Table 2:

Table 2: Coast Protection Board sea-flood risk level for Marion Council coastline.

Hallett Cove Beach/ Field River	*AHD*
Storm surge (1 in 100 ARI)	2.3m
Wave setup	0.4m
Wave run-up	1.0m
Total risk height	3.7m

Source: Email James Guy, DEWNR, 13th October, 2017

Flinders Ports operate seven ports in South Australia, and provides further insight into the storm surge characteristics of the region[14]:

> '…the most marked weather effects on the tide occur with the passage of a deep depression across the Southern Ocean. As the barometer starts falling and with the onset of northerly winds the tides are below prediction, but as the wind backs to the north-west, an increase in level occurs[15], with a gradual build-up if the wind remains steady. A strong gusty north-westerly wind, with such as depression, backing to the west south-west at about the time of low water, will cause a storm surge of maximum amplitude, and heights may be expected from 1m to 2m above prediction. These high levels will continue until the barometer starts to rise, and the wind backs rapidly to the south east within 12 hours, and with a rapidly rising barometer the tides return to normal (or below) in about that time'.

In the weather conditions described above by Flinders Ports, storms in the City of Marion region are accompanied by winds generally blowing onshore from the north-west, west, and south-west. More particularly, a north-west wind will tend to be directly onshore, while a south-west wind will tend to drive obliquely across the shoreline (Figure 8).

The highest recorded tide level at Outer Harbour occurred on 9th May, 2016 at 3.80m CD (2.35m AHD). Other key events in recent times are 4th July, 2007 and 25th April, 2009[16].

[14] Flinders Ports (ND) Port User Guide – General Information
[15] Lord 2012, adds that a north-west wind has the effect of banking water against KI which elevates water in the Gulf
[16] Bureau of Meteorology, http://www.bom.gov.au/ntc/IDO59001/IDO59001_2016_SA_TP001.pdf

Historical event assessment (second pass):

One way to quantify the impact of wave exposure upon a coastline is to conduct extreme event analysis. The highest recorded tide level at Outer Harbour occurred on 9th May, 2016 at 3.80m CD (2.35m AHD) and this event interacted with the City of Marion coastline in a significant way. Two sites were selected for review: The Esplanade, Marino, and Field River, Hallett Cove. Eyewitnesses of the events were identified through Council networks for Field River and 'cold' doorknocking was conducted at The Esplanade, Marino. The methodology to establish the likely height of the event was as follows:

Storm Surge: Marino

To calculate the storm surge height at Marino: secondary port relationship methodology was used with Brighton (95%) and wave height of 0.30m added in accordance with storm surge allowance allocated by Coast Protection Board for the Kingston Park Region. The height of this sea-flood event was calculated at 2.47m AHD (without wave-runup) and is depicted with a flood map at Marino 1:1 (See Part 4). The flood map indicated appropriate congruence with the pictures obtained from residents as part of this study (see example at Figure 9).

Figure 9: Storm surge impact at The Esplanade, Marion (17:20, 9th May 2016)

Photograph: Bill and Glenys Summersides of 4 Esplanade at 17.20

A more complete report of the event is found within the templates at Marino 1:1, along with the flood mapping of this event.

Storm Surge: Hallett Cove

To calculate the storm surge height at Marino: secondary port relationship methodology was used with Brighton (95%) and wave height of 0.30m added in accordance with storm surge allowance allocated by Coast Protection Board for the Kingston Park Region. The height of this flood map is depicted at 2.47 (AHD). Wave run up has not been included but depicted schematically with a dotted line. Historical photographs tend to correlate well with this flood depiction.

Figure 10: Storm surge in Field River region (9th May 2016)

Photograph: Bill and Glenys Summersides of 4 Esplanade at 17.50 (but the sky suggests it was earlier)

A more complete report of the event is found within the templates at Field River 4:1, along with the flood mapping of this event.

2.1.3 Tidal Range:

Synopsis[17]:

Tides can have significant impact on shoreline processes and on the development of coastal landforms. Tides are related to the moon's and sun's gravitational force acting on earth's water bodies and are 'present in the form of oceanic waves with wavelengths of thousands of kilometres, resulting in periodic fluctuations in coastal water levels'.

The tidal range controls the horizontal extent of the intertidal zone, the vertical distance over which coastal processes operate and the area being exposed and submerged during a tidal cycle (refer Figure 8). The effect of the tidal range on coastal morphology is largely controlled by the level of wave exposure. Therefore, the relative size of tides and waves of a location is more important than the magnitude of the tidal range itself. In other words, the impact on the coastline of a large tidal range is more benign without the associated impact of high wave exposure.

The tidal range is defined as the height difference between the high water and low water during a tidal cycle.

Tide type	Tidal Range	Examples
Micro-tidal	0 – 2m	Southern seaboard of Australia
Meso-tidal	2m – 4m	Malaysian and Indonesian coasts
Macro-tidal	Over 4m	NW European and NE North American coastlines

Preliminary assessment (first pass)

The effect of tides pushing up through a narrowing Gulf increases the tidal range in the northern parts of the Gulf. In the Marion region the categorisation is borderline in the upper ranges of micro-tidal but assessed as such by Lord 2012.

Climate change is not expected to alter the behaviour of the astronomical tide.

Table 3: Tidal range in Marion coastal region

Level	Chart Datum (m)	AHD (m)
Lowest astronomical tide	0.00	-1.45
Mean sea level	1.30	-0.15
Australian Height Datum	1.45	0.00
Mean high water neaps	1.30	-0.15
Mean high water springs	2.40	0.95

(Hallett Cove Coastal Management Study, 2012)

Tidal assessment (second pass)

Storm surge assessment evaluates the impact of very rare events upon the fabric of the coastline. Equally important is to assess the impact of routine tides upon the fabric of the coastline, especially in the context of rising sea levels. Many parts of the coastline are unlikely to have had any impact of the sea for 7000 years. Rising sea levels will change the way in which the ocean interrelates with the fabric of the various types of landforms.

[17] UNEP, 2016, Coastal Hazard Wheel Manual pp. 9

To calculate the height of a more routine tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for the City of Marion coastal region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been included at 0.7m by way of a dotted blue line. When this tide height was mapped within the digital model it appeared to be congruent with seaward strands that had remained after previous high tides. (However, how the actual impact of the sea upon the coastline may vary from location to location).

Scenarios were conducted for current tidal regime, and then for regimes that take into account projected sea level rise for 2050 and 2100. An example output is displayed in Figure 11. Note the location of the high tide line in relation to existing seaward strands.

Figure 11: Example of routine impact at Marino Rocks carpark (Cell 1:2)

Source: Integrated Coasts 2018

Summary Findings: See more detailed analysis in Part 4

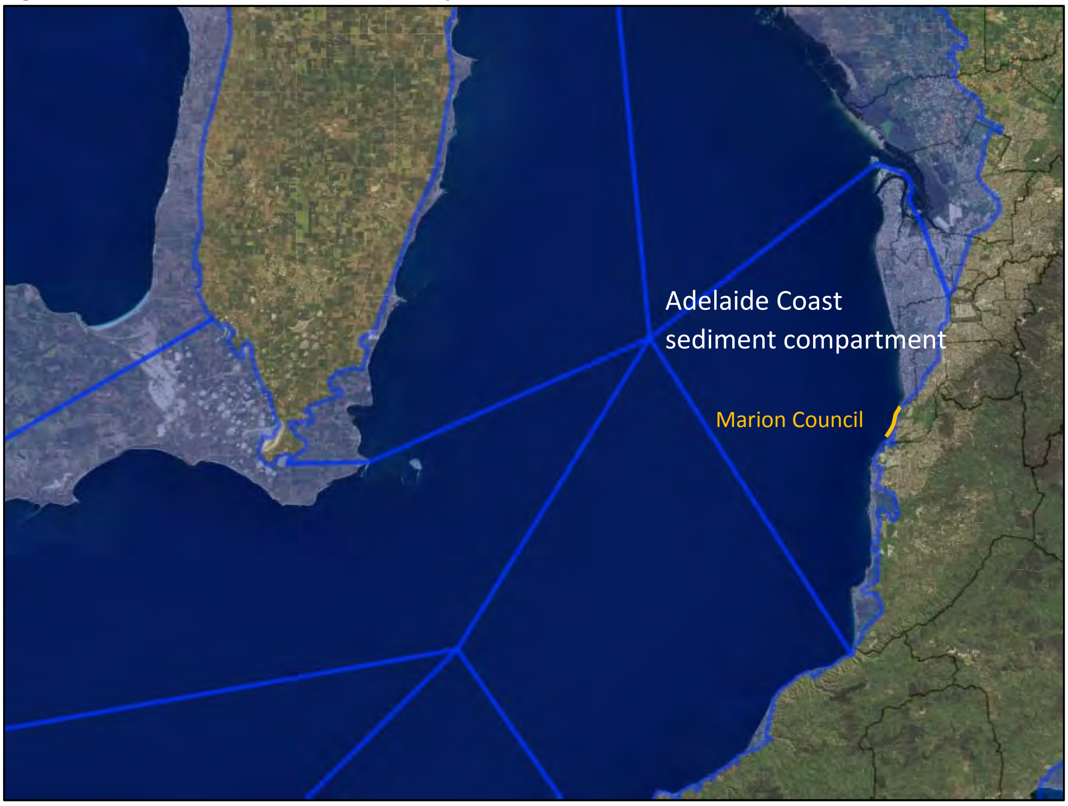
	Location	Current routine tidal regime	2100 regime
Cell 1	Marino Cliffs	The north portion (C1:1,2) has less impact on the coast than in the south (C1:3,4)	All sections will receive high impact from 2100 tidal regime.
Cell 2	Hallett Cliffs	Cells (C2:1, C2:6) are not impacted. The middle sections C2:2-4) all receive high impact from routine tides.	All sections will receive high impact from the 2100 tidal regime (less at C2:1, C2:6)
Cell 3	Hallett Beach	The north portion (C3:1,2) is not currently impacting the dunes. A small portion adjacent ramp in C3:3 is impacted with wave run-up.	C3:1,2 will be impacted by wave run-up only. C3:3,4 will be impacted by tidal action.
Cell 4	Field River	The current routine tide regime is not impacting the coastline	The tidal regime of 2100 will impact the sand spit and sand dune.
Cell 5	Southern Cliffs	The current routine tidal regime is not unduly impacting the coastline.	The high tide regime will impact parts of C5

2.1.4 Sediment Balance:

Synopsis[18]:

The sediment balance is an essential geomorphic parameter and particularly important for coastlines falling into the sedimentary/soft rock categories. The sediment balance determines whether there is a net balance, deficit or surplus of sediment at a location over time and is largely determined by the sediment transport/availability and the relative sea level change. The sediment compartment in which the coastline of City of Marion is located is known as 'Adelaide Coast'[19] (Figure 12).

Figure 12: Adelaide Coast sediment compartment



Source: Coastadapt.com.au/coastadapt-interactive-map

Preliminary assessment (First pass)

Coastadapt's general assessment for the region is,

> 'The dominant regional processes influencing coastal geomorphology in this region are the Mediterranean to humid cool-temperate climate, micro tides, high energy south-westerly swells, westerly seas, carbonate sediments with interrupted swell-driven longshore transport, and the Southern Annular Mode (driving dominant south westerly swells and storms). Regional hazards or processes driving large scale rapid coastal changes include: mid-latitude cyclones (depressions), storm surges and shelf waves'[20].

Overall sensitivity rating has been assigned within *Coastadapt* as 4 (with 1 being low sensitivity and 5 being high sensitivity). The southern section does have areas of resistant cliffed coast, but sediment supply to embayed beaches (such as Hallett Cove Beach) is predicted to decline.

[18] Abridged synopsis from Coastal Hazard Wheel as sediment supply issues are well known in Gulf St Vincent.
[19] See http://docs.coastadapt.com.au/sediment_compartments/SA02.01.04.pdf
[20] See http://docs.coastadapt.com.au/sediment_compartments/SA02.01.04.pdf

Second pass assessment

Due to the proximity of Hallett Cove Beach to the Metropolitan Beaches to the north, the region has been the focus of numerous studies (See Lord 2012, pp 17-20). Drawing upon these sources, the Hallett Cove Coastal Management Study (HCCMS) has thoroughly evaluated the coastal processes in Gulf St Vincent as they impact upon the Marion coastline (pps 17-26) and should be relied upon in the final coastal adaptation plan.

The HCCMS summarises the sediment environment in Hallett Cove Beach region:

> The foreshores of Hallett Cove present as a slowly receding coastline, starved of sediment.. The available coastal process modelling indicates the potential for sand transport out of the Hallett Beach compartment (100,000m^3 / year) is an order of magnitude greater than the natural rate of sand supply along the coastline from the south (5000m^3/ year)[21].

HCCMS also acknowledges:

> While the community perception that the sand cover has reduced over the past 30 years may be true, the likelihood is that over historical times the volume of sand on the beach has always been small and variable, providing a thin sand veneer from time to time over sections of the exposed shingle….[and that] …additional sand cover is unlikely to be a practically achievable outcome (p.v)

The work of Bourman and Harvey showed that over the past 7000 years, since present sea level stabilised, the metropolitan coast has been naturally running out of sand, making the metropolitan coast very vulnerable to the subsequent detrimental impacts of European settlement[22]. Bourman et al also notes that Gulf St Vincent only has 'important rivers such as the Onkaparinga and the Torrens have their outlets on this section of coast, they deliver minimal sediment to Gulf St Vincent'.

Future assessment

The HCCMS did recommend ongoing monitoring of beach processes (see pps iv, 78,79,):

- Ongoing profile monitoring (in conjunction with CPB)
- Bathymetric modelling and monitoring
- Monitoring using photographic analysis

The purpose of these monitoring strategies is to maintain a perspective on the impact that coastal processes are having on the coastal environment over time.

This monitoring may be important if proposals are put to attempt to retain sand on Hallett Cove beach by using groynes or other structures. These structures will only work if some sand is moving north up the Gulf.

2.1.5 Vegetation

Synopsis[23]

[21] HCCMS suggests that this calculation is based on modelling at O'Sullivans Beach boat ramp.
[22] Coastal Landscapes of SA, p. 66
[23] From: UNEP, 2016, Coastal Hazard Wheel Manual pp. 10,11

For some coastal environments, vegetation[24] constitutes an important parameter for their characteristics and hazard profile. In the Coastal Hazard Wheel system, vegetation is to be assessed where it is considered to play an important role for the coastal characteristics. The integration of the flora/fauna component in the classification system is complicated by its interdependence with other physical classification parameters and this is reflected in the application of the vegetational categories. In total, the classification system operates with nine different categories namely *intermittent marsh; intermittent mangrove; marsh/tidal flat*; *mangrove/tidal flat*; *marsh/mangrove*; *vegetated*; *not vegetated*; *coral* and *any*. The *vegetated* and *not vegetated* categories are applied to the geological layout category *sloping soft rock coast* where vegetation of the coastal slopes plays an important role for the coastline characteristics and determines whether it can be considered a coastal cliff. The *vegetated* category is applied when more than 25% of the initial coastal slope is covered with vegetation while the *not vegetated* category is used when less than 25% of the initial slope is vegetated. Possible vegetation includes different grasses, scrubs and trees depending on the soft rock properties, slope and climatic conditions.

Although some types of vegetation have a better stabilizing effect than others, the important criteria from a coastal classification perspective is whether the coastal slope is vegetated or not.

Preliminary assessment

There has been no specific assessment in relation to the stabilising effect of vegetation on dunes and cliffs in the Marion region. Four studies have reviewed vegetation in the Hallett Cove region and may be useful resources for future assessment:

- Hallett Cove Coastal Management Study[25] (2012)
- Hallett Cove Creeks Stormwater Management Plan (vegetation in the context of stormwater manage p. 59)[26]
- Coastal Management Strategy (1997) (Appendices)[27]
- Develop a coastal rehabilitation strategy. Lee Jeffery (2014)[28]
- City of Marion Draft Remnant Native Vegetation Plan [29]
- Metropolitan Adelaide and Northern Coastal Action Plan (MANCAP) [30]
- Hallett Cove and Marino Conservation Parks Management Plan[31]

Future assessment

In areas that become subject to coastal erosion, future studies on vegetation may be required to further understand their role in protection of coastal landforms, particularly in the dune areas of Hallett Cove Beach as identified by Lord (2012).

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[24] CHZ uses the term 'flora/fauna' because it also incorporates a review of coral systems. In the context of this study the term 'vegetation' is utilised.
[25] HCCMS did review vegetation but made no connection to coastal adaptation management.
[26] Southfront (2012) Hallett Cove Creeks Stormwater Management Plan
[27] Kinhill Engineers (1997) Draft Coastal Management Strategy
[28] Jeffery L (2014) Develop a coastal rehabilitation strategy
[29] City of Marion (2017). *City of Marion Remnant Native Vegetation Plan*. Adelaide, South Australia
[30] Caton, B., Fotheringham, D., Krahnert, E., Pearson, J., Royal, M. and Sandercock, R. (2009). *Metropolitan Adelaide and Northern Coastal Action Plan*. Prepared for the Adelaide and Mount Lofty Ranges NRM Board and Department for Environment and Heritage
[31] Department for Environment and Heritage (DEH) (2010). *Hallett Cove and Marino Conservation Parks Management Plan.* Adopted by Minister for Environment and Conservation. Adelaide South Australia.

It is also noted that several areas of the Marion coast contain species and ecological communities of conservation significance (City of Marion 2017; DEH 2010; Caton et al. 2009). Beyond the scope of this study, further analysis of the threats to these communities and future adaptation pathways may be needed.

2.1.6 Stormwater flow paths to coast

Many storm water outlets drain directly to the sea from City of Marion rainfall catchment areas. Some outlets to the coast are open drains or creeks, while others begin as open drains but are connected to the coast by way of pipes.

First pass assessment

The main ones are identified on the maps below (Figures 13-y). Note: The streamorder assignment recognises the number of tributaries that flow into the system. Streams with higher numbers may indicate large catchment systems.

In 2012, Southfront completed the Hallett Cove Creeks Stormwater Management Plan[32] and is referenced in this section where appropriate (See also Technical Context).

Cell 1: Marino Cliffs

Figure 13: Stormwater flow paths in Section 1 (Marino Cliffs)

Source: location.sa.gov.au

Cell 1: Marino (Cliffs)

	Watercourse name	Location	Streamorder	Nature of outlet
1:1	Unclassified	Holdfast border	2	Pipe
1:2	Unclassified	Marino boatramp	2	Pipe

[32] Southfront (2012) Hallett Cove Creeks Stormwater Management Plan

Cell 2: Hallett Cove (Cliffs)

Figure 14: Stormwater flow paths in Cell 2

Source: location.sa.gov.au

Cell 2: Hallett Cove (Cliffs)

	Watercourse name	Location	Streamorder	Nature of outlet
2:1	Unclassified	Perry Barr Rd/ Westcliff	3	Open creek
2:2	Unclassified	The Esplanade	2	Open creek
2:3	Waterfall Creek	Conservation Park	2	Open creek

The Waterfall Creek catchment area was defined by Southfront in the 2012 study in Figure 15.

Figure 15: Waterfall Creek Catchment area

Source: Southfront (2012), p. 47

Cell 3: Hallett Cove (Beach)

Figure 16: Stormwater flow paths in Cell 3

Source: location.sa.gov.au

Cell 3: Hallett Cove (Beach)

	Watercourse name	Location	Streamorder	Nature of outlet
3:1	Unclassified	Heron Street	1	Piped

The Heron Way stormwater catchment area was defined by Southfront in the 2012 study (Figure 17)

Figure 17: Heron Way stormwater catchment area

Source: Southfront (2012), pp 48

Cell 4: Field River Area

Field River was not part of the stormwater catchment area in the Southfront study (2012). The Field River largely forms the border between City of Marion and Onkaparinga Councils and most of the catchment area is within Onkaparinga Council.

Figure 18: Stormwater flow paths in Field River area

Source: location.sa.gov.au

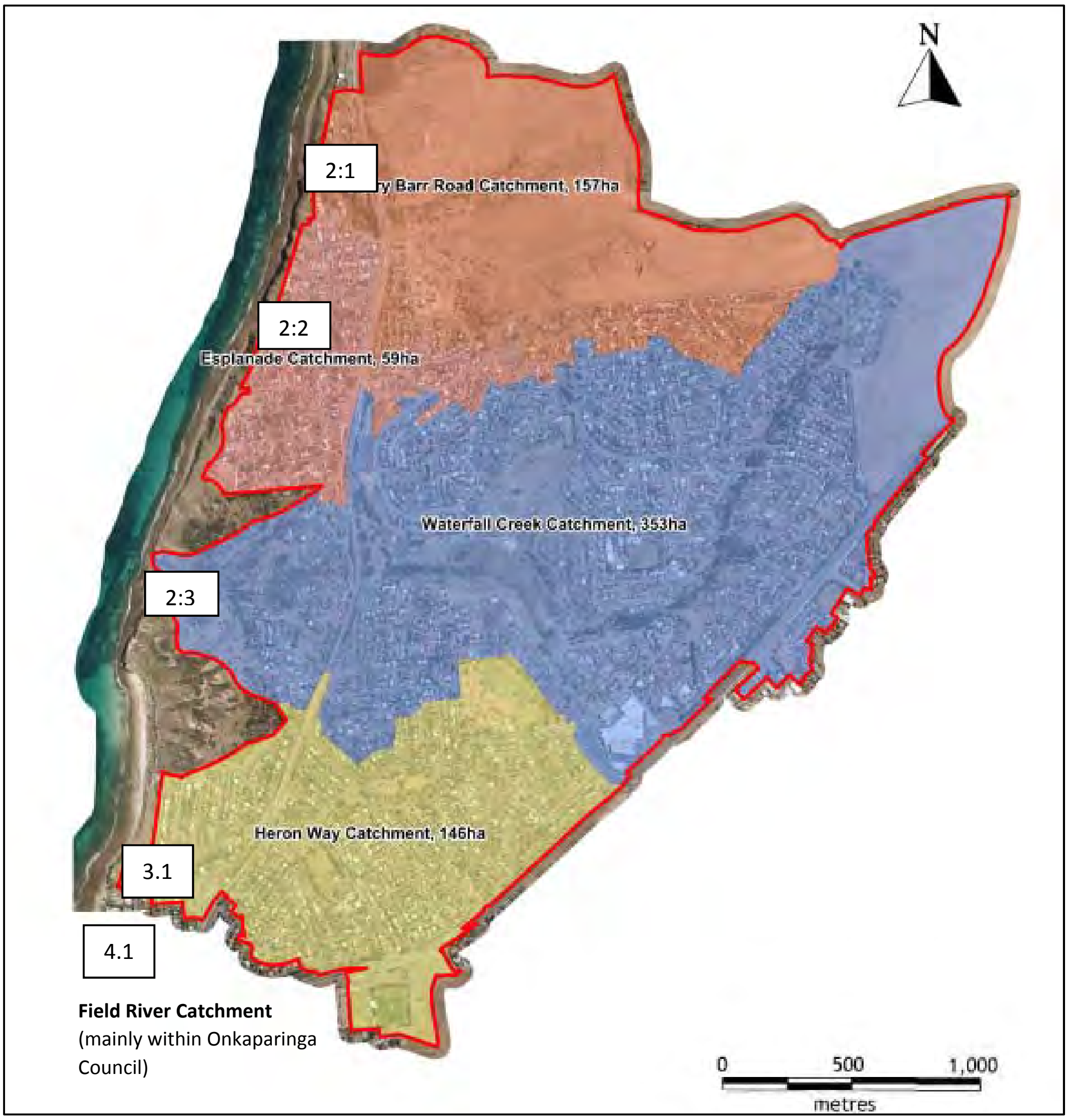
Cell 4: Hallett Cove (Field River)

	Watercourse name	Location	Streamorder	Nature of outlet
4:1	Field River	River Parade	4	Open

Cell 5: Southern Cliffs

There is no publicly available information regarding the disposal of stormwater in relation to the coast for Cell 5. A stormwater audit in the next section of work will quantify where storm water is discharged in this coastal region. Southfront depicted the various catchments in Cell 2 (Hallett Cove: Cliffs) and Cell 3 (Hallett Cove: Beach) in Figure 19. (Integrated Coasts has added outlet labels from above, and the location of the Field River catchment area).

Figure 19: Catchment areas in relation to coastal outlets



Source: Adapted from Southfront (p 3).

Storm water Assessment (Second pass)

A review of the Council storm water system in the coastal zone was conducted using Map Info. Maps were produced and inserted into the coastal templates. A review of storm water outlets was conducted using the digital model. An interview as conduced with relevant staff on 11th June 2018 at City of Marion.

Findings:

The detailed findings are recorded within the templates (Part 4).

The following general observations are made:

- In many locations storm water was being fed into the gullies and flowed out to the coast. Preliminary feedback suggest that there did not appear to be any particular problem to this approach apart from increased erosion of the gully base down to bedrock at which time erosion halted. Visual inspection of the locations where water flowed across the shingle beach did not appear to show signs of excessive erosion.
- In some locations, water is being piped to the edge of the cliff and allowed to flow over. Work is underway to provide dissipation devices at some locations. Some of these locations are areas of small catchment.
- The geological study did highlight several locations where the top of the cliff was deemed as 'friable' and 'likely vulnerable' to erosion.

Recommendation:

Further research and analysis is required to ascertain the nature of storm water flow over cliff areas, especially now in areas identified as 'likely vulnerable' to erosion.

The ongoing impact of storm water systems upon the coastal zone should be taken into account for ongoing coastal management in the following ways:

1. Possible confluence of stormwater with sea-water inundation in a storm event in the Field River and how this may increase erosion, damage, and danger to public safety,
2. Increase erosion of shorelines (and therefore make them less stable over time)
3. Impact on receiving environments including terrestrial and marine ecosystems.

2.1.8 Summary: Coastal Context

Coastal Context	Summary

Geological	Marion Council is categorised predominantly as a combination of ‘likely vulnerable, and likely resistant’ rocks. In the middle of very vulnerable and very resistant.
Wave Exposure	Generally categorised as Moderate Exposure. HCCMS provides comprehensive review.
Tidal Range	Micro-tidal (bordering on meso-tidal), but does not have major bearing on sediment supply or storm characteristics.
Sediment Balance	Deficit (much less supply coming up the Gulf) than will proceed from the region.
Vegetation at shoreline	The impact of vegetation in relation to coastal change and adaptation has not been assessed.
Storm water management	Four main catchment areas in Cells 2-5. Some work has been done in containing storm water outflows, but further research and remediation is required, especially in locations where geological assessment categorised as ‘likely vulnerable’.

Inherent hazard assessment:

The following inherent hazard categories apply to Cells 1,2,3,5:

Hard rock sloping shores Class- (R-1)

	Low	Moderate	High	Very high
Ecosystem disruption	X	2	3	4
Gradual inundation	X	2	3	4
Salt water intrusion	X	2	3	4
Erosion	X	2	3	4
Flooding	X	2	3	4

Soft rock sloping shores Class (SR-10)

	Low	Moderate	High	Very high
Ecosystem disruption	X	2	3	4
Gradual inundation	X	2	3	4
Salt water intrusion	X	2	3	4
Erosion	1	X	3	4
Flooding	X	2	3	4

The Field River (C4) is a narrow river set down in a deep gully. Modelling indicates that a current 1 in 100 ARI storm event would not penetrate as far as the road bridge. Because of the nature of this river the inherent hazard rating is set lower than a wider river with a large flood plain.

River Mouth Class (TSR)

	Low	Moderate	High	Very high
Ecosystem disruption	X	2	3	4
Gradual inundation	X	2	3	4
Salt water intrusion	1	X	3	4
Erosion	1	2	X	4
Flooding	1	X	3	4

2.2 Climate Adaptation Context

Section two deals with the climate adaptation context in which Southern Adelaide is located.

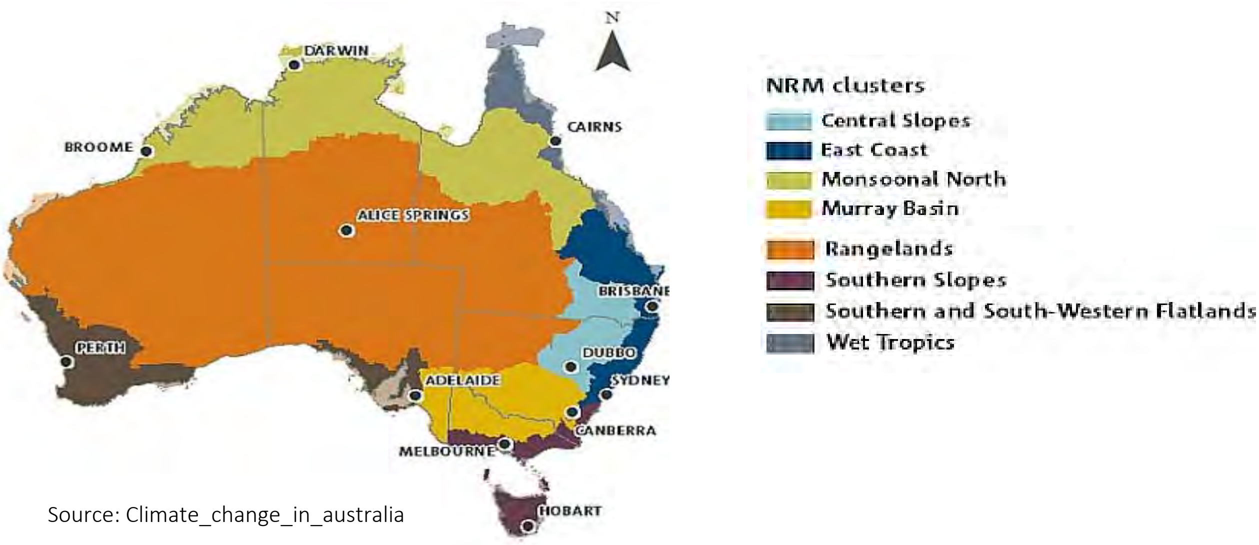
2.2.1 Climate Projections

General Circulation Models (GCMs) have been developed that are three-dimensional numerical models that take into account mass and energy transfer and radiant exchange and used to create projections that simulate the climate. The models are developed to mirror complex natural climate processes; while we are getting better at understanding some of these processes, there are still some things we cannot yet accurately explain, and this creates a measure of uncertainty. The models also need, as an input, information about our expectations of how greenhouse gas emissions will change in the future. This relies on predicting what direction government policies will take and the success of attempts to meet greenhouse gas emissions targets, again introducing considerable further uncertainty. Globally, projections are assembled through the Coupled Model Inter-comparison Projects (CMIPs) and evaluated by the Intergovernmental Panel on Climate Change (IPCC) in its assessment reports. The most recent models are called CMIP5. The CMIP5s are built on four future emission scenarios called the Representative Concentration Pathways (RCPs)[33].

In Australia, using the GCMs, projections have been produced at both national and regional scales by CSIRO and the Bureau of Meteorology (BoM) and by state governments or their agencies. Climate projections are spatially focussed around natural resource management regions (or clusters) for which information, data and reports are available. These regions are separated into four super clusters, eight clusters, and fifteen sub-clusters. Climate projections are given within the time frames of 2050 and 2090.

Southern Adelaide is located in the Southern and South-Western Flatlands Natural Resource Management Cluster[34].

Figure 20: Climate change modelling regions in Australia



Source: Climate_change_in_australia

[33] https://coastadapt.com.au/sites/default/files/information-manual/IM01_Building_the_Knowledge.pdf
[34] Climatechangeinaustralia.gov.au

The Australian Government *Climate Change in Australia*. program provides climate change projections which can be used to assist in planning climate change adaptation over time (see p 29). The designation of Southern Adelaide within the existing sub-cluster of Southern and South-Western Flatlands (East) is unlikely to change. Over time as more data is collected, these climate change models are likely to become more accurate, and the projections moderated accordingly.

Climate Change in Australia provides the following key messages for the sub-cluster in which Southern Adelaide is located[35]:**Table 4: Climate Projections for Southern and South-Western (Eastern sub-cluster)**

Climate parameter		Confidence
Temperature	Average temperatures will continue to increase in all seasons	Very high confidence
	More hot days and warms spells projected	Very high confidence
Rainfall	A continuation of the trend of decreasing winter rainfall projected	High confidence
	Spring rainfall decreases are projected	High confidence
	Changes in other seasons unclear, although downscaling results suggests a continuation of the observed autumn declines	Unclear
	Increased intensity of extreme rainfall events is projected	High confidence
Sea level rise	Mean sea level will continue to rise	Very high confidence
	The height of extreme sea-level events will increase	Very high confidence

Contextual note from Climate Change in Australia: On annual and decadal basis, natural variability in the climate system can act to either mask or enhance any long-term human induced trend, particularly in the next 20 years.

Particularly in relation to extreme rainfall events

Climate Change in Australia states:

> Increased intensity of extreme rainfall events is projected, with *high confidence*.
> Even though annual mean rainfall is projected to decrease in the region, understanding of the physical processes that cause extreme rainfall, coupled with modelled projections indicate with high confidence a future increase in the intensity of extreme rainfall events. However, the magnitude of the increases cannot be projected[36].

[35] https://www.climatechangeinaustralia.gov.au/en/climate-projections/
[36] https://www.climatechangeinaustralia.gov.au/en/climate-projections/

Particularly in relation to sea level rise

Two tidal gauges at Port Stanvac (currently decommissioned), and at Thevernard west of Ceduna, as part of the national SEAFRAME project have been collecting tidal data since 1990. These gauges remove the 'noise' from the movement of the sea and the land and calculate changes to mean sea level over time. The data from both of these gauges provide clear evidence that sea level rise from 1990 to 2010 has been an average of 4.3mm per year (Figure 21). By comparison, longer term monitoring from the gauge at Pt. Adelaide which has over a hundred years of data, indicates that the rate of increase over the last century was an average of 1.5mm per year. This data indicates that sea levels in the region are rising and that the rate of rise has increased over the last thirty years.

If the current rate of sea level rise remained reasonably constant until 2050, a simple multiplication of 4.3mm x 60 years suggests an increase in mean sea level of 258mm which is comparable with the 300mm (0.3m) rise that SA Coast Protection Board has incorporated into its policy framework.

Figure 21: Tidal gauges at Thevernard and Pt Stanvac have recorded an average rise of 4.3mm[37]

Source: Bureau of Meteorology

In the Field River region of Marion Council, Coast Protection Board has assigned the following sea-flood risk ratings:

	Current	2050 risk	2100 risk
Storm surge	2.3m AHD	2.6m AHD	3.3m AHD
Wave set-up	0.4m	0.4m	0.4m
Wave run-up	1.0m	1.0m	1.0m
Total Risk	3.7m AHD	4.0m AHD	4.7m AHD

[37] Bureau of Meteorology, 2013

Assessment Parameters

The purpose of the scoping study is to undertake a preliminary evaluation of the coastal zone in the context of coastal adaptation. Therefore, it is recommended that only a few coastal hazards be selected, and those that relate primarily to coastal adaptation. Three climate change hazards have been selected for this study:

- Increase in sea level (because a coastal adaptation study should include scenario assessment of sea level rise)
- Increased erosion (because erosion is already having an impact on Hallett Cove Beach. It is also possible that erosion is having an impact on the base of cliffs, but this is unknown)
- Increase rain intensity (because storm water outflows to the sea are already having an impact on cliff and dune erosion).

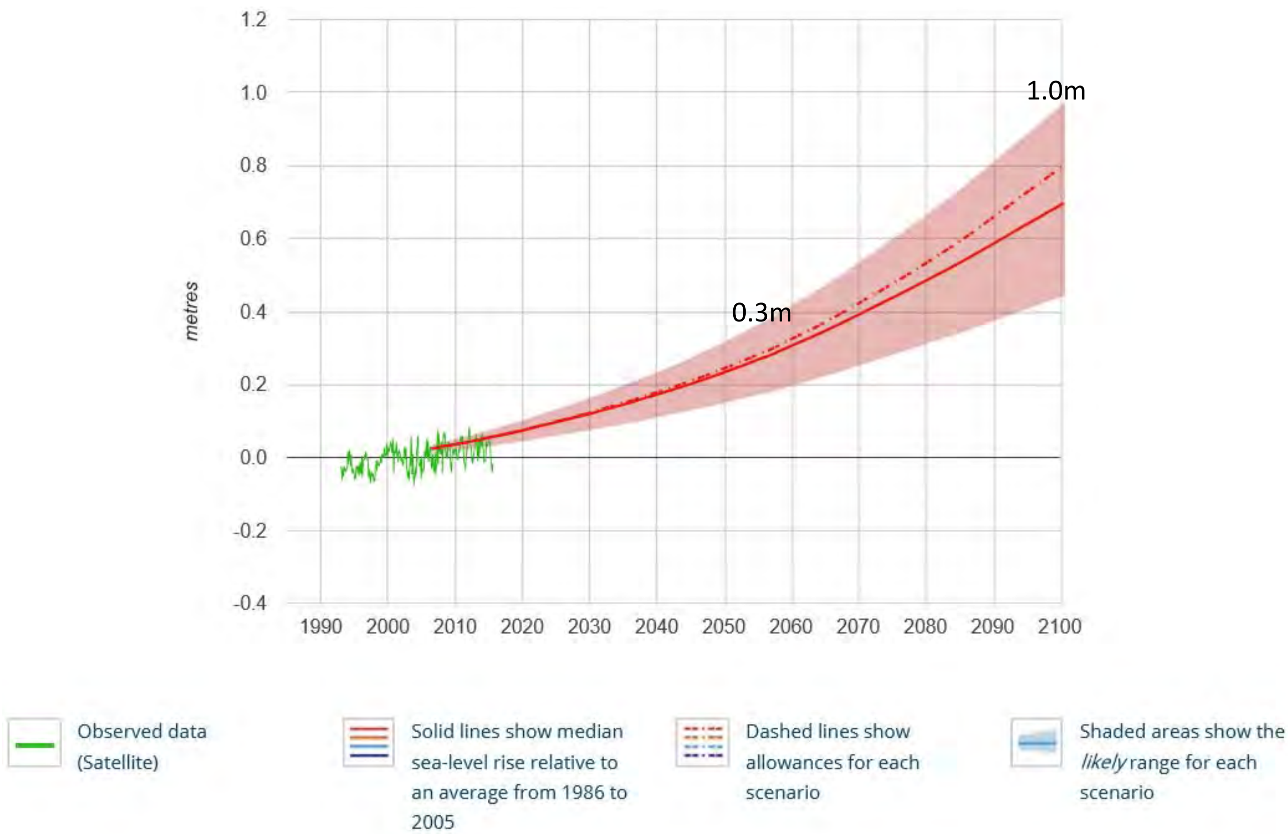
2.2.2 Emissions scenarios (RCPs):

The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) in 2014 identified four emissions scenarios to frame projected climate futures. These are known as Representative Concentration Pathways (RCPs) and are framed by *CoastAdapt* in the following manner:

RCP 8.5 Very high emissions pathway
RCP 6.0 High emissions pathway
RCP 4.5 Moderate emissions pathway
RCP 2.6 Low emissions pathway

This scoping study has chosen RCP 8.5, very high emissions pathway, because the sea level rise projections are most congruent with Coast Protection Board's sea level rise planning benchmarks of 1.0m rise by 2100 as illustrated in Figure 22 adapted from CoastAdapt[38].

Figure 22: Projected sea level rise for RCP8.5 (with CPB policy levels)



Source: Adapted from Coastadapt (https://coastadapt.com.au/sea-level-rise-information-all-australian-coastal-councils)

[38] CoastAdapt, Shoreline Explorer, accessed August, 2017

2.2.3 Adaptation time frames:

South Australian Coast Protection Board since 1992 has incorporated sea level rise bench marks into statutory planning processes. Councils are required to assess any new development within 2050 and 2100 time-frames. The current sea level rise planning benchmarks are:

- 0.3m sea level rise (within indicative time frame of 2050)
- 1.0m sea level rise (within indicative time frame of 2100)

These time frames are also more congruent with the Climate Change in Australia time scenarios mentioned above at 2050 and 2090 into which climate change projections will be updated over time. It is therefore recommended that any future scenario planning and/or adaptation planning utilises the following time frames:

- Current risk
- 2050 risk
- 2090/ 2100 risk

2.2.4 Receiving environments

Coastal hazards have impacts on receiving environments that can be divided into primary and secondary categories. Examples of primary receiving environments are:

- Publicly owned infrastructure (roads, parks, foreshore assets, buildings)
- Privately owned infrastructure (normally land and buildings)
- Safety of people (for example, in a storm surge event)
- Coastal eco-systems (beaches, dunes, flora and fauna)

To provide an illustrative example of secondary receiving environments the following scenario could play out at any number of settlements around South Australia.

> Primary impacts:
>
> Increased erosion exacerbated by sea level rise and wave actions impact on the shoreline and long term decreasing sand supply to the beach, cause the beach of a settlement to go into decline over a period of years, exposing rock and soil beneath.
>
> Secondary impacts:
>
> Activities that were once held at the beach are no longer viable. This causes a sense of social loss. People do not feel as proud of their township as they once did. The loss of the beach may impact on tourism revenue as people choose to holiday or recreate in another location. Property prices may go into decline, and local businesses suffer stress.

Integrated Coasts recommends that the initial context of coastal adaptation study, focus should remain on primary receiving environments (which tend to be physical environments) rather than expending large amounts of resources determining the effect of coastal impacts in secondary receiving environments. For example, too much time expended into researching the social value of a beach settlement beach, without first quantifying the long-term outlook for the beach, may raise false expectations, and expend a significant amount of resources in the process. The matter here is one of order, not importance, because over time the impacts of coastal processes into secondary receiving environments (for example social) may be much more substantial. The process of quantifying the impacts upon physical impacts first will tend to guide the community along a more realistic adaptation pathway, and then values can be more accurately gauged in that context.

In this study, the investigation into eco-systems will be contained to the consideration of how coastal change may impact an eco-system as a whole, rather than an analysis of the impact of coastal change on a particular species of flora or fauna. This approach is congruent with coastal assessment strategy of Coastal Hazard Wheel that assesses environmental matters in terms of larger scale 'ecosystem disruption'. Ecosystem disruption is more likely to occur in geological layouts such as mangrove tidal flats, river mouths or sand spit environments and is less likely to occur within a coastline which is dominated by cliffs.

Assessment Parameters

Coastal adaptation within the City of Marion will first focus on quantifying coastal impacts in the following categories:

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

2.2.6 Summary: Adaptation Context

Adaptation Context	Designation
NRM climate model sub-cluster	Southern and South-Western flat lands (West)
Regional adaptation planning	Southern Adelaide (Resilient South)
Adaptation time frames	2050 and 2090/2100 (deemed the same)
Representative Concentration Pathway	RCP 8.5 High Emission Pathway
Hazards under consideration	Increased sea level (0.3m by 2050, and 1.0m by 2100), increased erosion, increase rain intensity (albeit slight) (See p. 33 for CPB sea-flood risk levels)
Receiving environments	Public infrastructure, private infrastructure, public safety, and eco-system disruption.

Recommendations:

As part of an ongoing monitoring strategy City of Marion should monitor the Climate Change in Australia website and update projections as the models become more accurate. A commitment to using an evidence-based approach and the best available science is already made with the City of Marion Climate Change Policy.

2.3 Strategic Context:

Humans choose to reside, work and recreate in the coastal context. Governments are responsible to manage how humans operate in the context of the natural environment (land use planning and assessment), and are responsible for the safety and well-being of people. Reviewing the strategic context in which Marion Council operates will provide the context for the way in which adaptation is to be empowered over time.

2.3.1 National Legislation

There is currently no Australian legislation devoted to climate change adaptation. Rather, climate change has been considered in relation to broader environmental doctrines, such as environmentally sustainable development, and precautionary principle, often under planning and environmental legislation[39].

2.3.2 South Australian State strategic policy framework

Over time there has been a shift from individual Council's undertaking individual risk assessments to regional adaptation planning where Councils partner with regional stakeholders, such as Natural Resource Management Boards (NRMS) and Regional Development Australia Committes (RDA) to define and prioritise adaptation actions at a regional scale[40]. In 2011 the South Australian Local Government Association (SALGA), in partnership with the Central Local Government Association, the Department of Environment, Water and Natural Resources, NRMs and RDAs developed the first climate change adaptation guidelines to support the development of Regional Adaptation Plans. The South Australian Climate Adaptation Framework adopted in 2012 committed all twelve state administrative regions to the development of a regional adaptation plan (by the end of 2016).

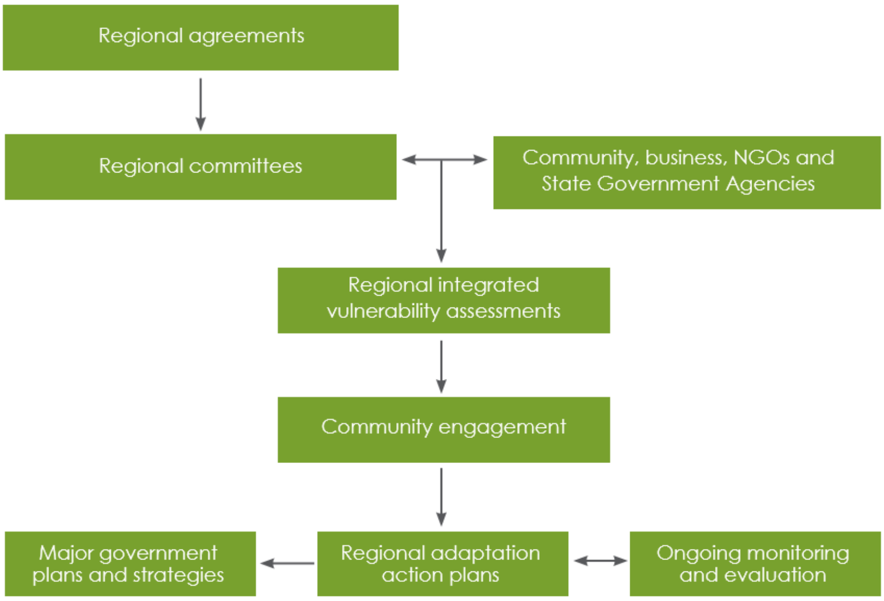
Specifically in relation to climate change adaptation, the *Climate Change and Greenhouse Emissions Reduction Act 2007* enabled voluntary regional agreements to be established in each of the State Government regions. These agreements are to define how partners (such as NRM Boards, Councils, key private sector organisations) will work together to plan and implement adaptation action. Signatories to the agreements may form 'regional steering committees'.

Over the last decade, State Government of SA has implemented a more regional approach to manage the State. The Natural Resources Management Act 2004 introduced eight natural resource management regions with independent management boards. Twelve administrative regions were also created and given impetus in the *30 Year Plan for Greater Adelaide (2010*). Southern Adelaide Region encompasses Holdfast Shores, Mitcham, Marion and Onkaparinga Council areas. The Southern Adelaide Region is situated within the much large Adelaide and Mt Lofty NRM region.

Specifically in relation to climate change adaptation, the *Climate Change and Greenhouse Emissions Reduction Act 2007* enabled voluntary regional agreements to be established in each of the State Government regions (Figure 23). These agreements are to define how partners (such as NRM Boards, Councils, key private sector organisations) will work together to plan and implement adaptation action. The Climate Change Adaptation Framework for South Australia (2012) advocated that climate change adaptation planning be conducted within these twelve adminstative regions.

Figure 23: Regional model for developing adaptation responses

[39] CoastAdapt, Information Manual 6: A guide to legal decision making in the face of climate change
[40] South Australian Local Government Association – Climate Adaptation Planning Guidelines



Source: SALGA

Resilient South

The Southern Adelaide region (Holdfast Bay, Mitcham, Marion and Onkaparinga Councils) have cooperated together to produce the Resilient South Climate Change Adaptation Plan (2014).

In relation to coastal adaptation, the regional plan explains the general impacts of rising sea levels, changes to rainfall patterns, and increased erosion, but does not specifically review the coastal environs of City of Marion. The regional plan did identify some general options for coastal adaptation (see table below). In reference to Figure 4-3 below, the report did not identify any preferred coastal adaptation options for Marion.

Summary of preferred options for maintaining the Southern Region's natural features (e.g. cliffs, beaches, dunes, estuaries, biodiversity) and built infrastructure along the coast as our climate changes

Now

- Coordinated planning and monitoring;
- Inform and educate the community and encourage behaviour change;
- Review and amend Development Plan policy; and
- Develop soft structural options.

Within 20 to 30 years

- Construct hard structural options like storm tide barriers or sea walls.

Preparatory work

- It is recommended that a monitoring strategy be developed to inform decision making regarding the timing of construction of hard structural barriers.

Figure 4-3 identifies where these preferred options might apply spatially for the Southern Region.

Source: Resilient South

2.3.3 Local strategic context

Climate Change Policy (Summary)

Subsequent to the completing Resilient South Climate Change Adaptation Plan, Marion Council has adopted a climate change policy as a basis for managing climate change in the future.

The scope of the policy applies to all of Council's activities and services, and to Council's collaboration and communication with community to mitigate against climate change and to assist the community to build resilience and adapt to the impacts of a changing climate.

The context of the policy acknowledges that changes to Australia's climate are being accelerated by human activity which will bring about a range of changes to the climate. City of Marion recognises the importance of reducing the production of greenhouse gas emissions and adapt to climate change that cannot be avoided.

A summary of the key policy principles of the policy[41]:

- Council will adopt an 'evidence based approach' using the best available science while recognising the need for for flexibility to adapt as scientific knowledge imporves,
- Mitigation and adaptation to climate change impacts will be undertaken particularly through land use planning powers, asset and infrasturcuture managemet, environmental planning, and natural resource management,
- Council will support its community…through education and encourage behaviour change that will increase community mitigation and adaptation efforts and to build resilience.
- Consideration of climate change and its potential impacts will be incorporated into Councils operations.
- Council will work regionally and at a State and federal level in partnership with others.

Council Strategic Planning (Summary)

Marion Council's strategic planning also explains how the Council intends to deal with climate change and associated adaptation over time[42].

The Council's community vision is, 'by 2040 our city will be deeply connected with nature to enhance people's lives, while minimising the impacts on the climate, and protecting the natural environment'.

The plan notes two key challenges: building capacity to adapt to climate change' and coping with the 'increasing impacts of climate change'.

10-year-strategies include: planning to respond to extreme weather events through services and urban form, managing infrastructure issues associated with flooding and stormwater, and to build community resilience to the impacts of climate change.

[41] City of Marion, Climate Change Policy
[42] City of Marion, Strategic Plan, 2017-2027

Council Business Plan 2016-2019

Council's business plan includes the items[43]:

- Implement the Climate Change Policy and Plan (Resilient South Program)
- Develop and deliver a Regional Coastal Management Plan to support effective coastal management
- Manage storm water in close partnership with our neighbours

In summary, Marion Council has already achieved significant policy shifts to manage climate change adaptation over time.

2.3.4 Land-use planning and assessment

Marion Council assesses proposals for new development under the Development Act 1993 using policy set out in the City of Marion Development Plan.

The South Australian Coast Protection Board provides the state-wide policy for dealing with coastal matters and this policy finds its expression and application through local Development Plans. The Development Act 1993 and Development Regulations 2008 require Councils to refer new development in coastal zones to Coast Protection Board for 'regard' or 'direction'. A typical matter for 'regard' relates to the height above 0 AHD that a housing site or floor level is to be set. Matters for 'direction' include the implementation of coastal protection works. Coast Protection Board policy since 1991 has been to advise Councils to set floor levels 0.25m above the one in hundred ARI event and an additional 0.3m to allow for sea level rise by 2050. New development should also be able to demonstrate how it will cater for an additional 0.7m sea level rise by 2100.

The Council Development Plan (consolidated 28th April, 2016) is the statutory policy document to manage new development in the region. The Development Plan has been revised using the *Better Development Plan* process and therefore does contain the current Coast Protection Board policy. Specifically, in relation to Coastal Policy the only variation from *Better Development Plan* wording in the general and residential section is found in Coastal Areas (PDC 7)[44]:

7 Unavoidable stormwater and effluent outfalls should be designed and located so as not to conflict with the objectives for coastal areas and if discharging across a beach do so at beach level from properly constructed pipes or channels.

Note: It is unknown if this has been achieved at Marion Council as yet. Strategic planning and the business plan identifies storm water management as a key focus.

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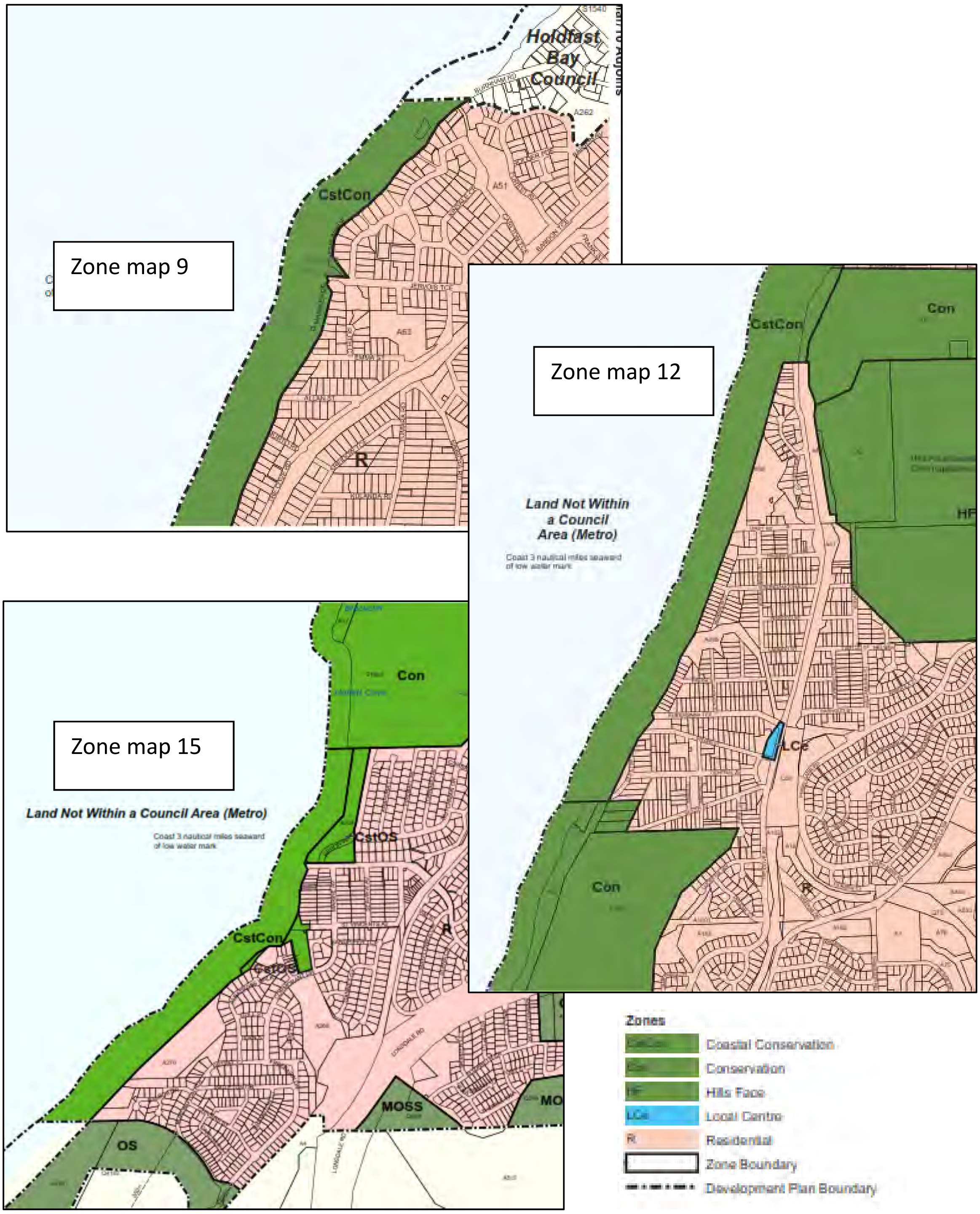
[43] City of Marion, Business Plan, 2016-2019
[44] Development Plan, City of Marion, consolidated 28th April, 2016

Prime land-use zones

The main land-use zonings applied to the City of Marion coastline are:

- Residential Zone
- Coastal Conservation Zone (for most of the shoreline)

Figure 24: Land-use zoning from Marion Development Plan



With this current zoning arrangement, there is <u>probably</u> no requirement for any development applications to be referred to Coast Protection Board for advice because all residential areas are separated from the ocean by a 'coastal conservation zone'. (Schedule 8, Development)

Secondary land-use policy areas

Land-use policy areas are limited to two: Hills Policy Area (11) and Coastal (21). All areas in proximity to the coast north of Grand Central at Hallett Cove Beach are zoned with Policy Area 11 (Hills) which is a low-density zoning suitable for hilly or undulating environments.

Hills Policy Area 11

Refer to the *Map Reference Tables* for a list of the maps that relate to this policy area.

OBJECTIVES

1 A policy area primarily comprising detached dwellings at low densities.

2 Residential development which is sensitive to the particular topography of the locality.

3 Residential development which has minimal visual and environmental impacts.

7 Dwellings should be designed to have a maximum site coverage of 35 per cent of the allotment area and a maximum floor area ratio of 0.4.

8 A dwelling should have a minimum site area, a frontage to a public road and an allotment depth not less than that shown in the following table:

Dwelling Type	Site Gradient	Minimum Site Area (square metres)	Minimum Frontage Width (metres)	Minimum Site Depth (metres)
Detached	less than 1-in-10	700	18	20
	between 1-in-10 and 1-in-5	900	20	20
	more than 1-in-5	1100	20	20
Group	less than 1-in-10	700	24	45
	between 1-in-10 and 1-in-5	900	26	45
	more than 1-in-5	1100	26	45

Coastal Policy Area 21 is confined to land south of Grand Central in the vicinity of the Field River. This policy area is also a low density environment that pays particular notice to floor and site level heights and requirements for coastal protection strategies (presumably by the proponents of the development).

Coastal Policy Area 21

Refer to the *Map Reference Tables* for a list of the maps that relate to this policy area.

OBJECTIVES

1 A policy area primarily comprising detached dwellings at low densities.

2 Residential development which is sensitive to the particular topography of the area and which has minimal visual and environmental impacts.

3 Residential development that mitigates the impacts of natural hazards such as sea level rise and flooding from the Field River through sensitive siting and design.

4 Development that contributes to the desired character of the policy area.

DESIRED CHARACTER

(portion only)

Land in the coastal policy area may be subject to coastal flooding and erosion and this risk will increase with sea level rise due to climate change. Protection strategies addressing the flooding and erosion risk are required. New development should be built to specific site and floor levels to minimise these risks.

PRINCIPLES OF DEVELOPMENT CONTROL

Land Use

1 The following forms of development are envisaged in the policy area:

- detached dwelling
- group dwelling.

Form and Character

2 Development should not be undertaken unless it is consistent with the desired character for the policy area.

3 Development including roads and parking areas should be protected from sea flooding by ensuring all of the following apply:

(a) site levels are at least 4 metres Australian Height Datum

(b) building floor levels are at least 4.25 metres Australian Height Datum

(c) there are practical measures which can be undertaken on-site to protect the development against an additional sea level rise of 0.7 metres, plus an allowance to accommodate land subsidence until the year 2100.

4 Development should avoid or mitigate the potential impacts of sea level rise and flooding adjacent the mouth of the Field River through intelligent siting and design based on sound coastal management practices.

5 Dwellings should be designed to have a maximum site coverage of 35 per cent of the allotment area and a maximum floor area ratio of 0.4.

6 A dwelling should have a minimum site area and a frontage to a public road and site depth not less than that shown in the following table:

Dwelling Type	Minimum Site Area other than for affordable housing (square metres)	Minimum Frontage Width (metres)	Minimum Site Depth (metres)
Detached	700	18	30
Group	700	24	45

Strategic context - Summary

Resilient South

In relation to Coastal Adaptation Planning:

- Resilient South doesn't provide an adaptation context for Marion Council apart from broad coastal adaptation themes/ guidelines.
- In particular, broad recommendations that within 20-30 years 'construct hard structural options like storm tide barriers or sea walls' should be disregarded
- There is a general recommendation to 'amend development plan policy' but no further context.

Statutory Planning (Development Plan Amendment):

Future reviews of planning policy should consider of the results of this study. Particularly noting the potential for:

- increased stormwater runoff that could cause instability in cliff areas. This is particularly likely with increasing urban density.
- future retreat of public and private infrastructure in high risk areas immediately along the coastline.
- additional open space to allow for assisted adaptation of some coastal ecosystems that may become isolated or inundated in the future.

Strategic planning

Marion Council has achieved excellent 'buy in' for coastal adaptation (and climate change adaptation in general) at a local and regional level with the adoption of the Climate Change Policy, and the implementation measures included in the Strategic Plan (2017-2027) and current Business Plan (2016-2019). Specifically, strategic planning recommends to:

- Mainstream climate change matters into Council operations
- Implement the Climate Change Policy and Plan (Resilient South Program)
- Develop and deliver a Regional Coastal Management Plan to support effective coastal management
- Manage storm water in close partnership with neighbours.

2.4 Historical context:

A history of each settlement provides an important cultural context to the study and may also improve understanding of any initial assessments that were undertaken in relation to potential impacts of the sea. In relation to Council liability, when a settlement was founded, and whether it has undergone any substantial expansion are key issues to be assessed. In particular in relation to coastal matters, any previous coastal studies that have been undertaken are identified and assessed.

Key assessment questions:

- When was the settlement established?
- Has the settlement been expanded, and if so what were the historical circumstances?
- What account was taken in relation to potential impacts from the sea in the establishment or expansion of the settlement?
- Have any coastal incidents occurred such as inundation or erosion?
- What previous coastal studies have been undertaken?
- Are any coastal management plans in place?

2.4.1 When were coastal settlements established?

Cell 1 – Marino: Cliffs

Marino was subdivided for residential occupation in 1912 (at the same time as Woodlands Park, Morphettville, Hallett Cove Model Estate)[45]. The research conducted into the cliff collapse at Hallett Cove (Cell 2 – Cliffs) in 1996 concluded that the initial subdivision was likely to have been completed in England with an esplanade road designed impractically over deep gullies[46].

Cell 2 – Hallett Cove: Cliffs

Hallett Cove (cliff section) in the north of the suburb of Hallett Cove was likely to have been subdivided at the same time as Marino. The Perry Barr area subdivision was completed in 1974. In 1976, the Hallett Cove Conservation Park was established[47]. The Hallett Cove Study Report in 1977 recommended that some of the vacant land be purchased from Hallett Cove Development Company to further consolidate and unify the conservation park[48].

Cell 3 – Hallett Cove: Beach

The same research in 1996 mentioned at Cell 1 above, also noted that houses were likely to have been constructed in Hallett Cove in late 1970s to 1980s. Several resources note the struggle between developers and conservations over the period of 1962 to 1974[49]. A likely impetus for the

[45] Dolling, A (1981) Marion on Sturt
[46] Fotheringham, D (1996) Communication to Minister for Environment and Natural Resources regarding potential collapse of cliff at The Esplanade.
[47] Dolling, A (1981) Marion on Sturt
[48] Cullen et al (1977) Hallett Cove Study Report
[49] Dolling, A (1981) Marion on Sturt

struggle may have had its genesis in State planning in the early 1960s that advocated Hallett Cove region for urban expansion[50].

2.4.2 What were the historical circumstances of any expansion (s)?

A preliminary search of Coast Protection Board (DEWNR) hardcopy archives, and report received via email from DEWNR revealed no significant expansions of settlements in coastal areas subsequent to 1990 apart from areas south of Field River. In 1992 six allotments were subdivided into 109 allotments (D109/92) and a further subdivision of 1 allotment into 14 allotments occurred in 1993 in an area closer the Field River (D060/93). A Development Plan Amendment has been completed for the residential area around Field River and a Coastal Policy Area 21 designated over the area.

2.4.3 Was there any requirement to assess potential impacts from the sea in the establishment or expansion of the settlement?

The subdivisions of Marino and Hallett Cove (North) were subdivided a very long time ago, and possibly executed in England.

Preliminary historical research indicates that subdivision and establishment of Hallett Cove suburb, and perhaps the construction of houses at Hallett Cove (North) was completed circa 1974 to early 1980s. These are likely to have been approved under the SA Planning and Development Act 1967. There was no requirement to assess any actions of the sea within this Act. The Coast Protection Board came into being in 1972, and one of its first actions in 1974 was to decline to approve the proposed marina for Hallett Cove. There is no record of any protest from Coast Protection Board in relation to the establishment of Hallett Cove generally.

Both subdivisions in the Field River (1992, 1993) area were referred to the Coastal Management Branch who stated no objections to the subdivisions. However, both referrals gave advice that the Coastal Management Branch was not opposed to the development from a coastal engineering viewpoint provided impacts on the adjoining cliff were minimised stating, 'without control of the disposal of stormwater from the site and increased pedestrian activity in the area the stability of the naturally erodible cliff area is at risk'. The Coastal Management Branch also recommended that to minimise the hazard… 'an engineering and geological study of the cliff area be undertaken to allow council to assess the suitability and design of the drainage system'[51].

This study has not evaluated whether any engineering and geological study' has been completed.

Both applications were referred and assessed under powers of the Planning Act 1982 and prior to the Development Act 1993 coming into effect. Considerations of impacts of the sea were first introduced into statutory planning documents in 1994.

<u>Implications for Marion Council</u>

It is unlikely that any residual liability exists in the founding or expansion of the settlements within Marion coastline. Most expansions were conducted well prior to 1990s (where coastal processes and climate change began to be taken into account in Development Plans). The expansion of Field

[50] Jeffery, L (2012)…but no historical source was included in this study.
[51] Coast Management Branch (now within DEWNR) 1993-1994, DA100.060.93 and DA100.026.94

River was conducted in the early 1990s, but was referred to Coast Protection for comment (under 1980 Planning Act).

2.4.4 What Development Applications have been referred to Coast Protection Branch?

Example 1

One example exists where Coast Protection Branch recommended against approval unless certain conditions were met. A proposal for a shop and residence at Marino (DA100/1791/97) was met with the following response from Coast Protection Branch:

> The coastline adjacent to this proposed development may be at risk by coastal storm flooding and erosion, and this risk will increase in the event of future sea level rise due to global warming. Accordingly, the Board recommends against approval unless Council is able to ensure that an adequate flood and erosion protection strategy is in place to protect the development, to make it comply with the 'Hazard Risk Minimisation' principles contained within the Council section of the Development Plan…
>
> Erosion
> The coastline at this location has been subject to slow coastal erosion and the proposed development is less than 50 metres from the top of the cliff edge. However, it is considered to provide sufficient protection to satisfy Council's current erosion criteria.
>
> The Board has no objections to this development providing… (3) Council accepts responsibility for future protection of Marine Parade and the existing carpark if it becomes necessary[52].
>
> The Board attaches the following disclaimer to the above advice;
>
> *Based upon current knowledge and information the development and development site is at some risk of coastal erosion due to extreme tides notwithstanding any recommendations or advice herein, or may be at future risk. Neither erosion nor the effect of sea level change on this can be predicted with certainty. Also, mean sea level may rise by more than the 0.3 metres assumed in assessing this application.*
>
> *Accordingly neither the South Australian Coast Protection Board nor any of its servants, agents or officers accept any responsibility for any loss of life and property that may occur as a result of such circumstances.*

This marks the first time that CPB advice is given in the context of climate change and associated sea level rise. CPB has also shifted responsibility to the Council for any future protection of Marine Parade (but on what basis, is unknown).

Example 2:

Several examples exist of advice from Coast Protection Board given to Council in relation to storm water management and cliff stability. This advice become prevalent after the 1996 cliff collapse at The Esplanade, Hallett Cove.

Example: DA 100/2253/01 Land Division includes the advice that:

> The Council is advised to seek a geotechnical report on the stability of the cliff in the vicinity of this land to ensure the suitability of the land for future development. Any runoff of stormwater from the proposed allotments should be considered in the design of future development proposals with a view to limiting the potential for impact on the cliff.

[52] Coastal Management Branch (now within DEWNR) response to DA100/1791/97.

2.4.5 Have any incidents of inundation or erosion occurred in the coastal zone?

Inundation

No record exists in the files at Coast Protection Branch (DEWNR) in relation to any inundation of any of Marion coastline and the Hallett Cove Coastal Management Study makes no findings in relation to inundation events. Anecdotes exist among staff about the impact of 9th May, 2016 and in October 2016 at Hallett Cove Beach.

Erosion

The Hallett Cove Coastal Management Study gave significant review of erosion patterns study Cells 3-4, and especially in relation to sand supply and erosion at Hallett Cove Beach (p, 15,30).

Two Development Applications were lodged by Council to CPB to deal with erosion issues:

<u>Development Application (DA100/0552/98):</u>

In 1998, a Development Application by Council for a rip rap sea wall to the south of Field River was referred to Coast Protection Board who responded:

> While it is appreciated that the coastline at this location is subject to slow coastal erosion, it is not currently threatening development and the Branch would appreciate justification for undertaking the work at this time. A considerable portion of the State's coastline is subject to erosion and the Board does not support the placement of rock protection on the coast without having due consideration to its impact on the beach and sand supply.

<u>Development Application (DA100/0932/99)</u>

An application was received by Coast Protection Branch in 1999 to place rock protection on the Hallett Cove Beach (DA 100/0932/99). However, this request was declined, among other reasons, because:

> An assessment of aerial photograph has indicated that the area has remained relatively stable for the past five years and the Board does not consider there is a need for heavy protection measures at this time. While it is appreciated that the exposed trolleys may represent some risk and appear unsightly burying them with the onsite sand and shingles is considered a more preferred option.

These responses seem to suggest a stable beach environment.

Cliff Collapse – The Esplanade, Hallett Cove

In October, 1996, a section of cliff collapsed at the Esplanade, Hallett Cove. Investigations concluded that the collapse was caused by a combination of the natural geology combined with an unusually wet winter. CPB concurred that the land slide was not as result of any coastal processes, and also refused any funding for rectification works (on that basis). A review of all the reports suggests that both the Council and the State Government received legal advice that neither were liable for the landslide. However, Council did raise funds to further collapse the cliff and stabilise the situation. The purpose of this study is not to investigate this incident, but rather to highlight that this case provides a crucial insight into liability issues relating to development in the vicinity of cliff tops should erosion begin to be felt at the base of the cliffs due to increased sea levels and wave action.

4.6 Summary: Historical context

Historical context	Designation
When were coastal settlements established?	Cell 1 -2: were initially established circa 1912, with the subdivision most likely completed in England Cell 3: HC Beach established in 1974 to early 1980s. Cell 4: Field River was established in 1992, 1993. Cell 5 : Southern Cliffs (later?)
What are the circumstances of any expansions?	Cell 4: Hallett Cove (Field River) should be regarded as expansions (1992, 1993).
Did any obligation exist for Council to assess actions of the sea when establishing settlements?	No legal obligation existed for Council to consider action of the sea in founding Cells 1-3. Coast Protection Board was in existence when Cell 3 (Hallett Cove Beach) was established, and despite opposing the proposed marina, made no objection to the establishment of Cell 3 (Hallett Cove Beach).
Did any obligation exist for Council to assess actions of the sea when expanding settlements?	Yes, Council was required to consider actions of the sea in founding Cell 4 Field River area. Two subdivisions were referred to CPB for 'regard' and no objections were raised to either. However, CPB did mention matters relating to cliff stability. Cell 5 was not referred.
What Development Applications have been referred to CPB?	Council made two applications for protection works for 'direction'. A rip rap wall for dune at Field River (declined), and rock walling for Hallett Cove Beach (more information requested). Private development applications were also referred. One was recommended for refusal unless certain conditions were met. No objections were raised to the remainder, but CPB recommend Council obtain geotechnical advice in relation to cliff stability, or in relation to storm water run-off impacting cliff stability.
Have any inundation events occurred?	No infrastructure or housing has been impacted by inundation. The storm even of 9th May 2016 did impact the shoreline (no photographs reviewed as yet).
Have any erosion taken place?	Erosion has occurred at various places along the beach as described in HCCMS.
Any other events?	The cliff collapse/ land slide of 1996 at The Esplanade (Cell 2) provides a very useful case study into matters of liability. Both the Council and the State appeared to have received advice that they were not liable for this land slide.

Future research:

A larger study should review the 1996 cliff collapse file would provide a 'window' into Council liability in relation to cliff top settlements. Such a review may be useful in the light of any recommendations that urban density be increased in these areas.

2.5 Technical context (studies and plans):

2.5.1 Hallett Cove Study Report (1977)

The main focus of this study is the conservation park, public access issues, and the possible purchase of further land to consolidate the park. However, one reference does give an insight into the nature of the beach at that time, and reports on a comparative examination of aerial photographs taken in 1949 which ‘show there have been no substantial changes to the beach over this period’[53].

2.5.2 Photographic Report (1993)

A photographic report was conducted by Colin Mayberry and Shaun Matschoss as part of their final year research project for University of Adelaide, Department of Civil and Environmental Engineering. The project, *Foreshore Erosion at Hallett Cove,* contains dozens of photographs from the time, as well as including historical photographs, which provide a window into the nature of the beach over time. Focus was given to the perceived role of the breakwater at Port Stanvac and the build-up of sand on the south side, with the inference that supply of sand was inhibited to Hallett Cove Beach[54].

A larger coastal adaptation study may wish to review this file (File at DEWNR).

2.5.3 Beach Profiles (1975 to 2010)

Coast Protection Branch (in its various forms, currently DEWNR), has been taking beach profiles at two locations on Hallett Cove Beach. Seven beach profiles have been taken in the period 1975 to 2010. However, these profiles are not accompanied by any interpretation as to what they might indicate is occurring at Hallett Cove Beach over time, but they were analysed by the Hallett Cove Management Plan (2012)[55].

Figure 25: Beach profiles by DEWNR

Source: Scanned from archives, August 2017 (DEWNR)

[53] P.W.Cullen et al (1977) Hallett Cove Study Report, p. 61

[54] Matschoss S, Mayberry, C (1993) Foreshore erosion at Hallett Cove (Research project, Uni of Adelaide)

[55] Accessed in DEWNR archives, Marion Council, August, 2017

2.5.4 Coastal Management Strategy Plan (26 July, 1997)

This report prepared by Kinhill Engineers provides insight into issues under consideration at the time, including storm water run-off over cliffs, dune erosion, cliff stability issues. One of the main issues under consideration was forming of coastal walkway. The report also provides a full inventory of coastal features including storm water outlets, and coastal protection measures.

The quote below from the introduction of the report contextualises the main issues under consideration,

> 'the coastal management strategy for Marion seeks to promote improvements in the management of the coastal strip by developing a coastal management plan which identifies appropriate uses and adjoining buffer areas, access paths, traffic management, car parking, the location of visitor facilities and tourist opportunities'.

In particular, and of relevance to this study the report recommends:

- Develop opportunities for stormwater management improvements
- Augment existing initiatives to protect sand dune areas where necessary to ensure the retention of dunes
- Develop a revegetation programme for the coastal areas[56]

2.5.5 Coastal Management Study – Hallett Cove (2012) by Doug Lord

The Coastal Management Study (2012) is a comprehensive review of coastal processes of the Hallett Cove Beach region (Cell 3 of this study) that brings together all the strands of previous coastal history and adaptation work and should be utilised as a foundation document for any coastal adaptation planning for Hallett Cove Beach.

The stated aim of the study 'was to assess current and potential future coastal management issues at Hallett Cove and to identify and evaluate alternative management strategies in response to those issues that could be considered in a coastal management plan for the area'.

The purpose of the coastal management plan was to inform the redevelopment of Heron Reserve (that reserve is now planned and out for consultation).

<u>Research Questions:</u>

Has the Heron Reserve proposal been approved/ reviewed by DEWNR in relation to coastal processes and climate change? (2050, 2100?) The answer is 'yes' it has been approved.

Did the Heron Reserve proposal take into account the HCCMS recommendation to decrease the slope of the escarpment between the reserve and the beach? (this may be imperative over time)

[56] Kinhill Engineers (1997)   Coastal Management Strategy Plan

2.5.6 Hallett Cove Creeks Stormwater Management Plan (2012)

The Hallett Cove Creeks Stormwater Management Plan (2012) produced by Southfront is a thorough investigation of the current storm water system for three catchment areas located in Cell 2 and 3, and a suggested improved management strategy.

The report concluded that stormwater infrastructure was assessed as meeting performance standards in line with current day expectations (with a few exceptions). The study used a 1 in 10 ARI rainfall event which it considers the standard event to use in evaluating the effectiveness of stormwater infrastructure capacity. Coincidently, such an event did occur within the study period and the effectiveness of the system was evaluated in that context.

The key issues flagged for improvement were:

- Erosion of Waterfall Creek channel, along most of its length (MW has reviewed the outlet to the sea only)
- Lack of stormwater quality improvement measures
- Lack of stormwater harvesting and reuse

The report lists numerous recommended upgrades and strategies, but none of these appear to relate to ocean outfalls (apart for GPT at Heron Reserve). However, the study did review coastal outlets (see below)[57].

4.3 Coastal Outlets

While the significant majority of the Study Area is drained to watercourses or gullies that ultimately discharge into the Gulf, there are a number of the underground stormwater drainage systems that also discharge directly to the Gulf.

There has previously been concern regarding the erosion of cliffs and beaches due to many of these outfalls discharging well above beach level, with little or no erosion control or pollutant interception measures in place. A review of these outfalls (AWE, 2005) developed concept designs to address the issues identified.

There are 6 outfalls within the study area that were reviewed. The status of the concepts proposed within AWE (2005) are summarised in Table 4.3 below.

Table 4.3 Coastal Outlet Works

Location	AWE Ref	AWE Recommendation	Status
Westcliff Ct	11	No work required	-
Nungamoora St	13	Install GPT	Outstanding
Peera St	14	No work required	-
Fryer Street	16	Install GPT	Outstanding
Clifftop Cr	18	Install rock-lined overflow swale	Completed (refer photo below)
Grand Central Ave	21	Install GPT	Outstanding

Source: Hallett Cove Stormwater Management Plan (p. 43)

[57] Southfront (2012) Hallett Cove Creeks Stormwater Management Plan

A digital terrain model was acquired for the study in 2008 and achieved a vertical accuracy of 0.15 RMS on open clear flat surfaces and contours created at 1m intervals.

The report did note that climate change leads to changes in frequency, intensity, duration of rainfall patterns. However, because the time frame of the study was limited to 2050, no account was taken of increased rain intensity in the study (and this is congruent to climate change projections).

2.5.7 Develop a coastal rehabilitation strategy, Lee Jeffery (2014)

This report was submitted as assessment item for Diploma of Conservation and Land Management at TAFE. All matters to do with coastal processes and adaptation are taken from the Hallett Cove Coastal Management Study. However, the report does provide significant review of flora and fauna in the Hallett Cove region[58].

2.5.8 Developing a management strategy for coastal cliff erosion hazards in SA (2014)

This report was produced by Coast Protection Board in response to several cliff collapses around the State. It provides a resource from which to undertake preliminary evaluation of the cliff environment in Marion Council. The report notes that CPB have recently undertaken a hazard assessment of coastal cliff landforms along the South Australian coast which flags potential hazard areas for priority management according to how susceptible they are to erosion[59].

2.5.9 Summary: Technical Context (Studies and Plans)

Research Questions

Has any account of sea level rise been undertaken with any DEM modelling? (the Hallett Cove Creeks Stormwater Management Plan did utilise a DEM for its study…see below)

Have storm water outlets to the ocean all been upgraded (in accordance with Figure 4.3). What works are outstanding? What outlets may still be causing erosion within cliff gullies?

Should long range storm water planning begin to consider how the storm water systems would cope to year 2100 (and beyond?) 2050 is only 20 years away, and infrastructure that is installed now is expected to have much longer life spans than this.

Would works and strategies mentioned above be effective in catering for larger rain events (or could some of them be expanded to cater for larger events in the future)?

Research question: Has been done on Field River catchment (the main section of Field River catchment is within Onkaparinga)?

Where is the CPB cliff study?

[58] Jeffrey, L (2014) Develop a coastal rehabilitation strategy
[59] Coast Protection Board (2014) Developing a management strategy for coastal cliff erosion hazards in SA

Has the Heron Reserve proposal been approved/ reviewed by DEWNR in relation to coastal processes and climate change? (2050, 2100?) (The answer is 'yes' it has been approved).

Did the Heron Reserve proposal take into account the HCCMS recommendation to decrease the slope of the escarpment between the reserve and the beach? (this may be imperative over time)

Studies and Plans	Scope	Relevance/ Focus
Hallett Cove Study Report 1977	Cell 2 Hallett Cove (cliffs) and Cell 3 Hallett Cove (beach)	The main focus relates to the establishment of the conservation park. One note about Hallett Cove Beach with comparison of photographs to 1949.
Photographic report 1993	Cell 3 Hallett Cove (beach) and Cell 4 Field River (and south)	Useful set of photographs providing a window into beach at 1993, but also contains older photographs.
Beach Profiles 1977 to 2010	Cell 3 Hallett Cove (beach)	Seven beach profiles at two locations provides data to analyse bathometry of the beach over 35 years.
Coastal Management Plan 1997	All cells	Main focus on managing public access and controls over coastal areas (Including the proposed walking trail). Very useful review of flora and fauna, existing coastal structures. Less useful in relation to coastal processes (and superseded by 2012 study (see below) However, does provide window into the time period.
Coastal Management Study – Hallett Cove Beach 2012	Cell 3 Hallett Cove (beach) but also includes Field River (Cell 4)	An exceptionally thorough report that reviews and details coastal processes, erosion history. The pupose of the report was to underpin proposed upgrade /development of Heron Reserve. This report should form the main basis for any coastal adaptation work for Hallett Cove Beach.
Hallett Cove Creeks Stormwater Management Plan 2012	Cell 2 Hallett Cove (cliffs), Cell 3 Hallett Cove (beach)	An effective review of the storm water system for three catchments. Main focus is the efficiency of the system (climate change is discussed in relation to 2050 only). Provides insight into locations of storm water outfall (to the ocean) and any associated works (including those still pending). Provides analysis of nature of outfall (pollutants etc) A DEM was obtained for the study.
Develop a coastal rehabilitation strategy 2014	Cell 3 Hallett Cove (beach)	A student report, but very thorough, and provides insight into ecosystem.
Development a management strategy for cliff erosion hazards (2014)	General report (produced by CPB for State)	A review of coastal processes that cause cliff failure.

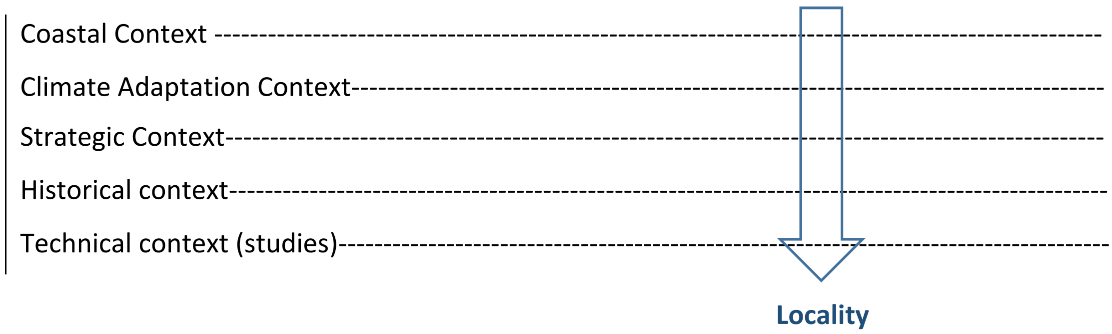
3. Coastal Tour

At this point of the project, a thematic review of the entire Marion coastline within the following categories has been concluded. The purpose of undertaking the contextual review is to 'draw a line in the sand' at today's date and declare, 'this is what we know'.

- Coastal context
- Adaptation context
- Strategic context
- Historical context
- Technical context (studies)

In conceptual terms, the study so far has been a thematic review across the entire coastline of Marion. The coastal tour is the point of the project where attention is focussed vertically at particular locations within the coastline. This methodology is congruent with Integrated Coasts view that coastal study adaptation is a 'bottom up' process, and not a regional process. Because the features of the coastline may vary significantly within a few minutes walking distance, so too does coastal vulnerability vary. This local nature of adaptation is the reason that coastal study requires sectioning in accordance with geological type.

Figure 26: Conceptual illustration



Coastal tour methodology

The methodology employed for the Marion coastline tour:

- Desktop review using Google Earth and Maps
- Walking tour on 29th and 30th August (using voice recorder and camera)
- Aerial tour (with drone) on 1st September, and 17th September.

Purpose of the tour

The purpose of the tour is to identify and photograph:

- All coastal protection structures
- Storm water outlets
- Locations where erosion has been evident
- Locations where inundation may have occurred
- The condition of dunes and cliffs (the escarpment)
- Nature of vegetation cover

4. Assessment

The following vulnerability assessment is conducted as a qualitative exercise in 'scoping mode' in the context of the following parameters:

Hazards

- Erosion
- Sea-water inundation
- Storm water (where it flows over the coastline)

Receiving environments

- Public infrastructure
- Private infrastructure
- Public safety
- Coastal eco-systems

Risk assessment:

The procedure to evaluate potential risk from hazards in each of the coastal cells:

- Display large photographs of each section of the coast north to south,
- Identify key data such as distances of infrastructure to escarpments, existing protection structures, key coastal features, current wave and tidal regimes, and to note any previous events in the locality,
- Include data from the Hallett Cove Coastal Management Study in Cells 3-5.

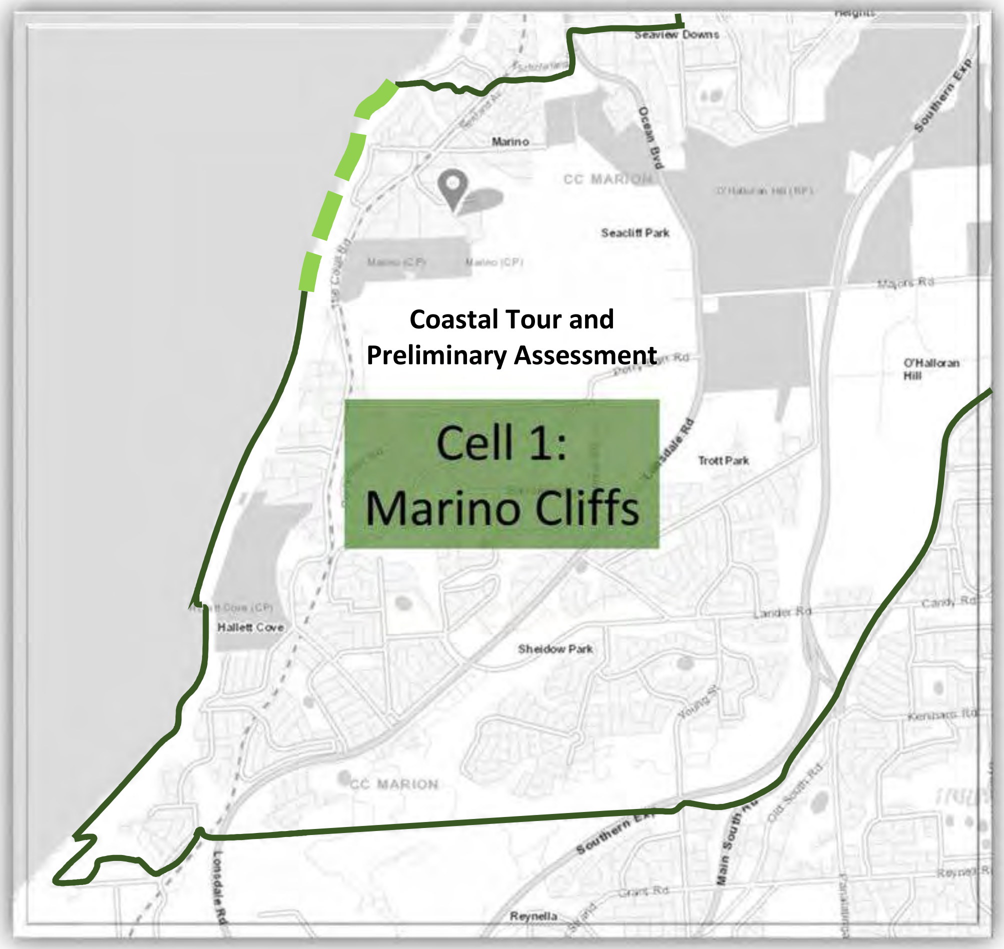
Each section of coast includes a general risk assessment for erosion (and inundation if relevant). In places where a risk 'hotspot' is identified, the hotspot locality is afforded its own assessment.

The risk assessment tables utilise two main time frames: current and 2100. The 'current' time frame includes events likely to occur within 10-20 years. The longer-range future time frame is intentionally utilised so as to determine the underlying long-term trends more clearly, and thus identifying localities which are more likely to require remedial action.

Integrated Coasts has reviewed National Emergency Risk Assessment Guidelines (NERAG)[60], CoastAdapt risk assessment templates, and Coastal Hazard Wheel as examples of suitable risk procedures meeting Australian and International risk assessment standards.

In this project, risk assessment procedures have been used to harmonize with the nomenclature and procedures outlined in Marion Council's Risk Management Framework.

[60] Also utilised by SAFECOM

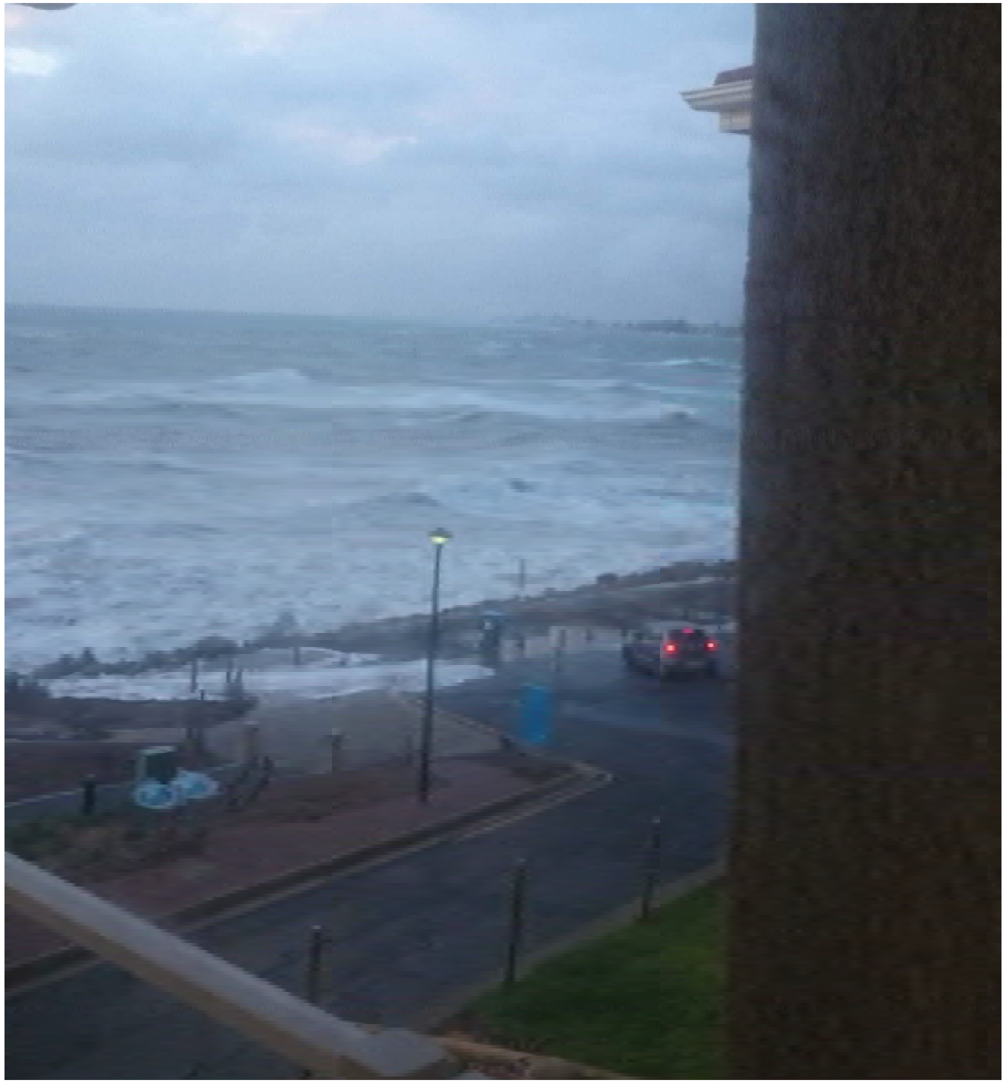

Coastal Tour and
Preliminary Assessment
Cell 1:
Marino Cliffs
Seaview Downs
Marino
CC MARION
Seacliff Park
Trott Park
O'Halloran
Hill
Hallett Cove
Sheidow Park
Reynella
Ocean Bvd
Southern Exp
Lonsdale Rd
Majors Rd
Main South Rd

Cell 1: Marino Cliffs (1:1)

Rock revetment protecting The Esplanade is degrading (1). Small groyne exists (see above) perhaps to act as protection for small boat launching in the past (2). Protection structure (3) is likely to have protected former building, now undermined with erosion.

Cell 1: Marino Cliffs (1:1)

Stormwater pipe appears to empty into gully. Gully is well-vegetated. The gully has not been inspected for storm water scouring (appears minimal). Small storm water scouring observed at top edge of gully.



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Notes

Photographs taken by Bill and Glenys Summersides of 4 Esplanade at 17.20 (used with permission). Some minor overtopping is observed, including water streaming up the concrete path, and minor over topping of the rock revetment. Water pooled on the road. Note: this event was prior to the installation of the current paving and landscaping which has altered the terrain.

Map

Marino Cliffs 1:1

Historical Event

Event: 9th May 2016
Datum: AHD
Date: 12 May 2018

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Map

Marino Cliffs 1:1

Historical Event

Event: 9th May 2016
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Notes

On 9th May 2016 the highest level of water was recorded at Outer Harbor in 80 years at 3.80 CD (2.36 AHD). To calculate the storm surge height at Marino: secondary port relationship methodology was used with Brighton (95%) and wave height of 0.30m added in accordance with storm surge allowance allocated by Coast Protection Board for the Kingston Park Region. The height of this flood map is depicted at 2.47 (AHD). Wave run up has not been included but depicted schematically with a dotted line. Historical photographs tend to corelate well with this flood depiction.

Map

Marino Cliffs 1:1

Historical storm event

Event: 9th May 2016: 2.47 AHD
Risk: Historical benchmark
Date: 12 May 2018

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Notes

DEWNR advises that current storm surge risk for Kingston Park to the immediate north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up. Wave run-up is depicted as a dotted line at approximately 1m above storm surge height (see photographs for 9th May 2016).However, in reality water would stream over the top at different locations along this stretch of road and it is likely that the entire road would suffer some inundation. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Marino Cliffs 1:1

Sea-flood 2.70m AHD

Event: Scenario: current
Risk: 1 in 100 ARI
Date: 12 May 2018

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Notes

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Map

Marino Cliffs 1:1

Sea-flood 3.0m AHD

Event: Scenario 2050

Risk: 1 in 100 ARI

Date: 12 May 2018

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Notes

DEWNR advises that current storm surge risk for Kingston Park to the immediate north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up. Wave run-up is depicted as a dotted line at approximately 1m above storm surge height (see photographs for 9th May 2016).. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100. The blue shading on the road indicates that waves are likely to be breaking on the Esplanade, and therefore the whole road would be awash. The houses within Marion Council are quite high set (>5m).

Map

Marino Cliffs 1:1

Sea-flood 3.7m AHD

Event: Scenario 2100
Risk: 1 in 100 ARI
Date: 12 May 2018

Risk assessment: Marino Cliffs (1:1)

Risk identification: Inundation is currently impacting The Esplanade, and projected sea level rise will exacerbate the impact.

Hotspot

Coastal processes	Storm surge and wave action hits this part of the shoreline obliquely (especially in vicinity of The Esplanade). The geology of the region is classified as soft rock/ hard rock sloping shores with rocky beach (intertidal zone), and rock shelf in sub-tidal zone. Sediment supply issues are not relevant in this region. Photographs taken on 9th May 2016 depict some overtopping.

Are any controls employed to mitigate the risk? In the northern part of Section 1, rock armour (in fair condition) reduces wave exposure

Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Consists of – esplanade road reserve, s/w infrastructure, walking trail, foreshore furniture and artwork. Rock armour and small rock groyne on beach.	current	*Possible*	*Insignificant*	low
		2100	*Likely*	*Moderate*	high
Private assets*	Houses within Marion Council are situated behind the esplanade road and set higher than the road. However, even at 2100 levels these are likely to be set high enough not to be severely impacted. The Council is not necessarily liable for private assets.	current	*Rare*	*No risk*	no risk
		2100	*Likely*	*Minor*	medium
Safety of people	People live and recreate in the region. Walking trail. The foreshore region is not used extensively by the public (apart from The Esplanade area)	current	*Rare*	*Minor*	low
		2100	*Unlikely*	*Moderate*	medium
Environment	Inter-tidal zone is rocky beach, backed by hard rock/ soft rock cliffs. This section contains threatened priority remnant vegetation and may provide habitat for threatened fauna. The subtidal reef and seagrass are vulnerable to change.	current	*Rare*	*Minor*	low
		2100	*Likely*	*Moderate*	medium

Inherent Hazard Rating

Hard /soft rock sloping shores
(R-1 and SR-10)

	Low	Moderate	High	Very high
Ecosystem disruption	X	2	3	4
Gradual inundation	X	2	3	4
Salt water intrusion	X	2	3	4
Erosion	1	X	3	4
Flooding	X	2	3	4

Inundation Hazard Rating
(current outlook)

	Low	Medium	High	Extreme
Public Infrastructure	X			
Private Assets*	X			
Public safety	X			
Environment	X			

Inundation Hazard Rating
(future outlook)

	Low	Medium	High	Extreme
Public Infrastructure			X	
Private Assets*		X		
Public safety		X		
Environment		X		

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

*CoM not necessarily liable for private assets

Summary	Photographs depict minor over-topping of The Esplanade on 9th May 2016 (at least a 1 in 20 event) due to wave runup and therefore events of similar magnitude will cause over-topping. The scenario planning demonstrates that projected rises by 2050 are unlikely to produce direct inundation from storm surge, but wave over-topping on to the Esplanade will be significant. Projections for 2100 depict significant impact on to the Esplanade. Some impact to private assets later in century.

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Map

Marino Cliffs 1:1

Sea-flood 2.47m AHD

Event: 9 May 2016
Risk: 1 in 100 ARI
Date: 12 May 2018

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Notes

DEWNR advises that current storm surge risk for Kingston Park to the immediate north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up. Wave run-up is depicted as a dotted line at approximately 1m above storm surge height (see photographs for 9th May 2016). However, in reality, the interaction of wave run up with the coastline would vary significantly from location to location. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Marino Cliffs 1:1

Sea-flood 2.7m AHD

Event: Scenario: current
Risk: 1 in 100 ARI
Date: 12 May 2018

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Notes

DEWNR advises that current storm surge risk for Kingston Park to the immediate north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up. Wave run-up is depicted as a dotted line at approximately 1m above storm surge height (see photographs for 9th May 2016). However, in reality, the interaction of wave run up with the coastline would vary significantly from location to location. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Marino Cliffs 1:1

Sea-flood 3.0m AHD

Event: Scenario 2050

Risk: 1 in 100 ARI

Date: 12 May 2018

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www.integratedcoasts.com
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Notes

DEWNR advises that current storm surge risk for Kingston Park to the immediate north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up. Wave run-up is depicted as a dotted line at approximately 1m above storm surge height (see photographs for 9th May 2016). However, in reality, the interaction of wave run up with the coastline would vary significantly from location to location. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Marino Cliffs 1:1

Sea-flood 3.7m AHD

Event: Scenario 2100
Risk: 1 in 100 ARI
Date: 12 May 2018

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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been included at 0.7m by way of a dotted blue line. However, how the actual impact of the sea upon the coastline would vary greatly. Sea level rise of 0.0 has been added.

Map

Marino Cliffs 1:1

High Tide 1.70m AHD

Event: Scenario: current
Risk: Escarpment Erosion
Date: 12 May 2018

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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been included at 0.7m by way of a dotted blue line. However, how the actual impact of the sea upon the coastline would vary greatly Sea level rise of 0.03 has been added.

Map

Marino Cliffs 1:1

High Tide 2.0m AHD

Event: Scenario 2050
Risk: Escarpment erosion
Date: 12 May 2018

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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been included at 0.7m by way of a dotted blue line. However, how the actual impact of the sea upon the coastline would vary greatly . Sea level rise of 1.0 has been added.

Map

Marino Cliffs 1:1

High tide 2.7m AHD

Event: Scenario 2100
Risk: Escarpment erosion
Date: 12 May 2018

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Notes

To analyse the rate of shoreline recession over the last seventy years, comparative analysis was conducted using georeferenced aerial photographs from 1949, 2002, and 2017. This analysis provides a long-term review (70 years), and a shorter term review (15 years). The longer term review is dependent on black and white photographs that are often difficult to decipher.

Map

Marino Cliffs 1:1

Erosion assessment

Event: Oct 2017
Risk: Shoreline recession
Date: 12 May 2018

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Notes

Nil visible recession of the cliff escarpment since 2002.

Map

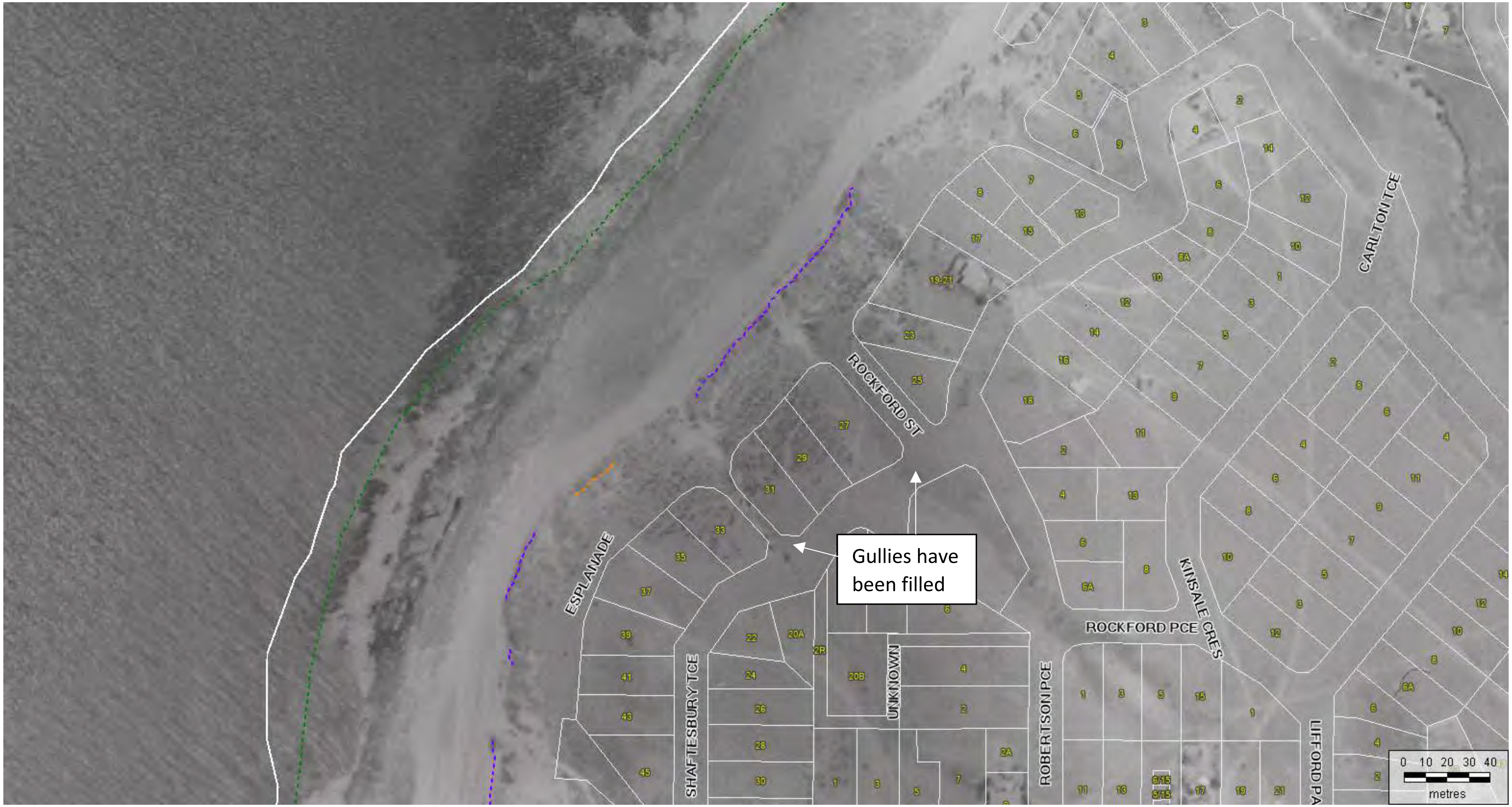
Marino Cliffs 1:1

Erosion assessment

Event: 2002

Risk: Shoreline recession

Date: 12 May 2018



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Notes

2-3 metres of erosion from the base of the cliff (in places of softer constituency, and not of the harder rock sections of cliff). Geological assessment on next slide suggests that the toe of this portion of cliff is erodible. Also note, gullies that originally took storm water to the ocean have been filled in areas upon which the walking trail is positioned.

Map

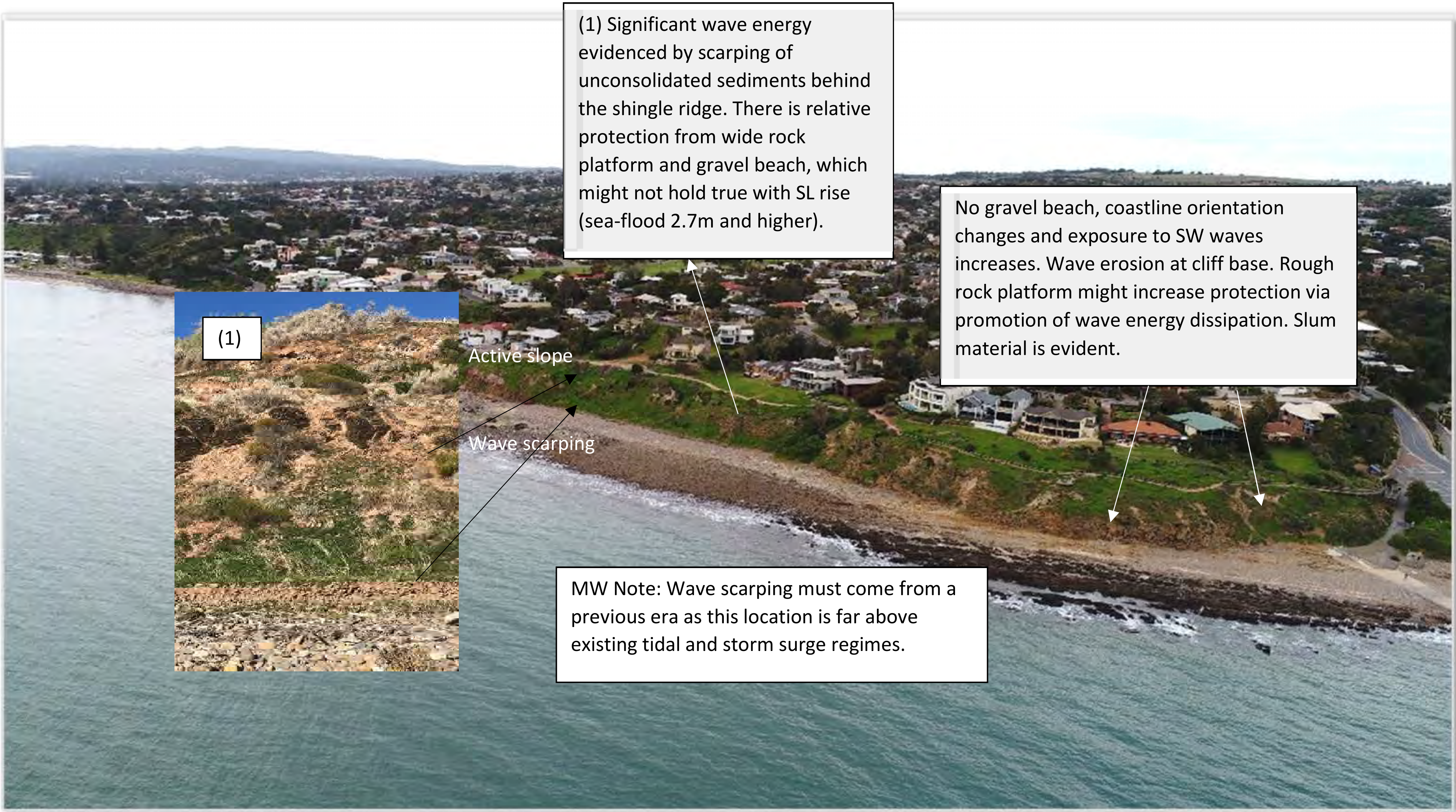
Marino Cliffs 1:1

Erosion assessment

Event: 1949

Risk: Shoreline recession

Date: 12 May 2018



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Notes

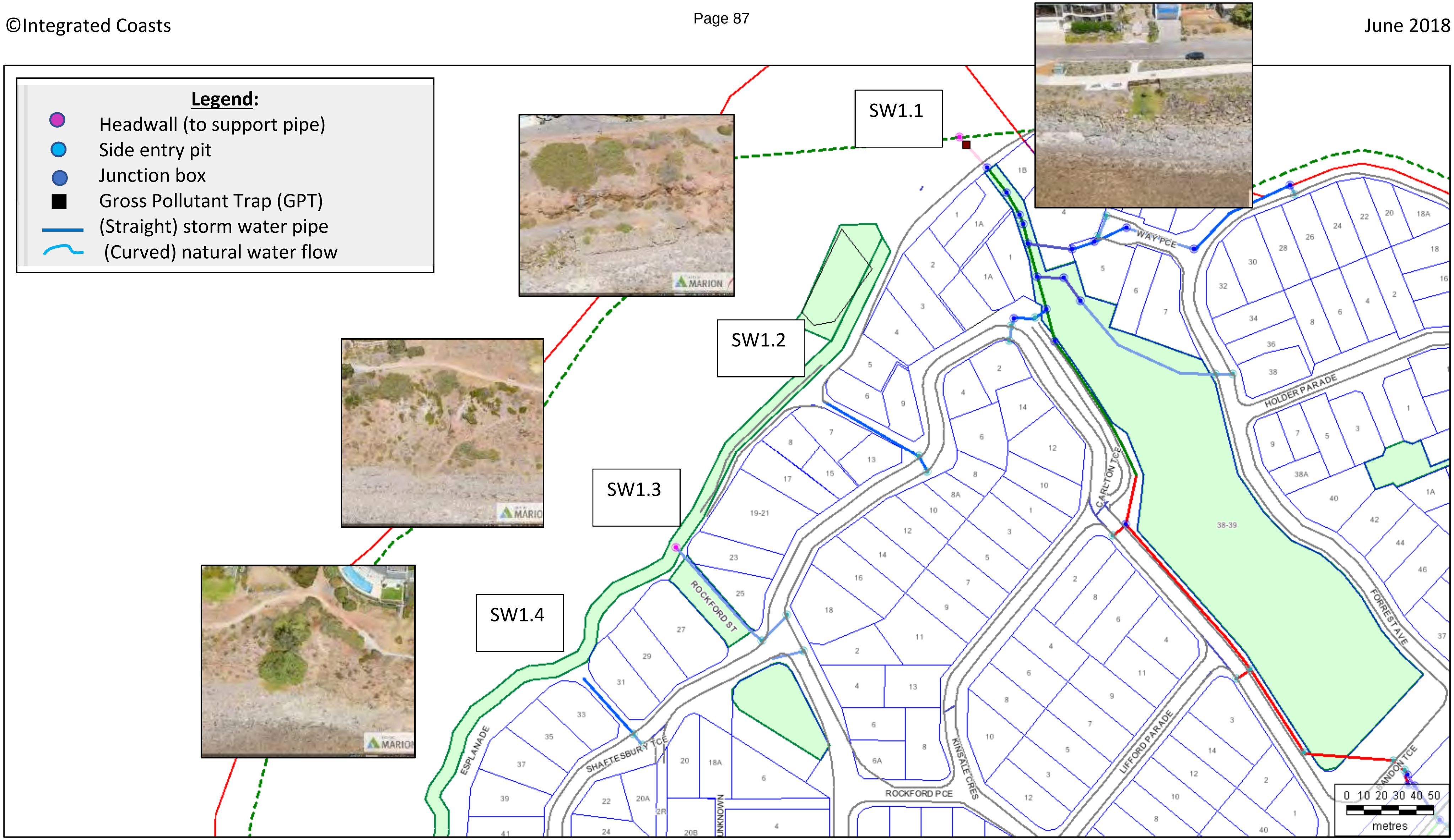
In the northernmost part of this section, the cliff is composed of alluvial clay from Pleistocene Ochre Cove and Ngaltinga Formations which terminate at about 200m southwards from the end of the Burnham Rd into more resistant Neo-Proterozoic siltstone from the Marino Arkose member of the Wilmington Formation. The most vulnerable part of this section is where the cliff is composed of friable Pleistocene clay, which is evidenced by active slopes and gullying (see photo (1) above for detail). Cliff morphology and relatively low slope indicate dominance of subaerial erosion. In a 1-4 erosion resistance scale (1, highly vulnerable; 2, likely vulnerable; 3, likely resistant; 4, highly resistant) this section is 2, likely vulnerable.

Map

Marino Cliffs 1:1

Geological assessment

Event: Ongoing
Risk: Shoreline recession
Date: 12 May 2018



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Notes

SW1.1 A series of junction boxes slow the rate of water. Gross pollutant trap captures sediment and trash (mostly organic)

SW1.2 Water flows over cliff (waterfalls into capture point MW).

SW1.3 Doesn't exist.

SW1.4 Water flows over cliff (periodically checked for operation, not scouring)

Map

Marino Cliffs 1:1

Stormwater assessment

Event: Ongoing

Risk: Cliff erosion

Date: 12 May 2018

Risk assessment: Marino Cliffs (1:1)

Risk identification: Erosion is currently, or may in the future, undermine the toe of the cliff, and cause the cliff to recede.

Coastal processes	The geology of the cliff in the northern section is alluvial Pleistocene clay and is the most vulnerable in this section. Storm surge indicates existing attack in this location. Other sections of the cliff come under direct attack with SLR. Historical photographs show some recession of the soft toe section (2-3m)

Are any strategies employed to mitigate the risk? No (and the assessment assumes that no action is taken to mitigate the risk)

Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Public road and footpath approx 7-10 m behind the Pleistocene clay, and walking trail behind the remainder.	current	*Rare*	*Moderate*	low
		2100	*Likely*	*Moderate*	high
Private assets*	Houses site behind the walking trail. The closest house to top of escarpment is about 20m. However, there may be other houses affected. The Council is not necessarily liable for private assets even if they are impacted.	current	*Rare*	*Moderate*	low
		2100	*Possible*	*Severe*	high
Safety of people	People use road and footpath (part of walking trail route). The current assessment assumes that people remain on roads and pathways. It is extremely unlikely that an event would occur without any warning and that someone might be impacted.	current	*Rare*	*Moderate*	low
		2100	*Unlikely*	*Major*	medium
Environment	Inter-tidal zone is rocky beach, backed by soft rock cliff. This section contains threatened priority remnant vegetation and may provide habitat for threatened fauna. The subtidal reef and seagrass are vulnerable to change.	current	*Rare*	*Minor*	medium
		2100	*Possible*	*Moderate*	medium

Inherent Hazard Rating

Hard /soft rock sloping shores (SR-10)

	Low	Moderate	High	Very high
Ecosystem disruption	X	2	3	4
Gradual inundation	X	2	3	4
Salt water intrusion	X	2	3	4
Erosion	1	X	3	4
Flooding	X	2	3	4

Erosion Hazard Rating (current outlook)

	Low	Medium	High	Extreme
Public Infrastructure	X			
Private Assets*	X			
Public safety		X		
Environment	X			

Erosion Hazard Rating (future outlook) 2100

	Low	Medium	High	Extreme
Public Infrastructure			X	
Private Assets*			X	
Public safety		X		
Environment	X			

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

*CoM not necessarily liable for private assets

Summary	The erodibility of the cliff in northern section is higher than the remainder of this section. Inspection and modelling demonstrate that this area of cliff is subject to intermitent wave attack. The remainder of the cliff is more stable and not subject to wave attack under current sea level conditions. However, with increase in sea level this area of cliff could become more vulnerable. In the context of the risk identification, and that the toe of the cliff is not under significant wave attack and it appears stable over the fifteen years, public safety risk low. This does not infer that there is no general risk to public safety.

Marino Cliffs (1:1)

Summary and recommended actions (draft)

Geological review: The northern section of Marino Cliffs (1) is composed of 'friable Pleistocene clay' which is more susceptible to erosion (rated as 'likely vulnerable). The southern section of Marino Cliffs (1) is more resistant Neo-Proterozoic siltstone (rated as 'likely resistant').

Historical recession: Based on photographic analysis, there appears to be no significant recession of the cliff since 2002, and some recession evident at the base of the cliff since 1949 (in the order of 2-3 metres, most likely material described in the geological assessment as 'friable Pleistocene clay').

Exposure:	**Routine tidal impact (bi-monthly)**	**Storm surge impact (1 in 100 ARI)**
Historical event - 2016	NA	Likely to have interacted with the base of the cliff with minor escarpment created.
Current	Unlikely that routine tidal action is interelating with the base of the cliff (apart from harder rock sections at either end)	The wave run up of storm surge and wave height of 2.70m will interact significantly with the base of the cliff (with wave run up only)
2050	Some routine tidal action will interelate with the base of the cliff (wave run up only)	The wave run up of storm surge and wave height of 3.00m will interact significantly with the base of the cliff (with wave run up only)
2100	Significant routine wave and wave run-up action will interelate with the base of the cliff	The base of the cliff will come under high impact direct wave attack from storm surge of 3.70m

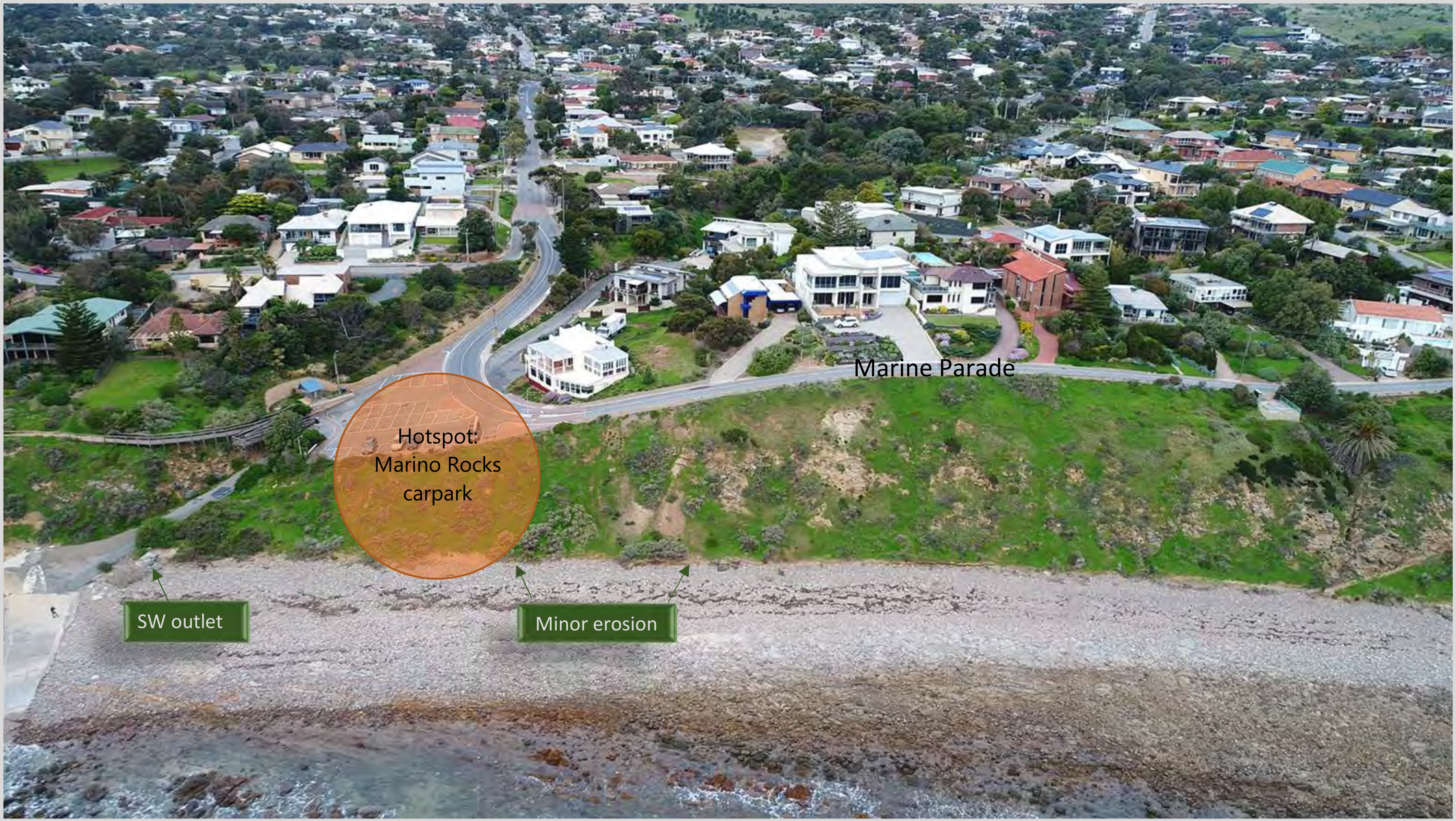
Storm water: Preliminary review suggests that water is flowing over cliff face in places although the catchment in these areas may be small.

Risk Assessment: Based on stable cliff with wave and tidal action likely to be limited to extreme events (wave run up) the current risk has been assigned an overall 'low' erosion rating. This risk assessment becomes elevated when taking sea level rise into account (See p. 23). Inundation risk to the Esplanade relates to minor wave run-up, but this too will become exacerbated with projected sea level rises.

Recommended actions (draft):

Number	Action	Comments	Time frame
1:1 (1)	Review nature of storm water outflows and monitor impacts	Routine inspections are taken of the outfall areas. Recommend that staff incorporate review of scouring impacts (use photography)	1-2 years
1:1 (2)	Quantify more accurately the nature of routine and storm surge interaction with cliff base.	Monitor tidal regime for period of three months (winter). Monitor the impact of storm surge events (if, and when they occur)	1-2 years
1:1 (3)	Recapture digital model as basis for comparison	Use appropriate software to quantify changes in the coastal environment.	3-5 years
1:1 (4)	Assess protection options for the Esplanade	Rock revetment is in poor condition in this location. However, a simple protection system would prevent overtopping in this location.	1-2 years

Cell 1: Marino Cliffs (2)



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Notes

On 9th May 2016 the highest level of water was recorded at Outer Harbor in 80 years at 3.80 CD (2.36 AHD). To calculate the storm surge height at Marino: secondary port relationship methodology was used with Brighton (95%) and wave height of 0.30m added in accordance with storm surge allowance allocated by Coast Protection Board for the Kingston Park Region. The height of this flood map is depicted at 2.47 (AHD). Wave run up has been included at 1.0m higher and depicted by way of dotted blue line. Historical photographs tend to corelate well with this flood depiction.

Map

Marino Cliffs 1:2

Sea-flood 2.47m AHD

Event: 9 May 2016
Risk: Historical benchmark
Date: 12 May 2018

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Notes

DEWNR advises that current storm surge risk for Kingston Park to the immediate north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up. Wave run-up is depicted as a dotted line at approximately 1m above storm surge height (see photographs for 9th May 2016). However, in reality the impact of wave run up would vary greatly from location to location. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Marino Cliffs 1:2

Sea-flood 2.70m AHD

Event:	Scenario: current
Risk:	1 in 100 ARI
Date:	12 May 2018

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Notes

DEWNR advises that current storm surge risk for Kingston Park to the immediate north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up. Wave run-up is depicted as a dotted line at approximately 1m above storm surge height (see photographs for 9th May 2016).. However, in reality the impact of wave run up would vary greatly from location to location. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Marino Cliffs 1:2

Sea-flood 3.00m AHD

Event: Scenario: 2050
Risk: 1 in 100 ARI
Date: 12 May 2018

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Notes

DEWNR advises that current storm surge risk for Kingston Park to the immediate north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up. Wave run-up is depicted as a dotted line at approximately 1m above storm surge height (see photographs for 9th May 2016). However, in reality the impact of wave run up would vary greatly from location to location. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Marino Cliffs 1:2
Sea-flood 3.70m AHD
Event: Scenario: 2100
Risk: 1 in 100 ARI
Date: 12 May 2018

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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up is depicted at 0.7m higher by way of a dotted blue line. However, in reality the impact of wave run up would vary greatly. Sea level rise of 0.0 has been added.

Map

Marino Cliffs 1:2

High tide 1.7m AHD

Event: Scenario: current
Risk: Escarpment erosion
Date: 12 May 2018

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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up is depicted at 0.7m higher by way of a dotted blue line. However, in reality the impact of wave run up would vary greatly. Sea level rise of 0.3 has been added.

Map

Marino Cliffs 1:2

High tide 2.0m AHD

Event: Scenario: 2050

Risk: Escarpment erosion

Date: 12 May 2018

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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up is depicted at 0.7m higher by way of a dotted blue line. However, in reality the impact of wave run up would vary greatly. Sea level rise of 1.0 has been added.

Map

Marino Cliffs 1:2

High tide 2.7m AHD

Event: Scenario: 2100
Risk: Escarpment erosion
Date: 12 May 2018

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Notes

To analyse the rate of shoreline recession over the last seventy years, comparative analysis was conducted using georeferenced aerial photographs from 1949, 2002, and 2017. This analysis provides a long-term review (70 years), and a shorter term review (15 years). The longer term review is dependent on black and white photographs that are often difficult to decipher.

Map

Marino Cliffs 1:2

Erosion assessment

Event: 2017
Risk: Shoreline recession
Date: 12 May 2018

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Notes

Some minor erosion on northern end (review in progress).

Map

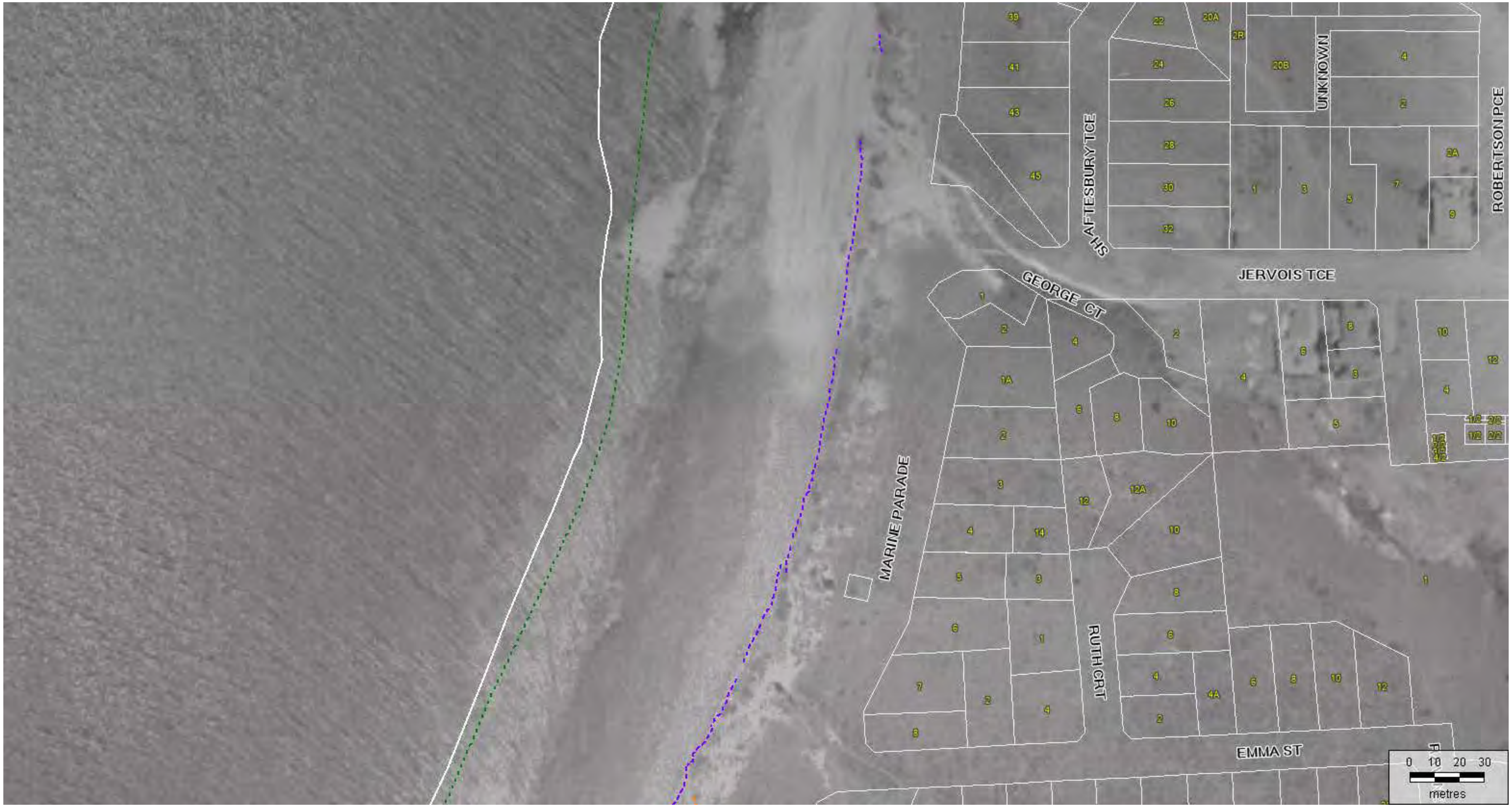
Marino Cliffs 1:2

Erosion assessment

Event: 2002

Risk: Shoreline recession

Date: 12 May 2018



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1300 767 333 (free call)

Notes

Some minor erosion on northern end (review in progress). There is likely to have been a higher ridge of shingles on the northern end (in front of what is now a drain location)

Map

Marino Cliffs 1:2

Erosion assessment

Event: 1947
Risk: Shoreline recession
Date: 12 May 2018

This section has been mapped as part of the Neo-Proterozoic Marino Arkose formation, which is a lime-cemented sandstone rich in feldspar. The arkose is a resistant material however it is covered by undifferentiated (weathered) material. Cliff morphology suggested that subaerial erosion (e.g. caused by stormwater flow) is more significant here than wave-driven erosion at this time. There is undercutting (scars) on top of the cliff and slumping material, nonetheless vegetated suggesting the movement is not recent. Presence of gravel beach will act as a natural protection against storm waves however sea-flood 3.7 m will cause significant erosion at cliff toe. In a 1-4 erosion resistance scale (1, highly vulnerable; 2, likely vulnerable; 3, likely resistant; 4, highly resistant) this section is 2, likely vulnerable. This section should be further inspected for geotechnical properties given the proximity of the road/car park to the edge of the cliff.

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Notes

Map

Marino Cliffs 1:2

Geological assessment

Event: Ongoing
Risk: Cliff erosion
Date: 12 May 2018

Legend:

- Headwall (to support pipe)
- Side entry pit
- Junction box
- Gross Pollutant Trap (GPT)
- (Straight) storm water pipe
- (Curved) natural water flow

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Notes

SW1:5 Headwall (to stabilise pipe). Series of junction boxes slow rate of flow.
SW1:6 Draining through side entry pit and over cliff escarpment into gully.
SW1:7 Draining into side entry pit, under Marine Pde and then into cliff gully

Generally, no signs of erosion at base of cliffs or on shingle beach. Difficult to assess impact of water flow in cliff gullies.

Map

Marino Cliffs 1:2

Stormwater assessment

Event: Ongoing
Risk: Cliff erosion
Date: 12 May 2018

8 A dwelling should have a minimum site area, a frontage to a public road and an allotment depth not less than that shown in the following table:

Dwelling Type	Site Gradient	Minimum Site Area (square metres)	Minimum Frontage Width (metres)	Minimum Site Depth (metres)
Detached	less than 1-in-10	700	18	20
	between 1-in-10 and 1-in-5	900	20	20
	more than 1-in-5	1100	20	20
Group	less than 1-in-10	700	24	45
	between 1-in-10 and 1-in-5	900	26	45
	more than 1-in-5	1100	26	45

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Notes

Planning zoning classifies this area as low density with no ability to subdivide further.

Map

Marino Cliffs 1:2

Planning Assessment

Event: Ongoing
Risk: Shoreline recession
Date: 12 May 2018

Hotspot Assessment: Marino Rocks Carpark

Technical context (studies)	No studies exist for this region. Council does have record of all stormwater infrastructure and outlets.
Historical Context	The original subdivision was completed in England and had no regard to the geological context when placing Marine Parade. CPB (1997) recommended that proposed restaurant be refused unless certain conditions were met. CPB noted possibility of increased erosion in the context of climate change. CPB transferred liability to Council for ongoing protection of the carpark and Marine Pde. The storm event of 9th May 2016 may be the first time the base of this cliff has been eroded (or this event certainly would have exacerbated it)
Coastal context	CHW assigned this section of coast as 'Soft rock sloping shores' with Moderate Erosion Hazard rating. Observations suggest higher level of sediment in this cliff. Coastal processes are well known in the region. Sediment supply is little consequence in this region (rocky beach/shelf).
Climate context	SLR is rising in the Gulf and projected to rise faster. Storm action may become more pronounced (but more likely later in the century).
Strategic context	Council has approved Climate Policy, Strategic and Business planning to provide direction in climate adaptation planning and stormwater management.

Risk assessment: Marino Cliffs (1:2)

Risk identification: Erosion is currently impacting the base of the cliff adjacent Marino Rocks carpark that may lead to a landslip

Hotspot

Coastal processes	The geology of the cliff adjacent the carpark is classified as Neo-Proterozoic Marino Arkose which is a resistant material, but in this instance covered by undifferentiated material. Likely to have been no recent movement at the top. Minor erosion escarpment likely to have been caused 9th May 2016 (see modelling). Shingle beach will provide some protection from waves but increasing sea levels will result in direct attack to the base of the escarpment

Are any strategies employed to mitigate the risk? No (and the assessment assumes that no action is taken to mitigate the risk)

Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Marino Rocks carpark, Marine Parade road reserve adjacent.	current	*Rare*	*Severe*	medium
		2100	*Likely*	*Severe*	extreme
Private assets*	Marino Rocks Restaurant sits behind Marine Parade. It isn't likely that if the carpark failed that Council would not mitigate the risk to the restaurant. The Council is not necessarily liable for private assets even if they are impacted.	current	*Rare*	*No risk*	no risk
		2100	*Unlikely*	*Major*	medium
Safety of people	People use the carpark frequently to access the restaurant or the boat ramp area. Also likely to be a place to park while walking the coastal trail.	current	*Rare*	*Major*	low
		2100	*Rare*	*Severe*	medium
Environment	Inter-tidal zone is rocky beach, backed by soft rock cliff. This section contains threatened priority remnant vegetation and may provide habitat for threatened fauna. The subtidal reef and seagrass are vulnerable to change.	current	*Rare*	*Minor*	low
		2100	*Possible*	*Moderate*	medium

Inherent Hazard Rating

Hard /soft rock sloping shores (R-1 and SR-10)

	Low	Moderate	High	Very high
Ecosystem disruption	X	2	3	4
Gradual inundation	X	2	3	4
Salt water intrusion	X	2	3	4
Erosion	1	X	3	4
Flooding	X	2	3	4

Erosion Hazard Rating

(current outlook)

	Low	Medium	High	Extreme
Public Infrastructure		X		
Private Assets*	No	risk		
Public safety	X			
Environment	X			

Erosion Hazard Rating

(future outlook)

	Low	Medium	High	Extreme
Public Infrastructure				X
Private Assets*		X		
Public safety		X		
Environment		X		

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

*CoM not necessarily liable for private assets

Summary	The geological hazard rating in this location is vulnerable with increasing risk with elevations in sea level. The proximity of the carpark at the edge of the escarpment, combined with observed minor erosion at the base of the cliff elevates the risk profile. Modelling in the DEM demonstrates that direct attack on the base of the escarpment would occur from routine tides as well as storm surges.

Marino Cliffs (1:2)
Summary and recommended actions (draft)

Geological review: This section has been mapped as part of the Neo-Proterozoic Marino Arkose formation, which is a lime-cemented sandstone rich in feldspar. The arkose is a resistant material however it is covered by undifferentiated (weathered) material. Cliff morphology suggested that subaerial erosion (e.g. caused by water flowing down cliff) is more significant here than wave-driven erosion at this time (but this action subaerial erosion appears to have occurred some time ago).

Historical recession: Based on photographic analysis, there appears to be no significant recession of the cliff since 2002, and some recession evident at the base of the cliff since 1949 (but minimal).

Exposure:	**Routine tidal impact (bi-monthly)**	**Storm surge impact (1 in 100 ARI)**
Historical event - 2016	NA	Likely to have interacted with the base of the cliff with minor escarpment created.
Current	Unlikely that routine tidal action is interelating with the base of the cliff (apart from harder rock sections at either end)	The wave run up of storm surge and wave height of 2.70m will interact significantly with the base of the cliff (with wave run up only)
2050	Some routine tidal action will interelate with the base of the cliff (wave run up only)	The wave run up of storm surge and wave height of 3.00m will interact significantly with the base of the cliff (with wave run up only)
2100	Significant routine wave and wave run-up action will interelate with the base of the cliff	The base of the cliff will come under high impact direct wave attack from storm surge of 3.70m

Storm water: Preliminary review suggests that major storm water flow is piped to below the cliff in north, but two flows into cliff gullies exist in the southern section.

Risk Assessment: Based on stable cliff with wave and tidal action likely to be limited to extreme events (wave run up) the current risk has been assigned an overall 'moderate' rating due to the close proximity to public assets. This risk assessment becomes 'extreme' when taking sea level rise into account (See p. 23)

Recommended actions (draft):

Number	Action	Comments	Time frame
1:2 (1)	Review nature of storm water outflows in south of this section and monitor impacts	Routine inspections are taken of the outfall areas. Recommend that staff incorporate review of scouring impacts (use photography)	1-2 years
1:2 (2)	Quantify more accurately the nature of routine and storm surge interaction with cliff base to ascertain if protection works are required.	Monitor tidal regime for period of three months (winter). Monitor the impact of storm surge events (if, and when they occur). Protection works may be required to ensure erosion escarpment does not increase in height.	1-2 years
1:2 (3)	Recapture digital model as basis for comparison	Use appropriate software to quantify changes in the coastal environment.	3-5 years
1:2 (4)	Quantify more accurately the nature of the cliff below Marine Pde and the carpark.	The cliff escarpment appears stable at the moment, but due to the proximity of public assets above, the nature of the cliff should be further quantified.	3-5 years

Cell: Marino Cliffs (3)

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1300 767 333 (free call)

Notes

On 9th May 2016 the highest level of water was recorded at Outer Harbor in 80 years at 3.80 CD (2.36 AHD). To calculate the storm surge height at Marino: secondary port relationship methodology was used with Brighton (95%) and wave height of 0.30m added in accordance with storm surge allowance allocated by Coast Protection Board for the Kingston Park Region. The height of this flood map is depicted at 2.47 (AHD). The dashed line depicts the likely impact of 1m wave runup. Historical photographs tend to corelate well with this flood depiction.

Map

Marino Cliffs 1:3

Sea-flood 2.47m AHD

Event: 9 May 2016
Risk: Historical benchmark
Date: 12 May 2018

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

Notes

DEWNR advises that current storm surge risk for Kingston Park to the immediate north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up. Wave run-up is depicted as a dotted line at approximately 1m above storm surge height (see photographs for 9th May 2016). However, in reality, the interaction of wave run up with the coastline would vary significantly from location to location. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Marino Cliffs 1:3

Sea-flood 2.70m AHD

Event: Scenario: current
Risk: 1 in 100 ARI
Date: 12 May 2018

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Notes

DEWNR advises that current storm surge risk for Kingston Park to the immediate north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up. Wave run-up is depicted as a dotted line at approximately 1m above storm surge height (see photographs for 9th May 2016). However, in reality, the interaction of wave run up with the coastline would vary significantly from location to location. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Marino Cliffs 1:3

Sea-flood 3.00m AHD

Event: Scenario: 2050
Risk: 1 in 100 ARI
Date: 12 May 2018

Integrated Coasts
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Notes

DEWNR advises that current storm surge risk for Kingston Park to the immediate north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up. Wave run-up is depicted as a dotted line at approximately 1m above storm surge height (see photographs for 9th May 2016). However, in reality, the interaction of wave run up with the coastline would vary significantly from location to location. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Marino Cliffs 1:3

Sea-flood 3.70m AHD

Event: Scenario: 2100
Risk: 1 in 100 ARI
Date: 12 May 2018

Integrated Coasts
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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up is depicted at 0.7m higher by way of a dotted blue line. However, in reality the impact of wave run up would vary greatly. Sea level rise of 0.0 has been added.

Map

Marino Cliffs 1:3

High tide 1.7m AHD

Event: Scenario: current
Risk: Escarpment erosion
Date: 12 May 2018

Integrated Coasts
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Notes

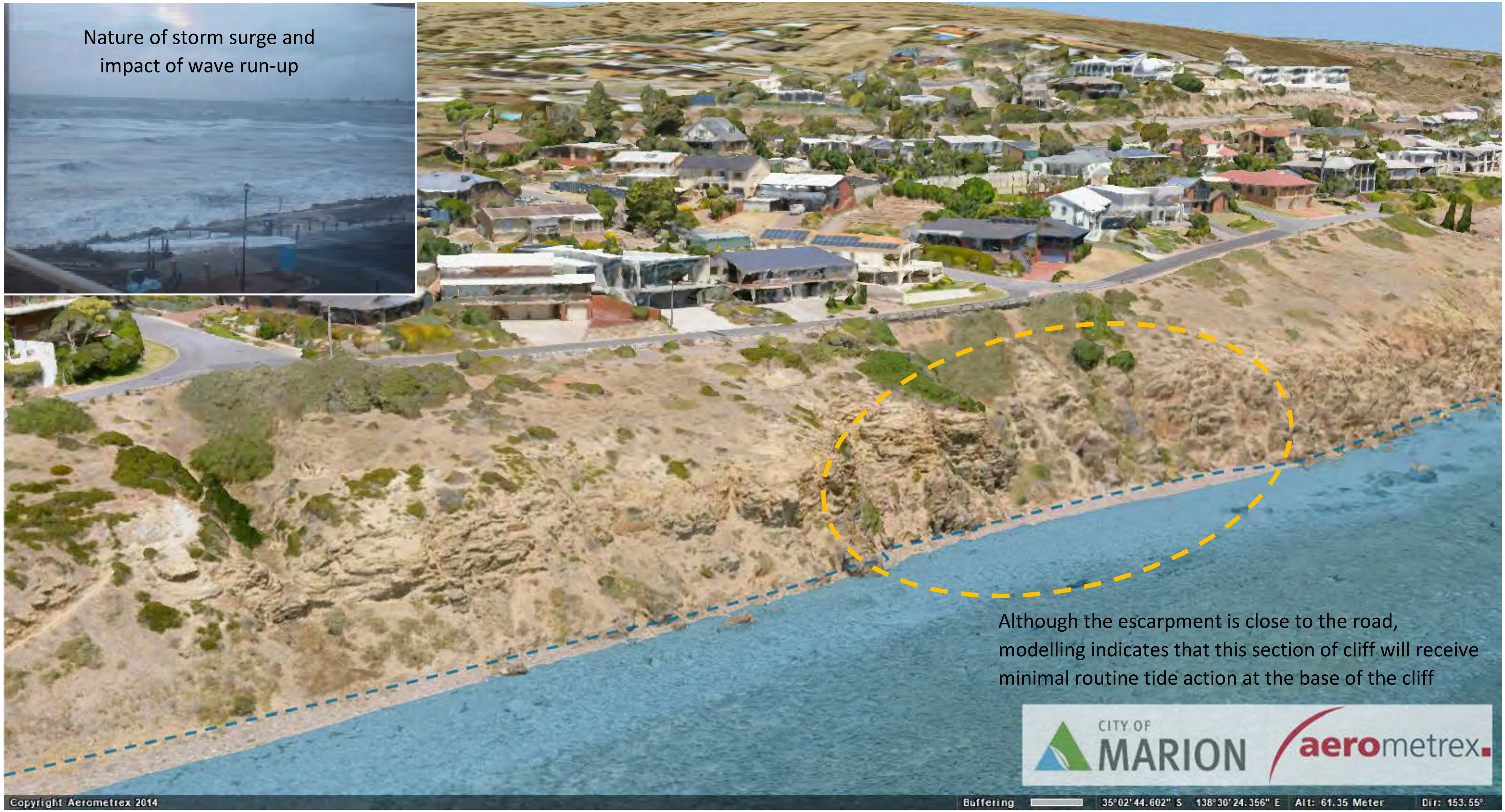
This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up is depicted at 0.7m higher by way of a dotted blue line. However, in reality the impact of wave run up would vary greatly. Sea level rise of 0.3 has been added.

Map

Marino Cliffs 1:3

High tide 2.0m AHD

Event: Scenario: 2050
Risk: Escarpment erosion
Date: 12 May 2018



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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up is depicted at 0.7m higher by way of a dotted blue line. However, in reality the impact of wave run up would vary greatly. Sea level rise of 1.0 has been added.

Map

Marino Cliffs 1:3

High tide 2.7m AHD

Event: Scenario: 2100
Risk: Escarpment erosion
Date: 12 May 2018

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Notes

To analyse the rate of shoreline recession over the last seventy years, comparative analysis was conducted using georeferenced aerial photographs from 1949, 2002, and 2017. This analysis provides a long-term review (70 years), and a shorter term review (15 years). The longer term review is dependent on black and white photographs that are often difficult to decipher.

Map

Marino Cliffs 1:3

Erosion assessment

Event: 2017
Risk: Shoreline recession
Date: 12 May 2018

Integrated Coasts
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Notes

Overall, a stable cliff. Minor erosion in places (review in progress)

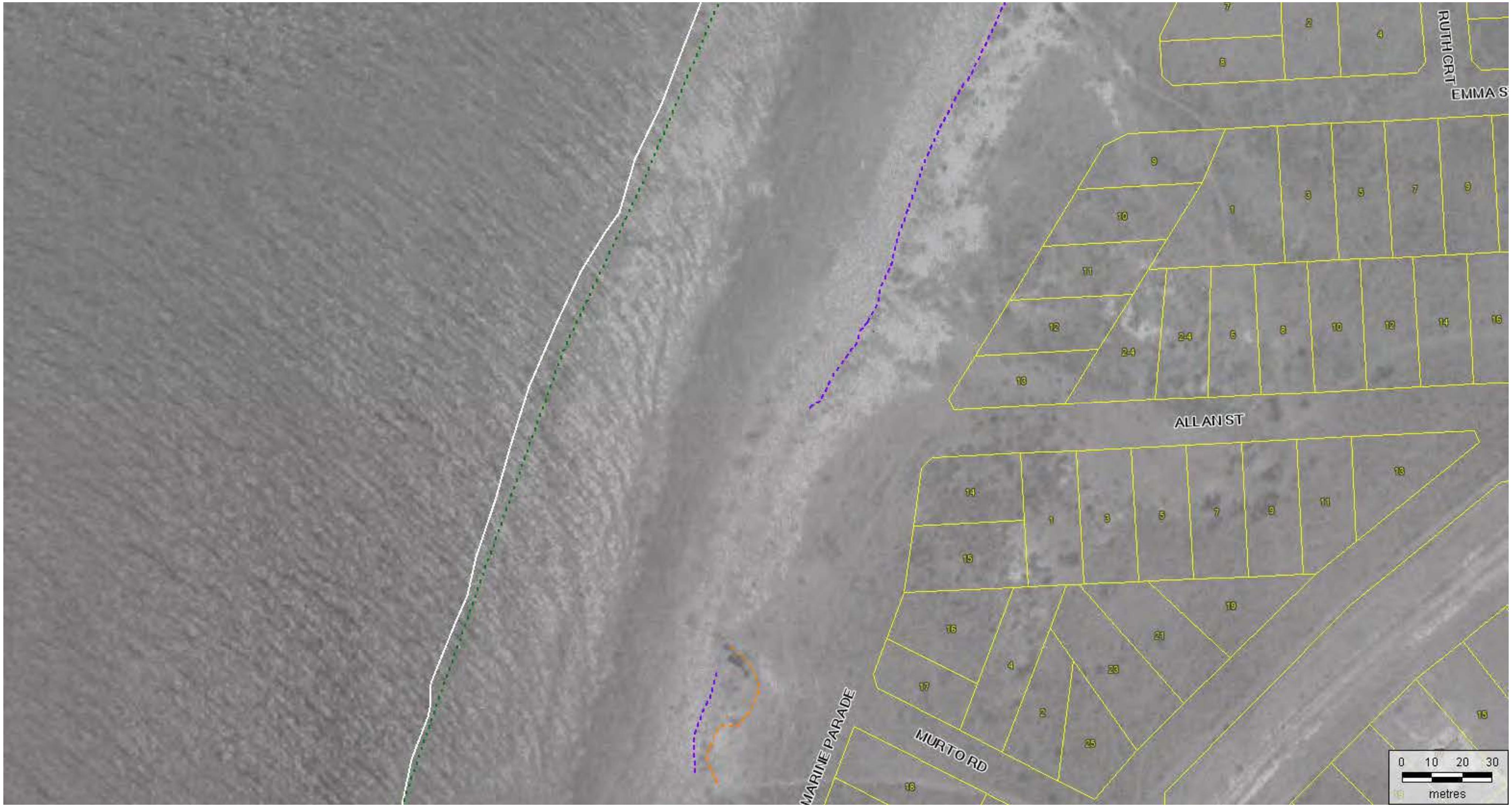
.

Map

Marino Cliffs 1:3

Erosion assessment

Event: 2002
Risk: Shoreline recession
Date: 12 May 2018



Integrated Coasts
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Notes

Overall no obvious movement of the cliff. Minor erosion in places (review in progress)

Map

Marino Cliffs 1:3

Erosion assessment

Event: 1949

Risk: Shoreline recession

Date: 12 May 2018

Integrated Coasts
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Notes

SW1:8 Draining into side entry pit (behind the 'triangle), then into cliff gully
SW1:9 Cannot find (but informed this is same methodology as SW1.8)
SW1:10 Cannot find (but informed this is same methodology as sw1.8)

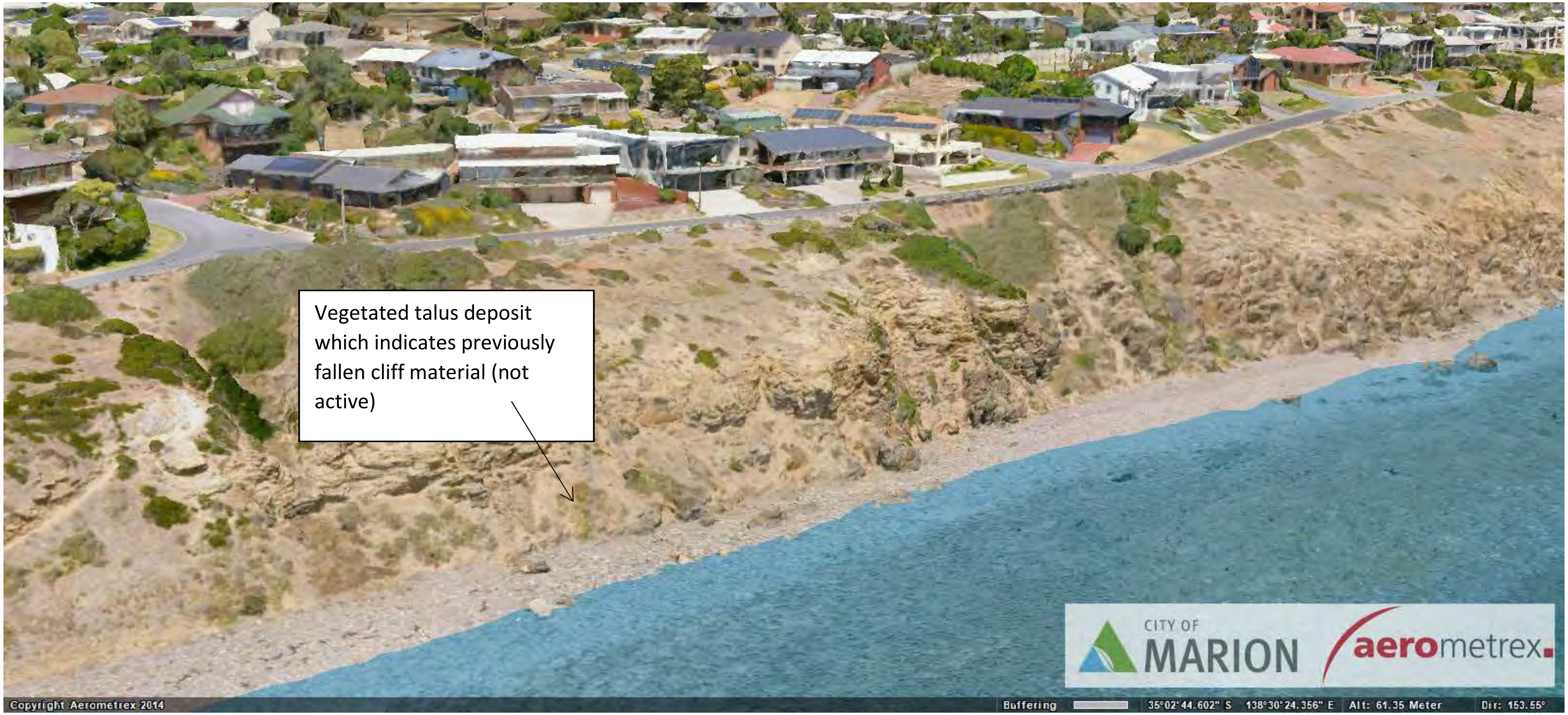
Generally, no signs of erosion at base of the cliff. Difficult to assess impact of water in the cliff gully itself.

Map

Marino Cliffs 1:3

Stormwater assessment

Event: Ongoing
Risk: Cliff erosion
Date: 12 May 2018



This cliff section has been mapped as part of the Neo-Proterozoic Marino Arkose formation, which is a resistant, lime-cemented sandstone rich in feldspar. Some slump material but cliff face mostly exposed. Narrow gravel beach, steeper and narrow intertidal width – hence more wave impact. The narrow intertidal rock platform also indicates less cliff recession over the last 7000 yrs in comparison to northerly sections. Sea-flood 2.7m will impact cliff toe, potential for significant erosion caused by wave run-up. In a 1-4 erosion resistance scale (1, highly vulnerable; 2, likely vulnerable; 3, likely resistant; 4, highly resistant) this section is 3, likely resistant.

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1300 767 333 (free call)

Notes

Map

Marino Cliffs 1:3

Geological Review

Event: Ongoing
Risk: Cliff erosion
Date: 12 May 2018

Risk assessment: Marino Rocks (1:3)

Risk identification: Erosion is currently, or may in the future, undermine the toe of the cliff, and cause the cliff to recede.

Coastal processes	This cliff section has been mapped as part of Neo-Proterozoic Marino Arkose formation which is resistant, lime-cemented sandstone rich in feldspar. The narrower rock platform indicates less cliff recession over last 7000 years compared to northerly sections. Modelling indicates that this section less likely to receive direct wave attack due to routine tides, but will suffer wave attack in storm surge events. Recent historical photographic analysis indicates stable cliff.

Are any strategies employed to mitigate the risk? No (and the assessment assumes that no action is taken to mitigate the risk)

Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Marine Parade road and associated infrastructure.	current	*Rare*	*Moderate*	low
		2100	*Unlikely*	*Severe*	high
Private assets*	Approximately 10 houses are situated landward of Marine Parade. The Council is not necessarily liable for private assets.	current	*Rare*	*No risk*	no risk
		2100	*Rare*	*Major*	low
Safety of people	People use the road in vehicles and on foot (as part of the walking trail)	current	*Rare*	*Moderate*	low
		2100	*Rare*	*Moderate*	low
Environment	Inter-tidal zone is rocky beach, backed by hard rock cliff. This section contains threatened priority remnant vegetation and may provide habitat for threatened fauna. The subtidal reef and seagrass are vulnerable to change.	current	*Rare*	*Moderate*	low
		2100	*Possible*	*Moderate*	medium

Inherent Hazard Rating

Hard rock sloping shores (R-1)

	Low	Moderate	High	Very high
Ecosystem disruption	X	2	3	4
Gradual inundation	X	2	3	4
Salt water intrusion	X	2	3	4
Erosion	X	2	3	4
Flooding	X	2	3	4

Erosion Hazard Rating (current outlook)

	Low	Medium	High	Extreme
Public Infrastructure	X			
Private Assets*	No risk			
Public safety	X			
Environment	X			

Erosion Hazard Rating (future outlook)

	Low	Medium	High	Extreme
Public Infrastructure			X	
Private Assets*	X			
Public safety	X			
Environment		X		

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

*CoM not necessarily liable for private assets

Summary	The geological hazard rating in is 'likely resistant'. Historical photographs indicate a stable cliff over last 80 years. This area of cliff will receive less direct wave and tide action due to normal tide cycles, but will be impacted by larger storm surges. The close proximity of Marine Parade between Emma Street and Allan Street sees the categorisation of high risk outlook, while recognising the stable nature of the cliff under current ocean processes. Marine Pde between Allan and Murto road is set much further back.

Marino Cliffs (1:3)
Erosion outlook and recommended actions (draft)

Geological review: This cliff section has been mapped as part of Neo-Proterozoic Marino Arkose formation which is 'likely resistant', lime-cemented sandstone rich in feldspar.

Historical recession: Based on photographic analysis, there appears to be no significant recession of the cliff since 2002, and no obvious recession since 1949 (based on black and white aerial photography)

Storm water: Preliminary review suggests that storm water is captured on Marine Pde and then piped over the cliff escarpment (perhaps small sw capture areas)

Exposure:	Routine tidal impact (bi-monthly)	Storm surge impact (1 in 100 ARI)
Historical event - 2016	NA	Wave run-up likely to have interacted with the base of the cliff
Current	Unlikely that routine tidal action is interelating with the base of the cliff (apart from harder rock sections)	The wave run up of storm surge and wave height of 2.70m will interact significantly with the base of the cliff (with wave run up only)
2050	Some routine tidal action will interelate with the base of the cliff (wave run up only)	The wave run up of storm surge and wave height of 3.00m will interact significantly with the base of the cliff (with wave run up only)
2100	Significant routine wave and wave run-up action will impact the base of the cliff	The base of the cliff will come under high impact direct wave attack from storm surge of 3.70m

Risk Assessment: Based on stable cliff of a 'likely resistant' nature with wave and tidal action likely to be limited to extreme events (wave run up) the current risk has been assigned an overall 'low'. This risk assessment becomes 'high' when taking sea level rise into account (See p. 23)

Recommended actions (draft):

Number	Action	Comments	Time frame
1:3 (1)	Review nature of storm water outflows in south of this section and monitor impacts	Routine inspections are taken of the outfall areas are taken annually. Recommend that staff take photographs of any evidence of scouring of the cliff (within 1 year).	1-2 years
1:3 (2)	Quantify more accurately the nature of routine and storm surge interaction with cliff base.	Monitor tidal regime for period of three months (winter). Monitor the impact of storm surge events (if, and when they occur)	1-2 years
1:3 (3)	Recapture digital model as basis for comparison	Use appropriate software to quantify changes in the coastal environment.	3-5 years

Cell 1: Marino Cliffs (4)

Falling rocks hazard contained with wire netting. Beach access stairs may come under increasing impact from sea processes but improved design can cater for impacts when stairs are upgraded.

Nature of storm surge and impact of wave run-up

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1300 767 333 (free call)

Notes

On 9th May 2016 the highest level of water was recorded at Outer Harbor in 80 years at 3.80 CD (2.36 AHD). To calculate the storm surge height at Marino: secondary port relationship methodology was used with Brighton (95%) and wave height of 0.30m added in accordance with storm surge allowance allocated by Coast Protection Board for the Kingston Park Region. The height of this flood map is depicted at 2.47 (AHD). Wave run up has not been included but depicted schematically with arrows. Historical photographs tend to correlate well with this flood depiction.

Map

Marino Cliffs 1:4

Sea-flood 2.47m AHD

Event: 9 May 2016
Risk: Historical benchmark
Date: 12 May 2018

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

Notes

DEWNR advises that current storm surge risk for Kingston Park to the immediate north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up. Wave run-up is depicted as a dotted line at approximately 1m above storm surge height (see photographs for 9th May 2016). However, in reality, the interaction of wave run up with the coastline would vary significantly from location to location. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Marino Cliffs 1:4

Sea-flood 2.70m AHD

Event: Scenario: current
Risk: 1 in 100 ARI
Date: 12 May 2018

Integrated Coasts
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Notes

DEWNR advises that current storm surge risk for Kingston Park to the immediate north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up. Wave run-up is depicted as a dotted line at approximately 1m above storm surge height (see photographs for 9th May 2016). However, in reality, the interaction of wave run up with the coastline would vary significantly from location to location. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Marino Cliffs 1:4

Sea-flood 3.00m AHD

Event: Scenario: 2050
Risk: 1 in 100 ARI
Date: 12 May 2018

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Notes

DEWNR advises that current storm surge risk for Kingston Park to the immediate north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up. Wave run-up is depicted as a dotted line at approximately 1m above storm surge height (see photographs for 9th May 2016). However, in reality, the interaction of wave run up with the coastline would vary significantly from location to location. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Marino Cliffs 1:4

Sea-flood 3.70 AHD

Event: Scenario: 2100
Risk: 1 in 100 ARI
Date: 12 May 2018

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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up is depicted at 0.7m higher by way of a dotted blue line. However, in reality the impact of wave run up would vary greatly. Sea level rise of 0.0 has been added.

Map

Marino Cliffs 1:4

High tide 1.7m AHD

Event: Scenario: current
Risk: Escarpment erosion
Date: 12 May 2018

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Coasts
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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up is depicted at 0.7m higher by way of a dotted blue line. However, in reality the impact of wave run up would vary greatly. Sea level rise of 0.3 has been added.

Map

Marino Cliffs 1:4

High tide 2.0m AHD

Event: Scenario: 2050
Risk: Escarpment erosion
Date: 12 May 2018

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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up is depicted at 0.7m higher by way of a dotted blue line. However, in reality the impact of wave run up would vary greatly. Sea level rise of 1.0 has been added.

Map

Marino Cliffs 1:4

High tide 2.7m AHD

Event: Scenario: 2100
Risk: Escarpment erosion
Date: 12 May 2018

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

Notes

To analyse the rate of shoreline recession over the last seventy years, comparative analysis was conducted using georeferenced aerial photographs from 1949, 2002, and 2017. This analysis provides a long-term review (70 years), and a shorter term review (15 years). The longer term review is dependent on black and white photographs that are often difficult to decipher.

Map

Marino Cliffs 1:4

Erosion assessment

Event: 2017
Risk: Shoreline recession
Date: 12 May 2018

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

Notes

Overall, no obvious signs of movement. Minor erosion in places (review in progress)

Map

Marino Cliffs 1:4

Erosion assessment

Event: 2002
Risk: Shoreline recession
Date: 12 May 2018

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

Notes

Overall, no obvious signs of movement. Minor erosion in places (review in progress)

Map

Marino Cliffs 1:4

Erosion assessment

Event: 1949
Risk: Shoreline recession
Date: 12 May 2018

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

Notes

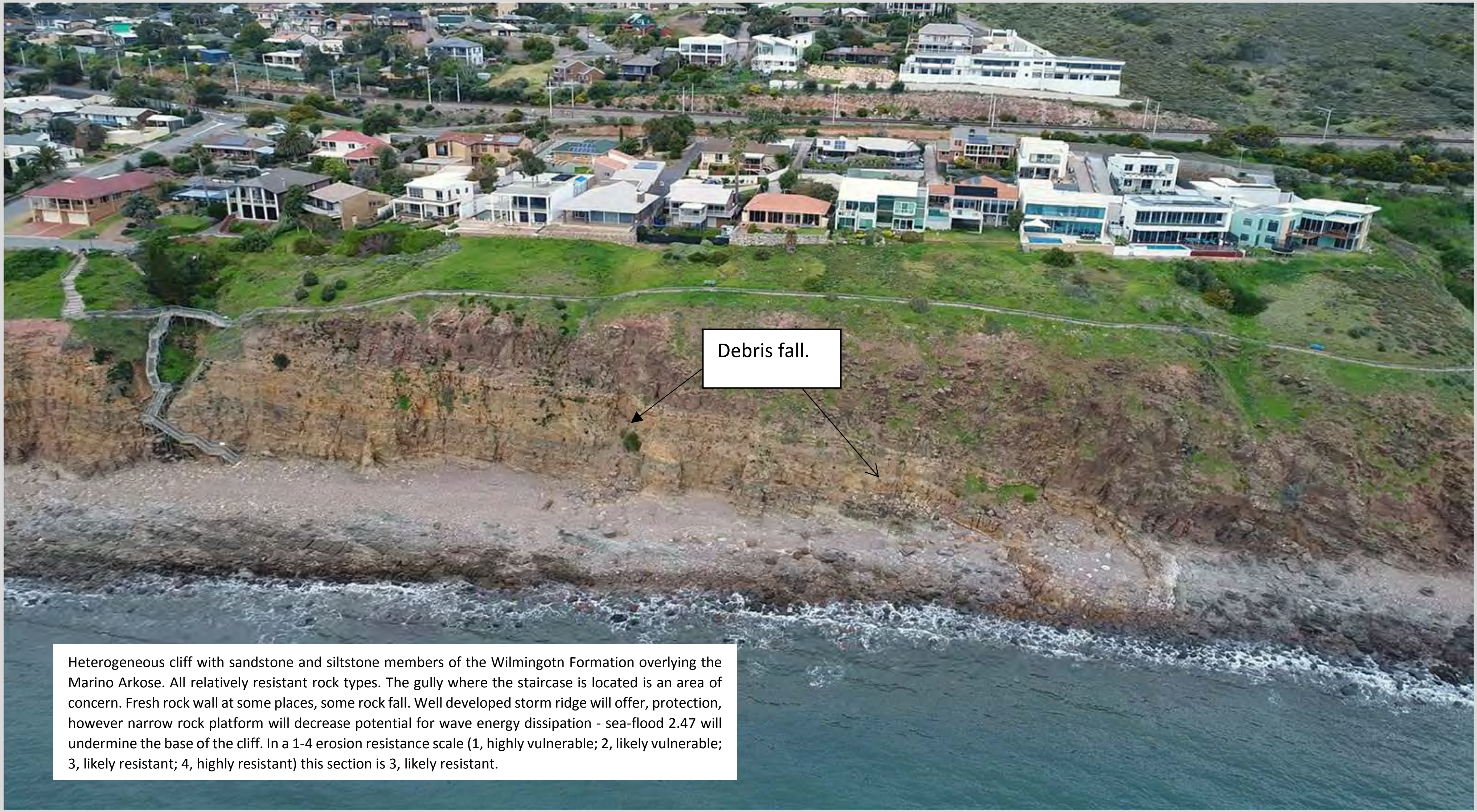
SW1.11 – Old pipe is situated under house on no 20. Water flows into well vegetated gully (small catchment…but is this coming from the other side of the trainline as well?)
SW1.12

Map

Marino Cliffs 1:4

Stormwater assessment

Event: Ongoing
Risk: Cliff erosion
Date: 12 May 2018



Heterogeneous cliff with sandstone and siltstone members of the Wilmingotn Formation overlying the Marino Arkose. All relatively resistant rock types. The gully where the staircase is located is an area of concern. Fresh rock wall at some places, some rock fall. Well developed storm ridge will offer, protection, however narrow rock platform will decrease potential for wave energy dissipation - sea-flood 2.47 will undermine the base of the cliff. In a 1-4 erosion resistance scale (1, highly vulnerable; 2, likely vulnerable; 3, likely resistant; 4, highly resistant) this section is 3, likely resistant.

Integrated Coasts
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1300 767 333 (free call)

Notes

Map

Marino Cliffs 1:4

Geological review

Event: Ongoing
Risk: Shoreline recession
Date: 12 May 2018

Risk assessment: Marino Cliffs (1:4)

Risk identification: Erosion is currently, or may in the future, undermine the toe of the cliff, and cause the cliff to recede.

Coastal processes	Geology in this section of cliff is classified as 'likely resistant' (heterogeneous cliff with sandstone and siltstone of the Wilmington Formation. Well developed stone ridge will offer protection however narrow rock platform will decrease potential for wave energy dissipation. Storm surge events are currently interacting with the toe of the cliff, routine tidal action is limited but will increase with sea level rise.

Are any strategies employed to mitigate the risk? Yes (wire netting is set over the cliff face to limit rock falls into stair area.)

Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Walking trail. Situated atop a stable cliff of a resistant nature it is unlikely the walking trail will come under threat. Possible erosion issues may emerge in the gully where the walking trail steps down to the beach.	current	*Rare*	*No risk*	No risk
		2100	*Rare*	*Moderate*	low
Private assets*	Houses are well set back from top of escarpment (20m – 30 m)	current	*Rare*	*No risk*	No risk
		2100	*Unlikely*	*No risk*	low
Safety of people	Pedestrians utilise the walking trail. Some evidence of rock falls. People at bottom of stairs could be in danger (signage exists?). Wire netting protects stair area.	current	*Unlikely*	*Moderate*	low
		2100	*Unlikely*	*Moderate*	low
Environment	Inter-tidal zone is rocky beach, backed by hard rock/ soft rock cliffs. This section contains threatened priority remnant vegetation and may provide habitat for threatened fauna. The subtidal reef and seagrass are vulnerable to change.	current	*Rare*	*Moderate*	low
		2100	*Possible*	*Moderate*	medium

Inherent Hazard Rating

Hard rock sloping shores (R-1)

	Low	Moderate	High	Very high
Ecosystem disruption	X	2	3	4
Gradual inundation	X	2	3	4
Salt water intrusion	X	2	3	4
Erosion	X	2	3	4
Flooding	X	2	3	4

Erosion Hazard Rating (current outlook)

	Low	Medium	High	Extreme
Public Infrastructure	No risk			
Private Assets*	No risk			
Public safety	X			
Environment	X			

Erosion Hazard Rating (future outlook)

	Low	Medium	High	Extreme
Public Infrastructure	X			
Private Assets*	X			
Public safety	X			
Environment		X		

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

*CoM not necessarily liable for private assets

Summary	The geological rating is resistent. Historical photographs indicate that the cliff has been stable. Private houses are set well back. Public infrastructure is limited to walking trail. Wire netting protects pedestrians who utilse the stairs (but not if they traverse along the base of the cliff (however, signage exists to warn of the danger CHECK). Note, risk assessment is conducted in the context of the identified risk and therefore this risk assesment does not extend to all risk matters in the context of public safety.

Marino Cliffs (1:4)
Erosion outlook and recommended actions (draft)

Geological review: Heterogeneous cliff with sandstone and siltstone members of the Wilmington Formation overlying the Marino Arkose. All relatively resistant rock types. Well-developed stone ridge will offer protection from tidal and storm surge impacts (but sea level rise will increase impact)

Historical recession: Based on photographic analysis, there appears to be no significant recession of the cliff since 2002 nor compared to photographs from 1949 (however these photographs are somewhat indistinct)

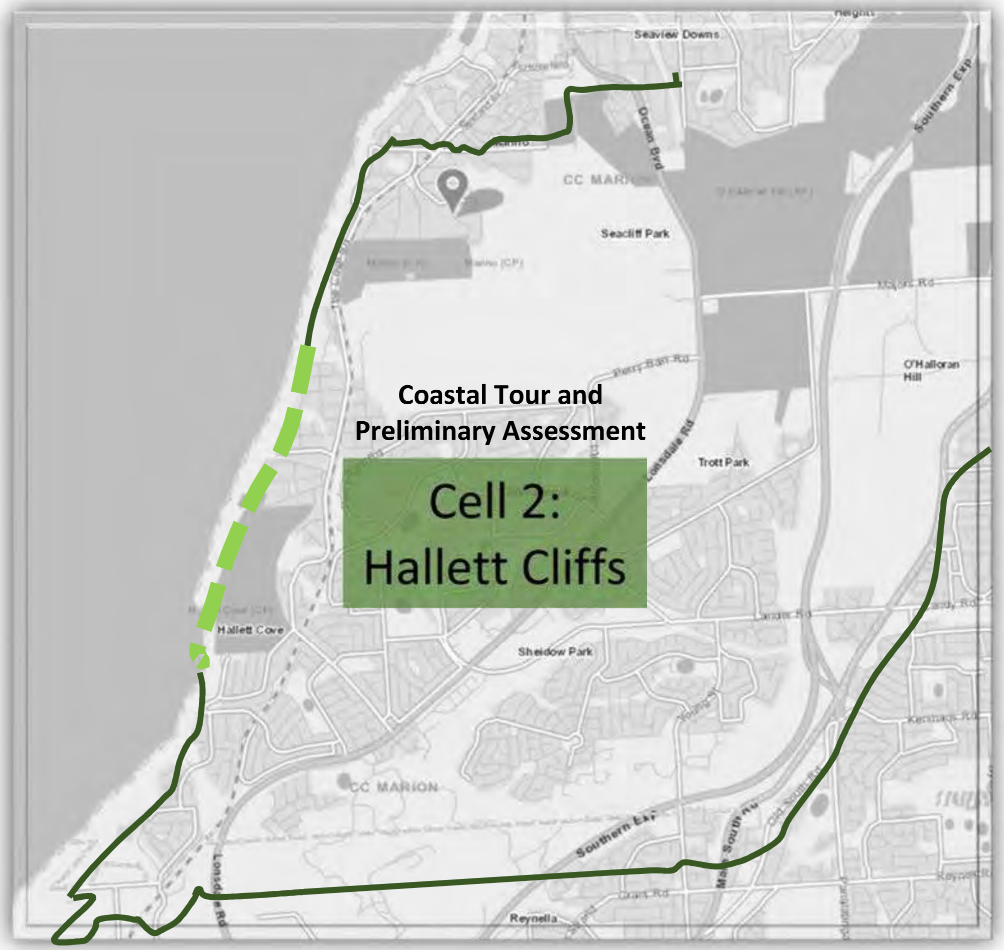
Exposure:	**Routine tidal impact (bi-monthly)**	**Storm surge impact (1 in 100 ARI)**
Historical event - 2016	NA	Likely to have interacted with the base of the cliff with minor escarpment created.
Current	Unlikely that routine tidal action is interelating with the base of the cliff (apart from harder rock sections at either end)	The wave run up of storm surge and wave height of 2.70m will interact significantly with the base of the cliff (with wave run up only)
2050	Some routine tidal action will interelate with the base of the cliff (wave run up only)	The wave run up of storm surge and wave height of 3.00m will interact significantly with the base of the cliff (with wave run up only)
2100	Significant routine wave and wave run-up action will interelate with the base of the cliff	The base of the cliff will come under high impact direct wave attack from storm surge of 3.70m

Storm water: Storm water is piped under one house in the north of this section and then into a well-vegetated gully, and into a gully in the south of this section.

Risk Assessment: Based on stable cliff of a 'likely resistant' nature with wave and tidal action likely to be limited to extreme events (wave run up) the current risk has been assigned an overall 'low' rating. This risk assessment becomes elevated when taking sea level rise into account (See p. 23)

Recommended actions (draft):

Number	Action	Comments	Time frame
1:4 (1)	Review nature of storm water outflows in this section and monitor impacts	SW drains into gullies. Routine inspections are taken of the outfall areas are taken annually. Recommend that staff take photographs of any evidence of scouring of the cliff.	1-2 years
1:4 (2)	Quantify more accurately the nature of routine and storm surge interaction with cliff base.	Monitor tidal regime for period of three months (winter). Monitor the impact of storm surge events (if, and when they occur)	1-2 years
1:4 (3)	Recapture digital model as basis for comparison	Use appropriate software to quantify changes in the coastal environment.	3-5 years


Coastal Tour and
Preliminary Assessment
Cell 2:
Hallett Cliffs
Seaview Downs
Seacliff Park
Trott Park
O'Halloran Hill
Sheidow Park
Hallett Cove
CC MARION
Reynella

Cell 2: Hallett Cliffs (2:1)

High tide was 2.03CD (high tides can be 2.30 to 2.50). Demonstrates that constant wave action is unlikely at cliff base. Houses set back in excess of 20m from top of escarpment (apart from first three on northern end. Cliff slope 45 degrees?)

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

Notes

On 9th May 2016 the highest level of water was recorded at Outer Harbor in 80 years at 3.80 CD (2.36 AHD). To calculate the storm surge height at Hallett Cove: secondary port relationship methodology was used with Port Stanvac (calculated at 90%) and wave height of 0.30m added in accordance with storm surge allowance allocated by Coast Protection Board for the Kingston Park Region. The height of this flood map is depicted at 2.43 (AHD). Wave run up has been drawn 1m higher. Historical photographs at The Esplanade, Marino and Field River, Hallett Cove tend to support an inundation of this height.

Map

Hallett Cliffs 2:1

Historical Storm Event

Event: 9th May 2016: 2.43 AHD
Risk: Historical Benchmark
Date: 12 May 2018

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1300 767 333 (free call)

Notes

DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has been mapped at 1.0m higher and is depicted by way of dotted blue line. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Hallett Cliffs 2:1

Sea-flood 2.60m AHD

Event: Scenario: current
Risk: 1 in 100 ARI
Date: 12 May 2018

Integrated Coasts
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Notes

DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has not been mapped but the need to consider this factor is indicated schematically by way of dotted blue line. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Hallett Cliffs 2:1

Sea-flood 2.90m AHD

Event: Scenario 2050
Risk: 1 in 100 ARI
Date: 12 May 2018

Integrated Coasts
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Notes

DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has not been mapped but the need to consider this factor is indicated schematically by way of dotted blue line. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Hallett Cliffs 2:1
Sea-flood 3.6m AHD
Event: Scenario 2100
Risk: 1 in 100 ARI
Date: 12 May 2018

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

Notes

This map represents the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been included at 0.7m higher and is depicted by way of a dotted blue line.

Map

Hallett Cliffs 2:1

High Tide 1.60m AHD

Event: Scenario: current

Risk: Escarpment Erosion

Date: 12 May 2018

Integrated Coasts
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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been included at 0.7m higher and depicted by way of a dotted blue line. Sea level rise of 0.3 has been added.

Map

Hallett Cliffs 2:1

High Tide 1.90m AHD

Event: Scenario 2050
Risk: Escarpment erosion
Date: 12 May 2018

Integrated Coasts
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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been included at 0.7m higher and depicted by way of a dotted blue line. Sea level rise of 1.0 has been added.

Map

Hallett Cliffs 2:1

High tide 2.6m AHD

Event: Scenario 2100
Risk: Escarpment erosion
Date: 12 May 2018

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Notes

To analyse the rate of shoreline recession over the last seventy years, comparative analysis was conducted using georeferenced aerial photographs from 1949, 2002, and 2017. This analysis provides a long-term review (70 years), and a shorter term review (15 years). The longer term review is dependent on black and white photographs that are often difficult to decipher.

Map

Hallett Cliffs 2:1

Erosion assessment

Event: Oct 2017
Risk: Shoreline recession
Date: 12 May 2018

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

Notes

Very little change to the base of the escarpment since 2002 (perhaps some very minor loss of sediment where indicated). Appears to be zero change to the top of the escarpment.

Map

Hallett Cliffs 2:1

Erosion assessment

Event: 2002
Risk: Shoreline recession
Date: 12 May 2018

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Notes

Not possible to do any realistic analysis. However, it appears that the location of bare rock escarpments are in the same location.

Map

Hallett Cliffs 2:1

Erosion assessment

Event: 1949
Risk: Shoreline recession
Date: 12 May 2018

Cliffs composed of Wilmington fm sandstones and siltstones are more resistant, however there is a tongue of friable Pleistocene Ochre Cove fm (pebbly sandstone) intersecting the coast (see between arrows for approximate location) and likely overlying the Wilmington fm. Caution should be taken with management of stormwater. Gullying has developed nearby the contacts between these formations. In a 1-4 erosion resistance scale (1, highly vulnerable; 2, likely vulnerable; 3, likely resistant; 4, highly resistant) this section is 2, likely vulnerable. This section should be further inspected for geotechnical properties.

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Notes

Map

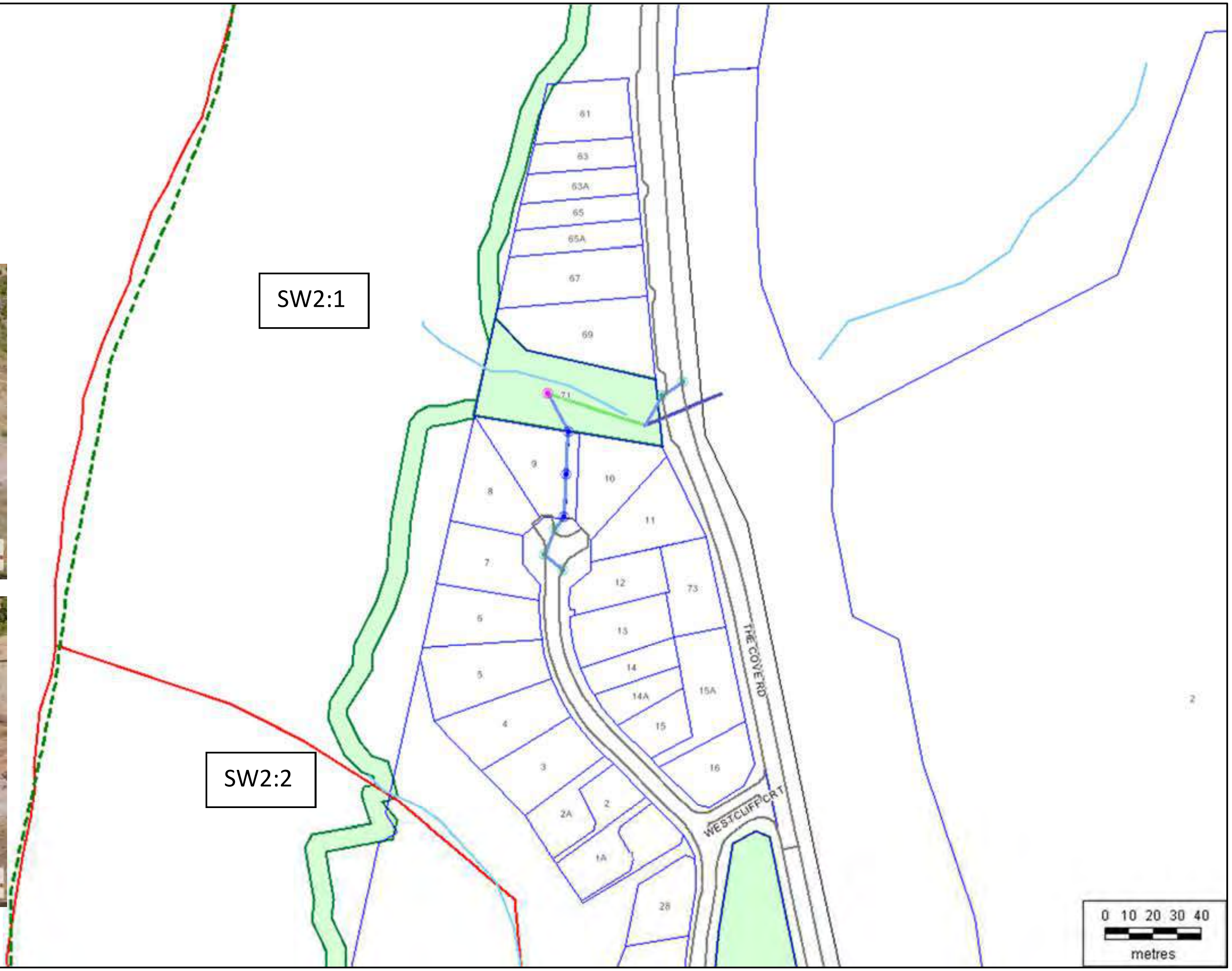
Hallett Cliffs 2:1

Geological review

Event: Ongoing
Risk: Cliff stability
Date: 12 May 2018

Legend:

- Headwall (to support pipe)
- Side entry pit
- Junction box
- Gross Pollutant Trap (GPT)
- (Straight) storm water pipe
- (Curved) natural water flow



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Notes

SW2:1 – Storm water drains into gully. No visible evidence of erosion at base of cliff nor within beach.

SW2.2 Southfront (2012) no further action required in Westcliff. Storm water drains directly to the coastline. No visible evidence of erosion at base of cliff nor within beach.

Map

Hallett Cliffs 2:1

Stormwater assessment

Event: Ongoing
Risk: Cliff erosion
Date: 12 May 2018

Risk assessment: Hallett Cove Cliffs (2:1)

Risk identification: Erosion is, or may in the future, impact the base of the cliffs so that they become unstable and/or recede.

Coastal processes	Cliffs composed of Wilmington fm sandstones and siltstones are more resistant, however there is a tongue of friable Pleistocene Ochre Cove fm (pebbly sandstone) in the middle of this section. Routine tidal action is not likely to be interrelating with the base of the cliff. Wave run-up from current storm surge events may have minor interaction.

Are any strategies employed to mitigate the risk? No (and the assessment assumes that no action is taken to mitigate the risk)

Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Walking trail set back at varying distances from the top of the cliff escarpment (v. close in north of this section).	current	*Rare*	*Moderate*	low
		2100	*Unlikely*	*Moderate*	medium
Private assets*	Houses in the north of this section are situated close to the top of the escarpment (3 houses within 10m). Houses situated in middle of this section are set well back from the top of the escarpment.	current	*Rare*	*Moderate*	low
		2100	*Unlikely*	*Major*	medium
Safety of people	People use the walking trail. It is extremely unlikely that an event would occur without any warning and that someone might be impacted (events such as earthquakes are excluded from this assessment)	current	*Rare*	*Moderate*	low
		2100	*Rare*	*Major*	medium
Environment	Inter-tidal zone is rocky beach, backed by soft rock cliff. This section contains threatened priority remnant vegetation and may provide habitat for threatened fauna. The subtidal reef and seagrass are vulnerable to change.	current	*Rare*	*Minor*	low
		2100	*Possible*	*Moderate*	medium

Inherent Hazard Rating

Hard /soft rock sloping shores (SR-10)

	Low	Moderate	High	Very high
Ecosystem disruption	X	2	3	4
Gradual inundation	X	2	3	4
Salt water intrusion	X	2	3	4
Erosion	1	X	3	4
Flooding	X	2	3	4

Erosion Hazard Rating

(current outlook)

	Low	Medium	High	Extreme
Public Infrastructure	X			
Private Assets*	X			
Public safety	X			
Environment	X			

Erosion Hazard Rating

(future outlook)

2100

	Low	Medium	High	Extreme
Public Infrastructure		X		
Private Assets*		X		
Public safety		X		
Environment		X		

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

*CoM is not necessarily liable for private assets

Summary	In the present time actions of the sea of low interaction with the toe of the cliff, but this will increase over time with sea level rise. Geologist notes one area of concern due to location of private houses in relation to the proximity of the cliff escarpment (although this area is noted as Wilmington Formation (and more resistant). This risk assessment does not take into account unforeseen events such as earthquakes.

Hallett Cliffs (2:1)
Erosion outlook and recommended actions (draft)

Geological review: Cliffs either side of this section are composed of sandstones and siltstone (likely resistant) but these are intersected by Pleistocene Ochre (pebbly sandstone) in the middle of this section (likely vulnerable).

Historical recession: Based on photographic analysis, there appears to be no significant recession of the cliff since 2002. The photograph from 1949 is difficult to analyse but it appears as though the location of the bare rock escarpments are in the same place.

Exposure	Routine tidal impact (bi-monthly)	Storm surge impact (1 in 100 ARI)
Historical event - 2016	NA	Minimal interaction with the toe of the cliff.
Current	Unlikely that routine tidal action is generally interelating with the base of the cliff	The wave run up of storm surge and wave height of 2.60m will interact significantly with the base of the cliff (with wave run up only)
2050	Some routine tidal action will interelate with the base of the cliff (wave run up only)	The wave run up of storm surge and wave height of 2.90m will interact significantly with the base of the cliff (with wave run up only)
2100	In this scenario, wave-run up impacts the base of the cliff, but unlikely that direct wave action will.	The base of the cliff will come under some direct wave attack, and substantial impact from wave run-up from storm surge of 3.60m

Storm water: Storm water flows by pipe and through several junction boxes and exits into the gully by way of GPT. Flows naturally to the sea.

Risk Assessment: Based on stable cliff with wave and tidal action likely to be limited to extreme events (wave run up) the current risk has been assigned an overall 'low' rating. This risk assessment becomes elevated to 'medium' when taking sea level rise into account (See p. 23). One 'area of concern' is close proximity of houses.

Recommended actions (draft):

Number	Action	Comments	Time frame
2:1 (1)	Review nature of storm water outflows and monitor impacts	Routine inspections are taken of the outfall areas. Recommend that staff incorporate review of scouring impacts of the gully.	1-2 years
2:1 (2)	Quantify more accurately the nature of routine and storm surge interaction with cliff base.	Monitor tidal regime for period of three months (winter). Monitor the impact of storm surge events (if, and when they occur)	1-2 years
2:1 (3)	Recapture digital model as basis for comparison	Use appropriate software to quantify changes in the coastal environment.	3-5 years

Cell 2: Hallett Cliffs (2:2)

High tide was 2.03CD (high tides can be 2.30 to 2.50). It is likely that some sections of this cliff base is receiving constant wave action. Houses are set well back from the escarpment which is much more vertical in this location. (Check house on south side)

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Notes

On 9th May 2016 the highest level of water was recorded at Outer Harbor in 80 years at 3.80 CD (2.36 AHD). To calculate the storm surge height at Hallett Cove: secondary port relationship methodology was used with Port Stanvac (calculated at 90%) and wave height of 0.30m added in accordance with storm surge allowance allocated by Coast Protection Board for the Kingston Park Region. The height of this flood map is depicted at 2.43 (AHD). Wave run up has not been included. Historical photographs at The Esplanade, Marino and Field River, Hallett Cove tend to support an inundation of this height.

Map

Hallett Cliffs 2:2

Sea-flood 2.43m AHD

Event: 9 May 2016
Risk: Historical benchmark
Date: 12 May 2018

Integrated Coasts
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www.integratedcoasts.com
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Notes

DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has been mapped at 1.0m higher and is depicted by way of dotted blue line. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Hallett Cliffs 2:2

Sea-flood 2.60m AHD

Event: Scenario: current
Risk: 1 in 100 ARI
Date: 12 May 2018

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Notes

DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has been mapped at 1.0m higher and is depicted by way of dotted blue line. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Hallett Cliffs 2:2

Sea-flood 2.90m AHD

Event: Scenario: 2050
Risk: 1 in 100 ARI
Date: 12 May 2018

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Notes

DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has been mapped at 1.0m higher and is depicted by way of dotted blue line. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Hallett Cliffs 2:2

Sea-flood 3.60m AHD

Event: Scenario: 2100
Risk: 1 in 100 ARI
Date: 12 May 2018

Integrated Coasts
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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been included at 0.7m higher and depicted by way of a dotted blue line. Sea level rise of 0.0 has been added.

Map

Hallett Cliffs 2:2

High tide 1.6m AHD

Event: Scenario: current
Risk: Escarpment erosion
Date: 12 May 2018

Integrated Coasts
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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been included at 0.7m higher and depicted by way of a dotted blue line. Sea level rise of 0.3 has been added.

Map

Hallett Cliffs 2:2

High tide 1.90m AHD

Event: Scenario: 2050
Risk: Escarpment erosion
Date: 12 May 2018

Integrated Coasts
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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been included at 0.7m higher and depicted by way of a dotted blue line. Sea level rise of 1.0 has been added.

Map

Hallett Cliffs 2:2

High tide 2.6m AHD

Event: Scenario: 2100
Risk: Escarpment erosion
Date: 12 May 2018

Integrated Coasts
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Notes

To analyse the rate of shoreline recession over the last seventy years, comparative analysis was conducted using georeferenced aerial photographs from 1949, 2002, and 2017. This analysis provides a long-term review (70 years), and a shorter term review (15 years). The longer term review is dependent on black and white photographs that are often difficult to decipher.

Map

Hallett Cliffs 2:2

Erosion assessment

Event: 2017
Risk: Shoreline recession
Date: 12 May 2018

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

Notes

No visible change from 2017. Top and bottom of escarpment appear in the same location. (Minor erosion to sediment at base of escarpment in far north of picture?)

Map

Hallett Cliffs 2:2

Erosion assessment

Event: 2002
Risk: Shoreline recession
Date: 12 May 2018

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

Notes

The location of the bottom of the escarpment appears to be in the same location as 1949. Analysis indicates that rock has broken away from the escarpment (top arrow), with evidence of visible cracking in 1949. Possible increase of rock on the beach (bottom arrow) may indicate loss of cliff.

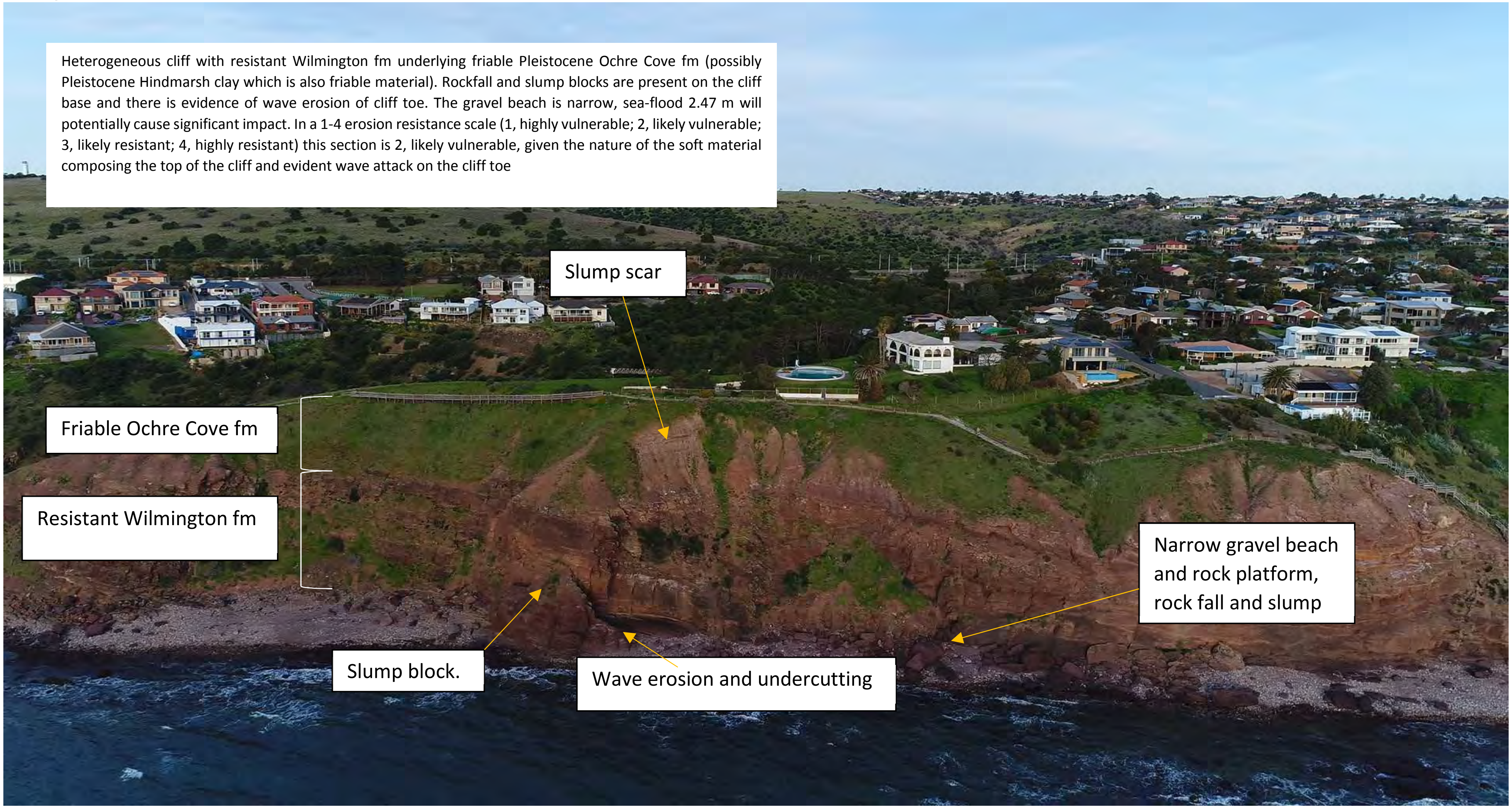
Map

Hallett Cliffs 2:2

Erosion assessment

Event: 1947
Risk: Shoreline recession
Date: 12 May 2018

Heterogeneous cliff with resistant Wilmington fm underlying friable Pleistocene Ochre Cove fm (possibly Pleistocene Hindmarsh clay which is also friable material). Rockfall and slump blocks are present on the cliff base and there is evidence of wave erosion of cliff toe. The gravel beach is narrow, sea-flood 2.47 m will potentially cause significant impact. In a 1-4 erosion resistance scale (1, highly vulnerable; 2, likely vulnerable; 3, likely resistant; 4, highly resistant) this section is 2, likely vulnerable, given the nature of the soft material composing the top of the cliff and evident wave attack on the cliff toe



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www.integratedcoasts.com
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Notes

Map

Hallett Cliffs 2:2

Geological review

Event: Ongoing
Risk: Cliff stability
Date: 12 May 2018

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Notes

Storm water empties into the gully.

SW2:3 CoM has recently redirected storm water to the north to protect cliff erosion and assets. At culmination of pipe rock is used to dissipate the flow, and more rock is situated either side of the walking trail. (See MW schematic line above)

Map

Hallett Cliffs 2:2

Stormwater assessment

Event: Ongoing
Risk: Cliff erosion
Date: 12 May 2018

Risk assessment: Hallett Cove Cliffs (2:2)

Risk identification: Erosion is, or may in the future, impact the base of the cliffs at causing them to become unstable and/or to recede.

Coastal processes	Heterogeneous cliff with resistant Wilmington fm underlying friable Pleistocene Ochre Cove fm (ie base of cliff is likely resistant material, top of cliff is friable material, likely vulnerable). Modelling high impact wave and wave run-up in storm surge events. Routine tide action suggests significant wave run-up interaction with base of cliff, increasing significantly due to sea level rise.

Are any strategies employed to mitigate the risk? No (and the assessment assumes that no action is taken to mitigate the risk)

Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	The walking trail is set back at various distances from the top of the escarpment.	current	*Rare*	*Moderate*	Low
		2100	*Unlikely*	*Moderate*	Medium
Private assets*	Two houses on north side of this section are set back in excess of 30m from the top of the escarpment, one house on south side is set 20m approx from top.	current	*Choose item*	*Choose item*	No risk
		2100	*Rare*	*Moderate*	Low
Safety of people	People use the walking trail. It is extremely unlikely that an event would occur without any warning and that someone might be impacted (events such as earthquakes are excluded from this assessment)	current	*Rare*	*Moderate*	Low
		2100	*Rare*	*Moderate*	Low
Environment	Inter-tidal zone is rocky beach, backed by hard rock/ soft rock cliffs. This section contains threatened priority remnant vegetation and may provide habitat for threatened fauna. The subtidal reef and seagrass are vulnerable to change.	current	*Rare*	*Moderate*	Low
		2100	*Possible*	*Moderate*	Medium

Inherent Hazard Rating

Hard /soft rock sloping shores (SR-10)

	Low	Moderate	High	Very high
Ecosystem disruption	X	2	3	4
Gradual inundation	X	2	3	4
Salt water intrusion	X	2	3	4
Erosion	1	X	3	4
Flooding	X	2	3	4

Erosion Hazard Rating

(current outlook)

	Low	Medium	High	Extreme
Public Infrastructure	X			
Private Assets*	No risk			
Public safety	X			
Environment	X			

Erosion Hazard Rating

(future outlook) 2100

	Low	Medium	High	Extreme
Public Infrastructure		X		
Private Assets*	X			
Public safety	X			
Environment		X		

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

*CoM is not necessarily liable for private assets

Summary	The base of the cliff in this section is resistant but already under significant wave interaction. The top of the cliff is friable (crumbly) and therefore control of storm water is essential. Some evidence exists of rock falls based on historical photographic evidence, but overall the cliff appears to have been stable for some time. Increasing sea levels will increase the impact at the base of the cliff. This risk assessment does not take into account unforeseen events such as earthquakes.

Hallett Cliffs (2:2)
Erosion outlook and recommended actions (draft)

Geological review: A Heterogeneous cliff with resistant Wilmington fm underlying friable Pleistocene Ochre Cove fm (ie base of cliff is likely *resistant* material, top of cliff is friable material, *likely vulnerable*).

Historical recession: Based on photographic analysis, there appears to be no significant recession of the cliff since 2002. Possible evidence of rock/cliff falls based on review of 1949 photograph (albiet difficult to analyse)

Exposure:	**Routine tidal impact (bi-monthly)**	**Storm surge impact (1 in 100 ARI)**
Historical event - 2016	NA	Storm surge including direct wave action is very likely to have impacted this section of cliff
Current	Routine tidal action is interacting with the base of the cliff (mostly with wave run up)	Storm surge and wave height at 2.60m would interact with bottom of cliff with high impact.
2050	Routine tidal action will interelate with the base of the cliff (including direct wave action)	Storm surge and wave height at 3.00m would interact with bottom of cliff with high impact.
2100	Routine tidal action will interelate with the base of the cliff (including high impact direct wave action)	Storm surge and wave height at 3.60m would interact with bottom of cliff with veryhigh impact.

Storm water: Storm water is piped into the gully. Storm water at the end of Grey Street has been diverted north and rocks are utilised to dissipate and slow flow.

Risk Assessment: Private infrastructure is set well back from top of the escarpment. The walking trail could come under threat over time. Risk to public safety for those on the walking trail is very low. Risk assessment does not take into account unforeseen events such as earthquakes.

Recommended actions (draft):

Number	Action	Comments	Time frame
2:2 (1)	Review nature of storm water outflows and monitor impacts	Routine inspections are taken of the outfall areas. Recommend that staff incorporate review of scouring impacts (use photography)	1-2 years
2:2 (2)	Quantify more accurately the nature of routine and storm surge interaction with cliff base.	Monitor tidal regime for period of three months (winter). Monitor the impact of storm surge events (if, and when they occur)	1-2 years
2:2 (3)	Recapture digital model as basis for comparison	Use appropriate software to quantify changes in the coastal environment.	3-5 years

Cell 2: Hallett Cliffs (2:3)

High tide was 2.03CD (high tides can be 2.30 to 2.50). It is likely that some sections of this cliff base is receiving constant wave action. Houses are set well back from the escarpment in this location which is almost vertical. Note: the house within the circle is situated in a gully between two cliffs. Check to see storm water drainage in the area.

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

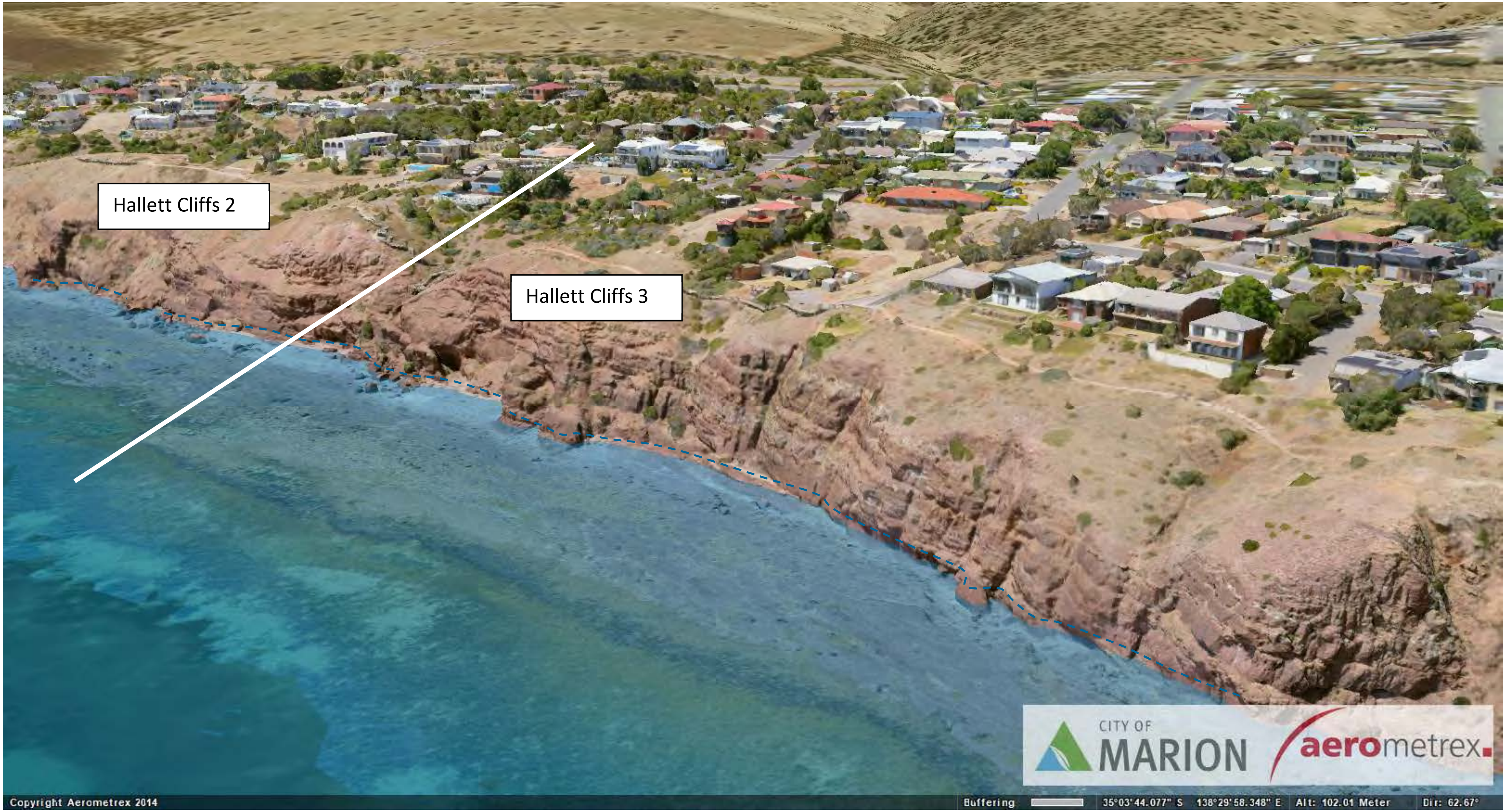
Notes

Map

Hallett Cliffs 2:3

Initial view

Event: None
Risk: NA
Date: 12 May 2018



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1300 767 333 (free call)

Notes

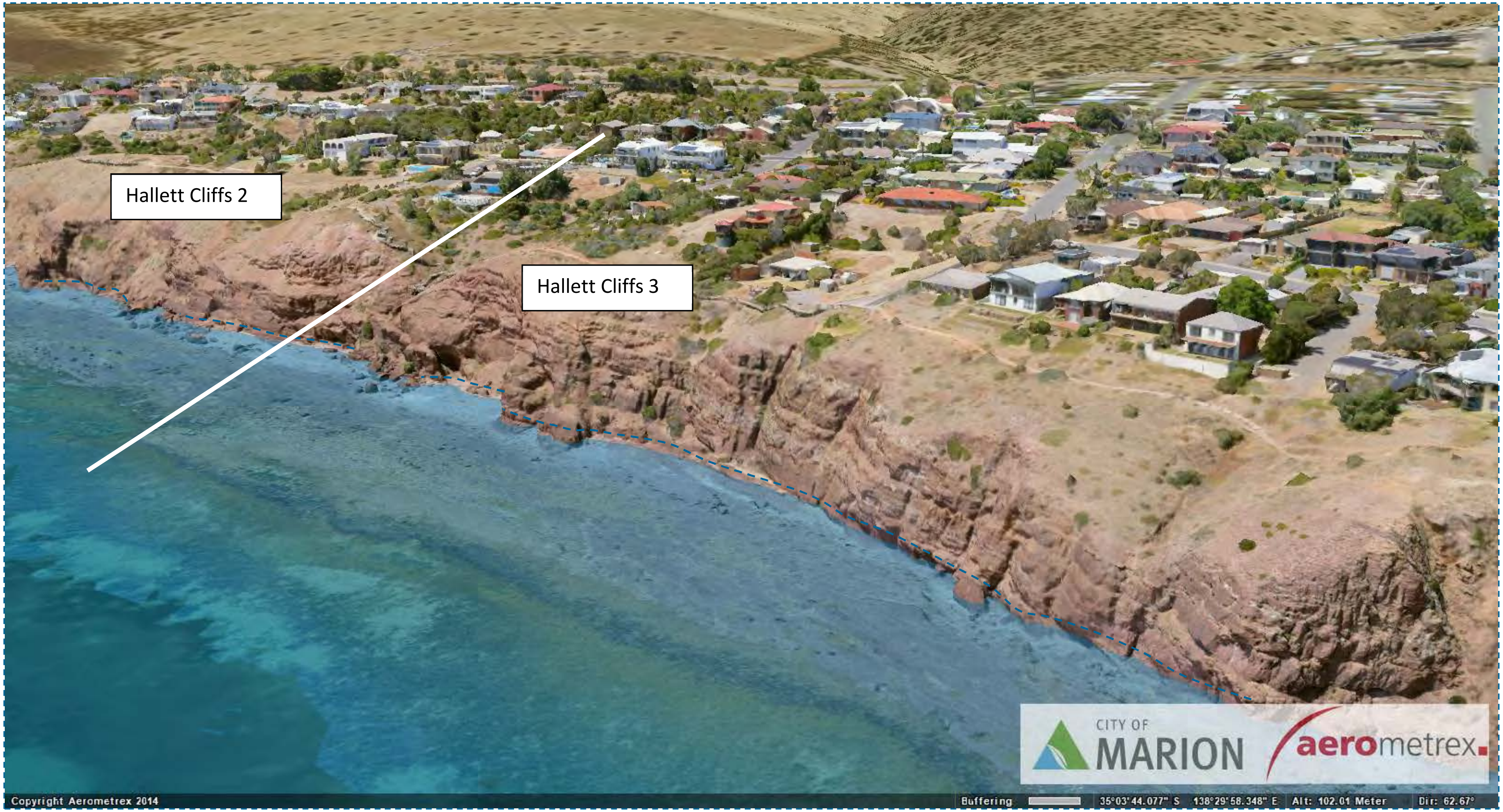
On 9th May 2016 the highest level of water was recorded at Outer Harbor in 80 years at 3.80 CD (2.36 AHD). To calculate the storm surge height at Hallett Cove: secondary port relationship methodology was used with Port Stanvac (calculated at 90%) and wave height of 0.30m added in accordance with storm surge allowance allocated by Coast Protection Board for the Kingston Park Region. The height of this flood map is depicted at 2.43 (AHD). Wave run up has been drawn 1m higher. Historical photographs at The Esplanade, Marino and Field River, Hallett Cove tend to support an inundation of this height.

Map

Hallett Cliffs 2:3

Sea-flood 2.43m AHD

Event: 9 May 2016
Risk: Historical benchmark
Date: 12 May 2018



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1300 767 333 (free call)

Notes

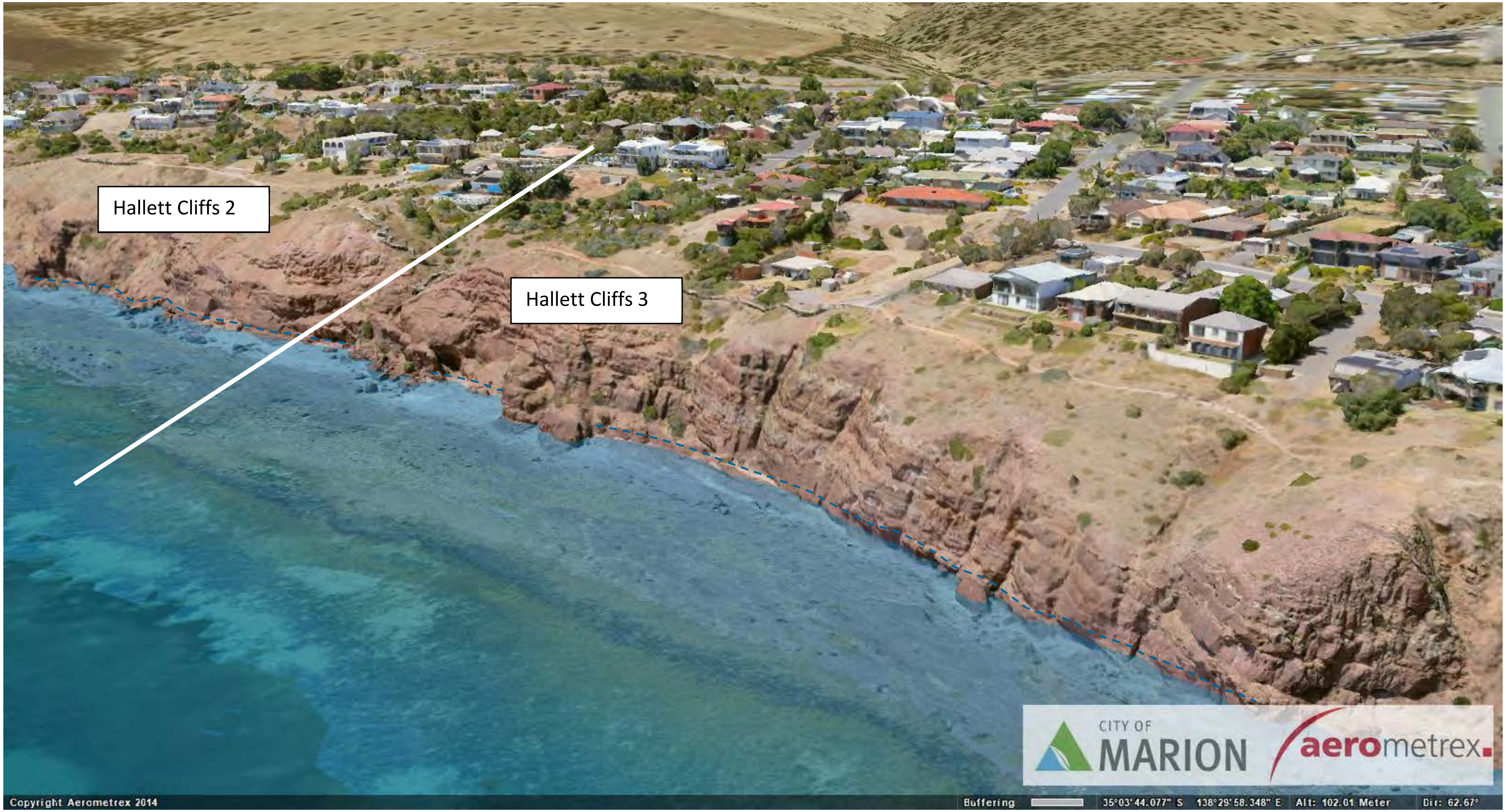
DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has been mapped at 1.0m higher and is depicted by way of dotted blue line. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Hallett Cliffs 2:3

Sea-flood 2.60m AHD

Event: Scenario: current
Risk: 1 in 100 ARI
Date: 12 May 2018



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1300 767 333 (free call)

Notes

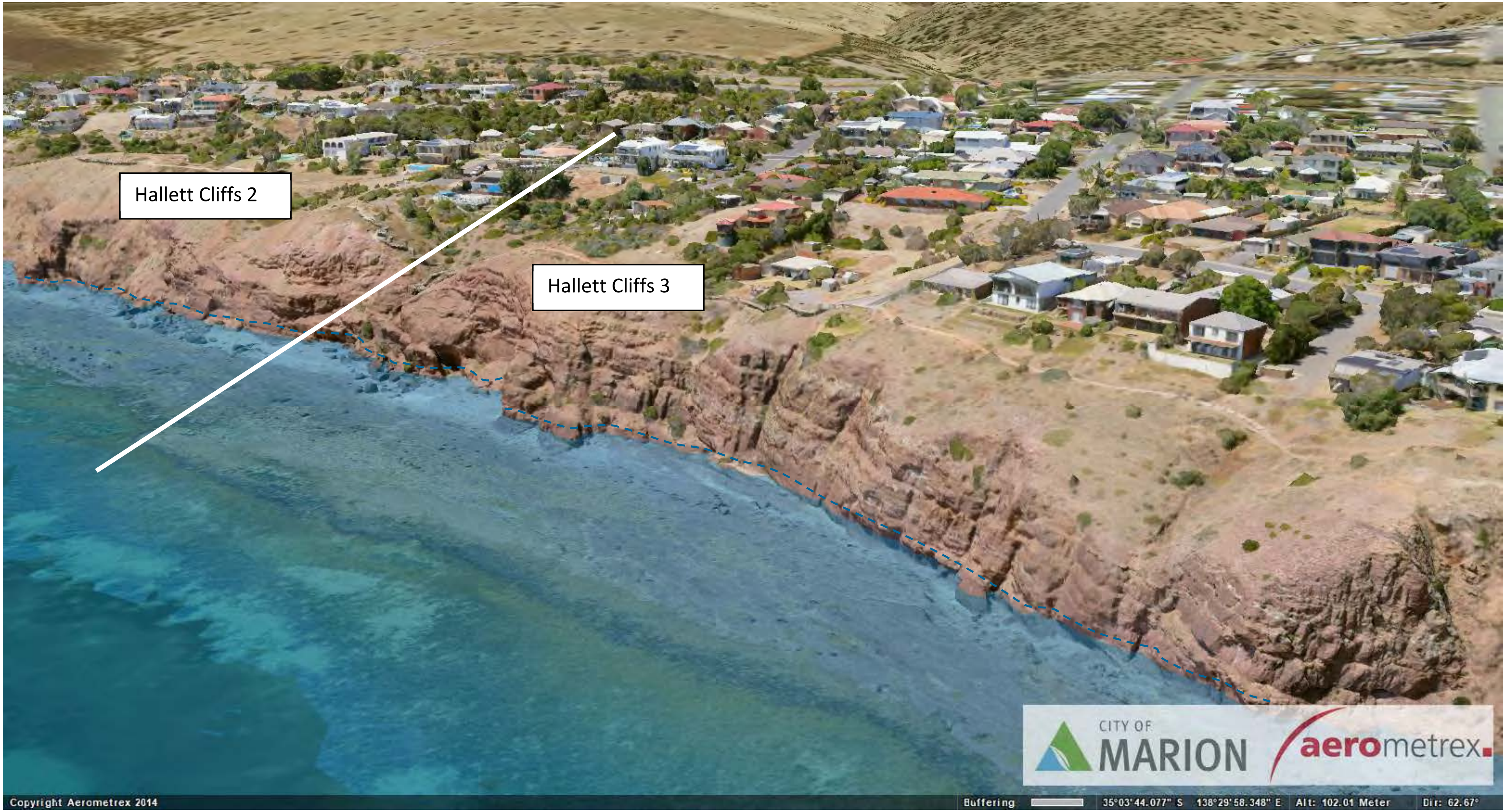
DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has been mapped at 1.0m higher and is depicted by way of dotted blue line. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Hallett Cliffs 2:3

Sea-flood 2.90m AHD

Event: Scenario: 2050
Risk: 1 in 100 ARI
Date: 12 May 2018



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Notes

DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has been mapped at 1.0m higher and is depicted by way of dotted blue line. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Hallett Cliffs 2:3
Sea-flood 3.60m AHD
Event: Scenario: 2100
Risk: 1 in 100 ARI
Date: 12 May 2018

Integrated Coasts
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1300 767 333 (free call)

Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been included at 0.7m higher and depicted by way of a dotted blue line. Sea level rise of 0.0 has been added.

Map

Hallett Cliffs 2:3

High tide 1.6m AHD

Event: Scenario: current
Risk: Escarpment erosion
Date: 12 May 2018

Integrated Coasts
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1300 767 333 (free call)

Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been included at 0.7m higher and depicted by way of a dotted blue line. Sea level rise of 0.3 has been added.

Map

Hallett Cliffs 2:3

High tide 1.90m AHD

Event: Scenario: 2050
Risk: Escarpment erosion
Date: 12 May 2018

Integrated Coasts
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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been included at 0.7m higher and depicted by way of a dotted blue line. Sea level rise of 1.0 has been added.

Map

Hallett Cliffs 2:3

High tide 2.6m AHD

Event: Scenario: 2100
Risk: Escarpment erosion
Date: 12 May 2018

Integrated Coasts
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1300 767 333 (free call)

Notes

To analyse the rate of shoreline recession over the last seventy years, comparative analysis was conducted using georeferenced aerial photographs from 1949, 2002, and 2017. This analysis provides a long-term review (70 years), and a shorter term review (15 years). The longer term review is dependent on black and white photographs that are often difficult to decipher.

Map

Hallett Cliffs 2:3

Erosion assessment

Event: 2017
Risk: Shoreline recession
Date: 12 May 2018

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

Notes

There appears to be no change from 2017 at top or bottom of escarpment.

Map

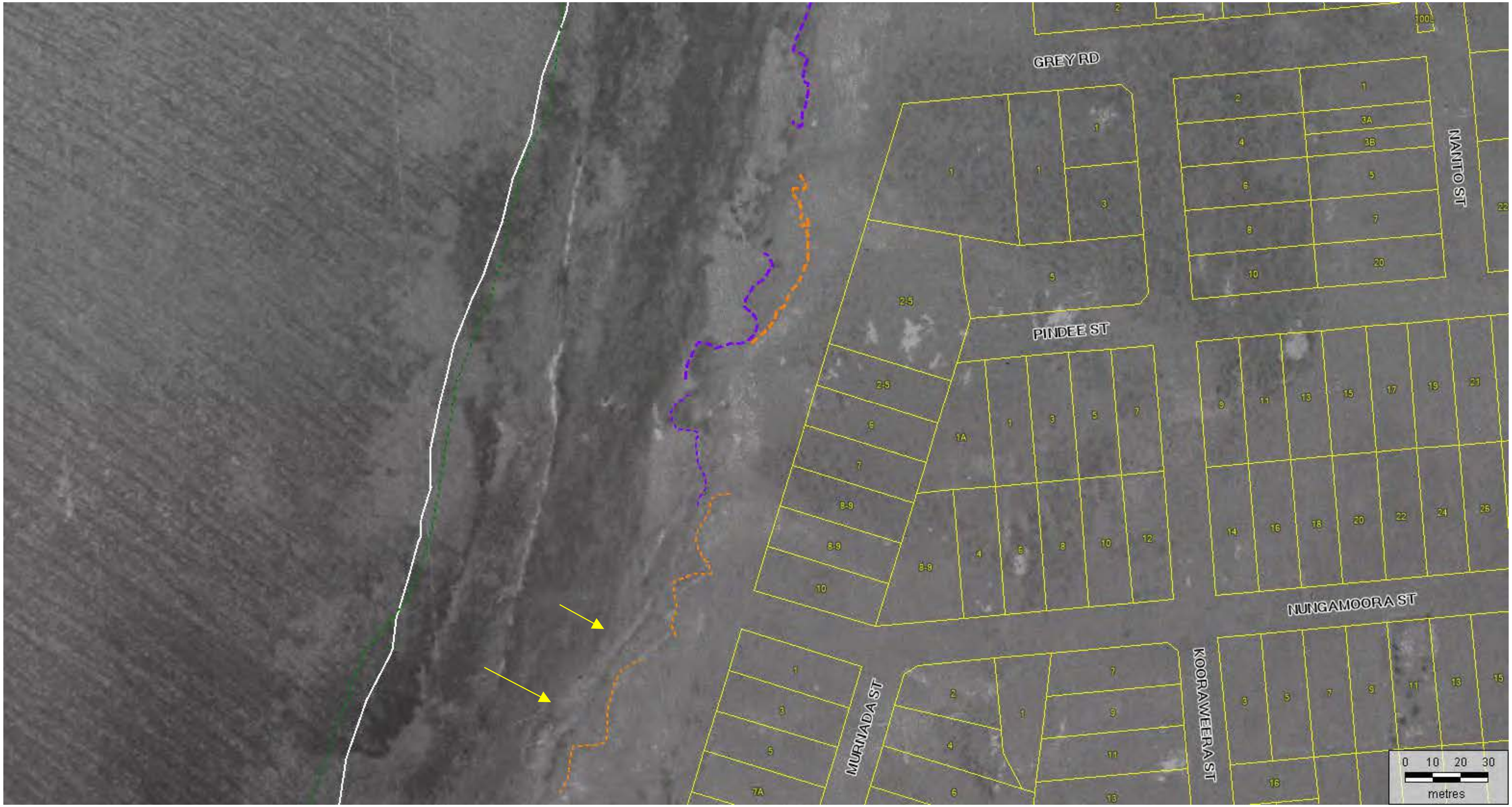
Hallett Cliffs 2:3

Erosion assessment

Event: 2002

Risk: Shoreline recession

Date: 12 May 2018



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Notes

There appears to be recession of the top of the escarpment (assuming that the darker line is the top of the escarpment). This location does receive much higher wave impact at toe of cliff. (Note…it may be the location of shadows on photographs of 2017 and 2002 giving the appearance of recession)

Map

Hallett Cliffs 2:3

Erosion assessment

Event: 1949

Risk: Shoreline recession

Date: 12 May 2018

There is a contact between the Wilmington fm and the Neo-Proterozoic Reynella siltstone member (mostly massive siltstone with small rock fragments) along this section. Gullying seems to be on the Reynella siltstone (which should be an area of concern given the proximity to some houses). There is evidence of wave erosion at cliff base however this seems to be a resistant cliff with relatively little slump blocks and rock fall. The 2050 SL scenario shows that the cliff toe will be flooded and vulnerable susceptible to wave erosion, which could further undermine the cliff. In a 1-4 erosion resistance scale (1, highly vulnerable; 2, likely vulnerable; 3, likely resistant; 4, highly resistant) this section is 3, likely resistant.

Integrated Coasts
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1300 767 333 (free call)

Map

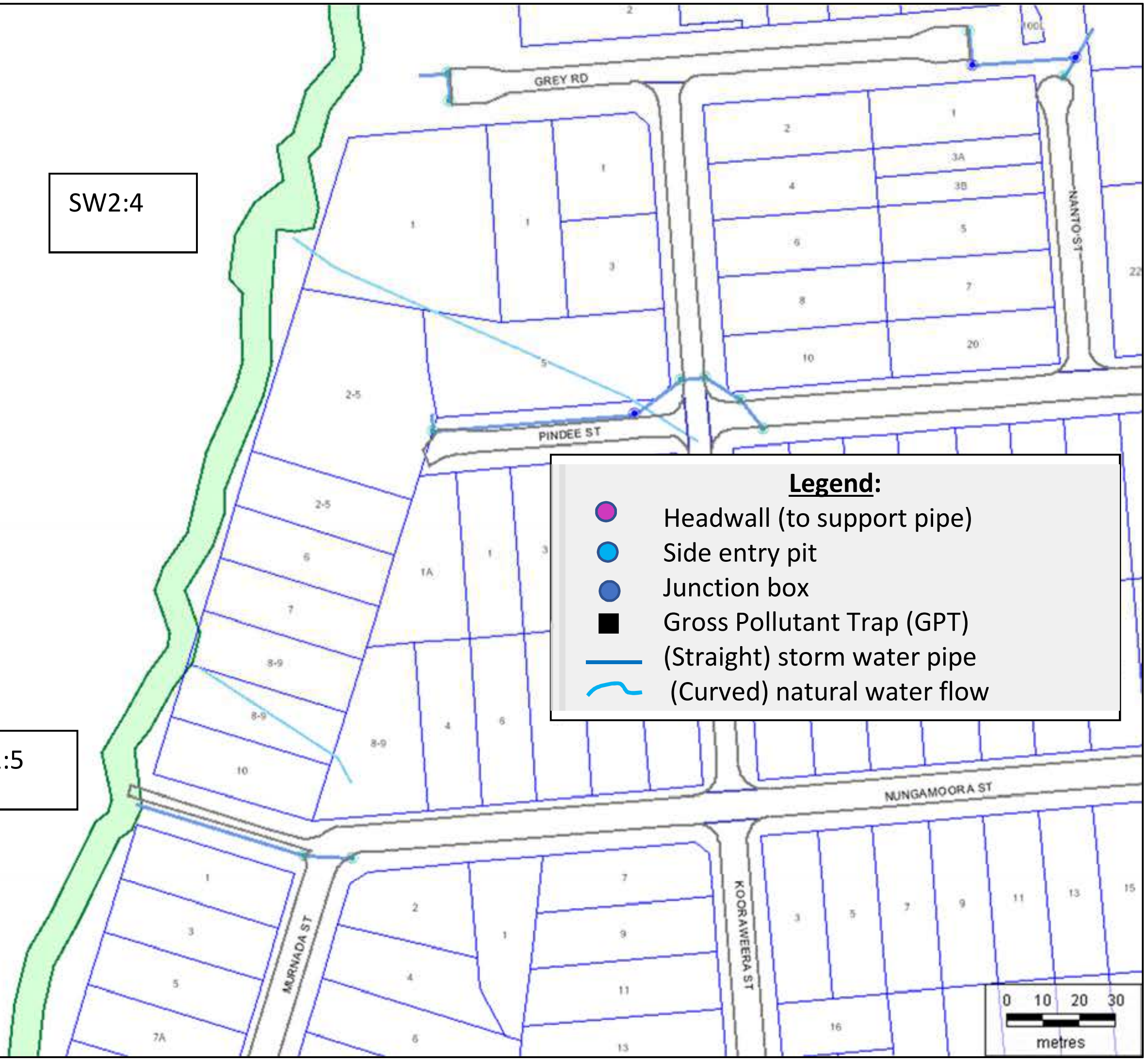
Hallett Cliffs 2:3

Geological review

Event: Ongoing
Risk: Cliff stability
Date: 12 May 2018

SW2:4

SW2:5



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Notes

SW2:4 Open water course (some storm water draining into this)
SW2:5 Nungamoora Street. Southfront (2012) recommended installation of GPT. CoM has this item as a low priority with possible installation at 2020 (would be elevated if erosion problems became evident).

Map

Hallett Cliffs 2:3

Stormwater assessment

Event: Ongoing
Risk: Cliff erosion
Date: 12 May 2018

Risk assessment: Hallett Cove Cliffs (2:3)

Risk identification: Erosion is, or may in the future, impact the base of the cliffs so that they become unstable and/or recede.

Coastal processes	IN this area Reynella siltstone predominates which is a *likely resistant* material to erosion. Historical photographs suggest there has been recession of the cliff top (see end of Nungamoora Street and Pindee Street). The toe of the cliff in this region receives routine interaction with tides and storm surges. The impact of these will increase with sea level rise.

Are any strategies employed to mitigate the risk? No (and the assessment assumes that no action is taken to mitigate the risk)

Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	The walking trail is set back at various distances from the top of the escarpment (Normally around 10m)	current	*Rare*	*Moderate*	Low
		2100	*Unlikely*	*Moderate*	Medium
Private assets*	Houses are set back from top of the escarpment 20 – 30 m.	current	*Rare*	*No risk*	No risk
		2100	*Rare*	*Major*	Medium
Safety of people	People use the walking trail. It is extremely unlikely that an event would occur without any warning and that someone might be impacted (events such as earthquakes are excluded from this assessment)	current	*Rare*	*Moderate*	Low
		2100	*Rare*	*Moderate*	Low
Environment	Inter-tidal zone is rocky beach, backed by hard rock cliffs. This section contains threatened priority remnant vegetation and may provide habitat for threatened fauna. The subtidal reef and seagrass are vulnerable to change.	current	*Rare*	*Moderate*	Low
		2100	*Possible*	*Moderate*	Medium

Inherent Hazard Rating

Hard /soft rock sloping shores (SR-10)

	Low	Moderate	High	Very high
Ecosystem disruption	X	2	3	4
Gradual inundation	X	2	3	4
Salt water intrusion	X	2	3	4
Erosion	X	2	3	4
Flooding	X	2	3	4

Erosion Hazard Rating

(current outlook)

	Low	Medium	High	Extreme
Public Infrastructure	X			
Private Assets*	No risk			
Public safety	X			
Environment	X			

Erosion Hazard Rating

(future outlook)

2100

	Low	Medium	High	Extreme
Public Infrastructure		X		
Private Assets*	X			
Public safety	X			
Environment		X		

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

*CoM is not necessarily liable for private assets

Summary	The base of the cliff in this section is *likely resistant* but already under significant wave interaction. Some evidence exists of rock falls and cliff recession over last 80 years based on historical photographic evidence. Increasing sea levels will increase the impact at the base of the cliff. Private assets are set a long way back from the cliff escarpment and therefore are currently rated as 'no risk'. This risk assessment does not take into account unforeseen events such as earthquakes.

Hallett Cliffs (2:3)
Erosion outlook and recommended actions (draft)

Geological review: In this area Reynella siltstone predominates which is a resistant material to erosion.

Historical recession: Historical photographs suggest there has been recession of the cliff top (see end of Nungamoora Street and Pindee Street).

Exposure:	Routine tidal impact (bi-monthly)	Storm surge impact (1 in 100 ARI)
Historical event - 2016	NA	Wave and wave run up would have impacted the toe significantly.
Current	Routine tidal action impacts the toe of the cliff	The wave run up of storm surge and wave height of 2.60m will interact significantly with the base of the cliff.
2050	Routine tidal action will have higher impact on the toe of the cliff.	The wave run up of storm surge and wave height of 2.90m will interact significantly with the base of the cliff
2100	Routine tidal action will be significant with constant wave action.	The base of the cliff will come under high impact direct wave attack from storm surge of 3.60m

Storm water: Storm water is drained into the gully. At end of Grey Street has been recently diverted to the north. Rocks dissipate flow and slow rate.

Risk Assessment: The cliffs are of *likely resistent* material, but are under continual tidal and wave influence. Private assets are set well back.

Recommended actions (draft):

Number	Action	Comments	Time frame
2:3 (1)	Review nature of storm water outflows and monitor impacts	Routine inspections are taken of the outfall areas. Recommend that staff incorporate review of scouring impacts (use photography)	1-2 years
2:3 (2)	Quantify more accurately the nature of routine and storm surge interaction with cliff base.	Monitor tidal regime for period of three months (winter). Monitor the impact of storm surge events (if, and when they occur)	1-2 years
2:3 (3)	Recapture digital model as basis for comparison	Use appropriate software to quantify changes in the coastal environment.	3-5 years

Cell 2: Hallett Cliffs (2:4)

High tide was 2.03CD (high tides can be 2.30 to 2.50). It is likely that some sections of this cliff base is receiving constant wave action. The Esplanade Road is set back only a couple of metres from the top of the escarpment. Houses are set back about 15m. (See hotspot assessment below for The Esplanade)

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

Notes

Map

Hallett Cliffs 2:4

Initial view

Event: None
Risk: NA
Date: 12 May 2018

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

Notes

On 9th May 2016 the highest level of water was recorded at Outer Harbor in 80 years at 3.80 CD (2.36 AHD). To calculate the storm surge height at Hallett Cove: secondary port relationship methodology was used with Port Stanvac (calculated at 90%) and wave height of 0.30m added in accordance with storm surge allowance allocated by Coast Protection Board for the Kingston Park Region. The height of this flood map is depicted at 2.43 (AHD). Wave run up has been drawn 1m higher. Historical photographs at The Esplanade, Marino and Field River, Hallett Cove tend to support an inundation of this height.

Map

Hallett Cliffs 2:4

Sea-flood 2.43m AHD

Event: 9 May 2016
Risk: Historical benchmark
Date: 12 May 2018

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

Notes

DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has been mapped at 1.0m higher and depicted by way of dotted blue line. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Hallett Cliffs 2:4

Sea-flood 2.60m AHD

Event: Scenario: current
Risk: 1 in 100 ARI
Date: 12 May 2018

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

Notes

DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has been mapped at 1.0m higher and is depicted by way of dotted blue line. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Hallett Cliffs 2:4

Sea-flood 2.90m AHD

Event: Scenario: 2050

Risk: 1 in 100 ARI

Date: 12 May 2018

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1300 767 333 (free call)

Notes

DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has been mapped at 1.0m higher and is depicted by way of dotted blue line. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Hallett Cliffs 2:4

Sea-flood 3.60 AHD

Event: Scenario: 2100
Risk: 1 in 100 ARI
Date: 12 May 2018

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

Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been included at 0.7m higher and depicted by way of a dotted blue line. Sea level rise of 0.0 has been added.

Map

Hallett Cliffs 2:4

High tide 1.6m AHD

Event: Scenario: current
Risk: Escarpment erosion
Date: 12 May 2018

Integrated Coasts
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www.integratedcoasts.com
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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been included at 0.7m higher and depicted by way of a dotted blue line. Sea level rise of 0.3 has been added.

Map

Hallett Cliffs 2:4

High tide 1.90m AHD

Event: Scenario: 2050
Risk: Escarpment erosion
Date: 12 May 2018

Integrated Coasts
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Notes

Th This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been included at 0.7m higher and depicted by way of a dotted blue line. Sea level rise of 1.0 has been added.

Map

Hallett Cliffs 2:4

High tide 2.6m AHD

Event: Scenario: 2100
Risk: Escarpment erosion
Date: 12 May 2018

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

Notes

To analyse the rate of shoreline recession over the last seventy years, comparative analysis was conducted using georeferenced aerial photographs from 1949, 2002, and 2017. This analysis provides a long-term review (70 years), and a shorter term review (15 years). The longer term review is dependent on black and white photographs that are often difficult to decipher.

Map

Hallett Cliffs 2:4

Erosion assessment

Event: 2017
Risk: Shoreline recession
Date: 12 May 2018

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

Notes

There appears to be no changes to the top of bottom of the position of the cliff escarpment.

Map

Hallett Cliffs 2:4

Erosion assessment

Event: 2002

Risk: Shoreline recession

Date: 12 May 2018

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

Notes

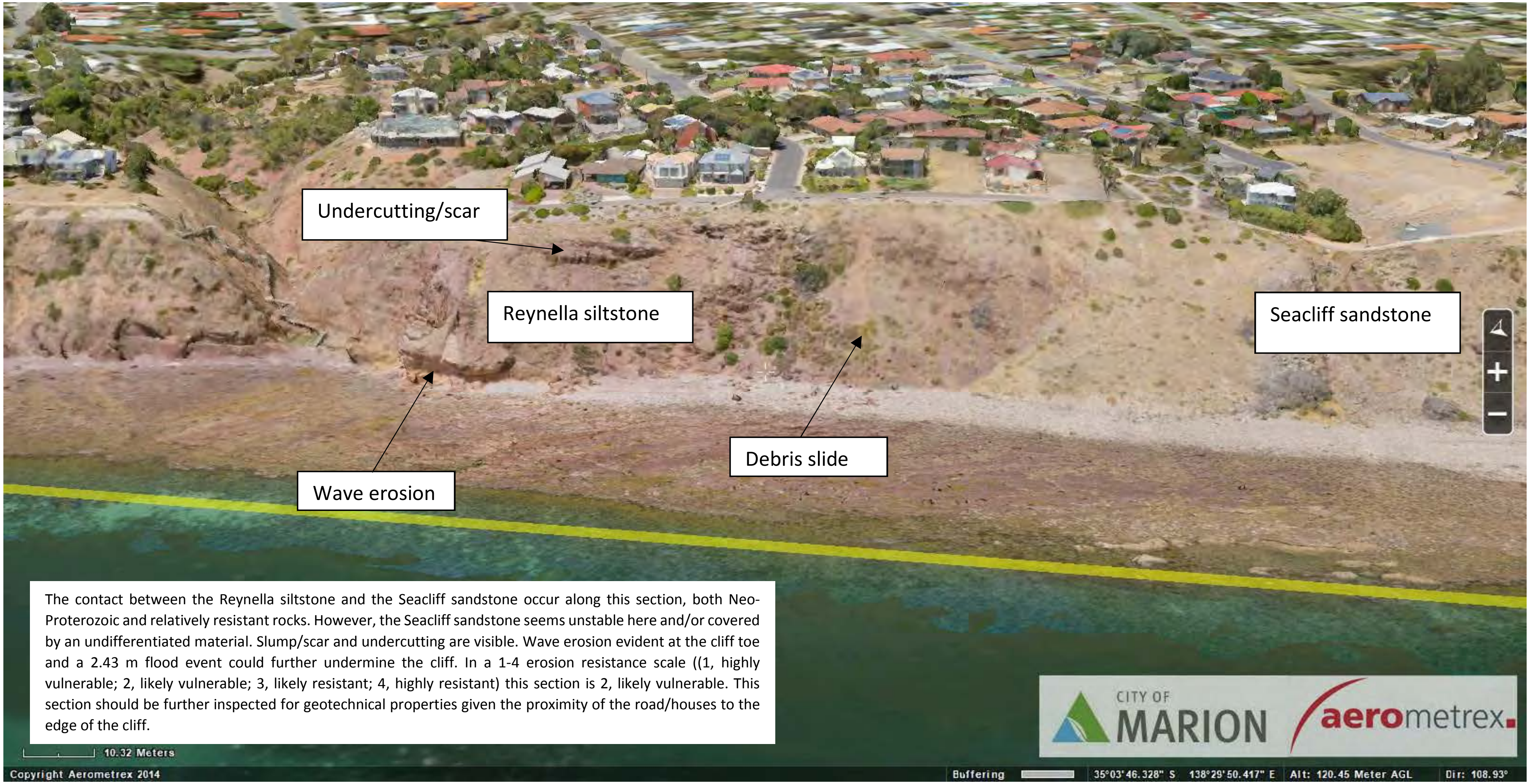
The section depicted by arrows appears to be a location of significant clifftop recession (this area is subject to much higher wave attack).

Map

Hallett Cliffs 2:4

Erosion assessment

Event: 1949
Risk: Shoreline recession
Date: 12 May 2018



The contact between the Reynella siltstone and the Seacliff sandstone occur along this section, both Neo-Proterozoic and relatively resistant rocks. However, the Seacliff sandstone seems unstable here and/or covered by an undifferentiated material. Slump/scar and undercutting are visible. Wave erosion evident at the cliff toe and a 2.43 m flood event could further undermine the cliff. In a 1-4 erosion resistance scale ((1, highly vulnerable; 2, likely vulnerable; 3, likely resistant; 4, highly resistant) this section is 2, likely vulnerable. This section should be further inspected for geotechnical properties given the proximity of the road/houses to the edge of the cliff.

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

Notes

Map

Hallett Cliffs 2:4

Geological review

Event: Ongoing
Risk: Cliff stability
Date: 12 May 2018

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Notes

SW2.6 Gully adjacent The Esplanade (name?). Storm water drains into this gully from various locations (no flow controls. Apparently no issues. Gully erodes to bedrock. Gully empties into hard rock location on coast)
SW2.7 Peera Street (one small pit)…on corner.

Map

Hallett Cliffs 2:4

Stormwater assessment

Event: Ongoing
Risk: Cliff erosion
Date: 12 May 2018

Risk assessment: Hallett Cove Cliffs (2:4)

Risk identification: Erosion is, or may in the future, impact the base of the cliffs so that they become unstable and/or recede.

Coastal processes	The contact between the Reynella siltstone and the Seacliff sandstone occur along this section, both Neo-Proterozoic and relatively resistant rocks. However, the Seacliff sandstone seems unstable here and/or covered by an undifferentiated material. Slump/scar and undercutting are visible. Wave erosion evident at the cliff toe and a 2.43 m flood event could further undermine the cliff. Therefore the geological rating is assigned as 'likely vulnerable'.

Are any strategies employed to mitigate the risk? No (and the assessment assumes that no action is taken to mitigate the risk)

Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	The Esplanade (2m from the escarpment) and the northern end of Clifftop Cres (5m from the escarpment) (and associated infrastructure and street furniture)	current	*Rare*	*Extreme*	Medium
		2100	*Possible*	*Extreme*	High
Private assets*	9 allotments (7 houses) sit behind the Esplanade. 3 houses (close to the escarpment) sit behind Clifftop Cres. 1 house and 1 allotment directly front the cliff.	current	*Rare*	*Moderate*	Low
		2100	*Unlikely*	*Major*	Medium
Safety of people	People use the walking trail. It is extremely unlikely that an event would occur without any warning and that someone might be impacted (events such as earthquakes are excluded from this assessment)	current	*Rare*	*Moderate*	Low
		2100	*Rare*	*Moderate*	Low
Environment	Inter-tidal zone is rocky beach, backed by hard rock/ soft rock cliffs. This section contains threatened priority remnant vegetation and may provide habitat for threatened fauna. The subtidal reef and seagrass are vulnerable to change.	current	*Rare*	*Moderate*	Low
		2100	*Possible*	*Moderate*	Medium

Inherent Hazard Rating

Soft rock sloping shores
(SR-10)

	Low	Moderate	High	Very high
Ecosystem disruption	X	2	3	4
Gradual inundation	X	2	3	4
Salt water intrusion	X	2	3	4
Erosion	1	X	3	4
Flooding	X	2	3	4

Erosion Hazard Rating
(current outlook)

	Low	Medium	High	Extreme
Public Infrastructure			X	
Private Assets*		X		
Public safety	X			
Environment	X			

Erosion Hazard Rating
(future outlook)

	Low	Medium	High	Extreme
Public Infrastructure				X
Private Assets*			X	
Public safety	X			
Environment		X		

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

*CoM is not necessarily liable for private assets

Summary	The section of cliff is composed of relatively resistant rocks but overlain by more vulnerable rocks, and the cliff is exposed to constant tide and wave action at the base which will only increase with sea level rise. The proximity of the Esplanade above, and the row of houses situated behind the Esplanade elevates the risk level.

Hallett Cliffs (2:4)
Erosion outlook and recommended actions (draft)

Geological review: The contact between the Reynella siltstone and the Seacliff sandstone occur along this section, both Neo-Proterozoic and relatively resistant rocks. However, the Seacliff sandstone seems unstable here and/or covered by an undifferentiated material. Slump/scar and undercutting are visible.

Historical recession: Based on photographic analysis, there appears to be no movement from 2002, but possible significant recession since 1949 (based on photographs with limited clarity).

Exposure:	Routine tidal impact (bi-monthly)	Storm surge impact (1 in 100 ARI)
Historical event - 2016	NA	Storm surge and direct wave action would have impacted the toe of the cliff
Current	Routine tide action directly impacts toe of the cliff around steps and to the north (less action to the south)	The wave run up of storm surge and wave height of 2.60m will interact significantly with the base of the cliff (on both sides of the stairs)
2050	Routine tide action will directly impacts toe of the cliff around steps and to the north (less action to the south)	The wave run up of storm surge and wave height of 2.90m will interact significantly with the base of the cliff (on both sides of the stairs)
2100	Significant routine wave action will impact the toe of the cliff very frequently.	The base of the cliff will come under high impact direct wave attack from storm surge of 3.60m

Storm water: Most storm water is drained into the gully. Small catchment area is drained over the cliff at Peera Street.

Risk Assessment: The nature of the cliff is likely vulnerable. The proximity of the public and private assets to the cliff top elevate the risk.

Recommended actions (draft):

Number	Action	Comments	Time frame
2:4 (1)	Review nature of storm water outflows and monitor impacts	Routine inspections are taken of the outfall areas. Recommend that staff incorporate review of scouring impacts (use photography)	1-2 years
2:4 (2)	Quantify more accurately the nature of routine and storm surge interaction with cliff base.	Monitor tidal regime for period of three months (winter). Monitor the impact of storm surge events (if, and when they occur)	1-2 years
2:4 (3)	Recapture digital model as basis for comparison	Use appropriate software to quantify changes in the coastal environment.	3-5 years
2:4 (4)	Further geological review of cliff required	Proximity of assets to cliff top warrant further review	1 years

Cell 2: Hallett Cliffs (2:5)

High tide was 2.03CD (high tides can be 2.30 to 2.50). The Esplanade Road is set back only a couple of metres from the top of the escarpment. Houses are set back about 15m. A landslip occurred in this location in 1996-1997 and the cliff was subsequently collapsed to decrease the slope of the escarpment. Fortunately, this area does not appear to be receiving constant wave action at the base. (See hotspot risk assessment)

Integrated Coasts
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1300 767 333 (free call)

Notes

Map

Hallett Cliffs 2:5

Initial View

Event: None
Risk: NA
Date: 12 May 2018

Integrated Coasts
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1300 767 333 (free call)

Notes

On 9th May 2016 the highest level of water was recorded at Outer Harbor in 80 years at 3.80 CD (2.36 AHD). To calculate the storm surge height at Hallett Cove: secondary port relationship methodology was used with Port Stanvac (calculated at 90%) and wave height of 0.30m added in accordance with storm surge allowance allocated by Coast Protection Board for the Kingston Park Region. The height of this flood map is depicted at 2.43 (AHD). Wave run up has been drawn 1m higher. Historical photographs at The Esplanade, Marino and Field River, Hallett Cove tend to support an inundation of this height.

Map

Hallett Cliffs 2:5

Sea-flood 2.43m AHD

Event: 9 May 2016
Risk: Historical benchmark
Date: 12 May 2018

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

Notes

DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has been mapped at 1.0m higher and is depicted by way of dotted blue line. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Hallett Cliffs 2:5

Sea-flood 2.60m AHD

Event:	Scenario: current
Risk:	1 in 100 ARI
Date:	12 May 2018

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Notes

DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has been mapped at 1.0m higher and is depicted by way of dotted blue line. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Hallett Cliffs 2:5

Sea-flood 2.90m AHD

Event: Scenario: 2050
Risk: 1 in 100 ARI
Date: 12 May 2018

Integrated Coasts
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Notes

DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has been mapped at 1.0m higher and is depicted by way of dotted blue line. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Hallett Cliffs 2:5

Sea-flood 3.60m AHD

Event: Scenario: 2100
Risk: 1 in 100 ARI
Date: 12 May 2018

Integrated Coasts
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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been included at 0.7m higher and depicted by way of a dotted blue line. Sea level rise of 0.0 has been added.

Map

Hallett Cliffs 2:5

High tide 1.6m AHD

Event: Scenario: current
Risk: Escarpment erosion
Date: 12 May 2018

Integrated Coasts
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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been included at 0.7m higher and depicted by way of a dotted blue line. Sea level rise of 0.3 has been added.

Map

Hallett Cliffs 2:5

High tide 1.9m AHD

Event: Scenario: 2050
Risk: Escarpment erosion
Date: 12 May 2018

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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been included at 0.7m higher and depicted by way of a dotted blue line. Sea level rise of 1.0 has been added.

Map

Hallett Cliffs 2:5

High tide 2.6m AHD

Event: Scenario: 2100
Risk: Escarpment erosion
Date: 12 May 2018

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Notes

Map

Hallett Cliffs 2:5

View: Land slip 1996

Event: Historical 1996

Risk: Unknown

Date: 12 May 2018

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Notes

To analyse the rate of shoreline recession over the last seventy years, comparative analysis was conducted using georeferenced aerial photographs from 1949, 2002, and 2017. This analysis provides a long-term review (70 years), and a shorter term review (15 years). The longer term review is dependent on black and white photographs that are often difficult to decipher.

Map

Hallett Cliffs 2:5

Erosion assessment

Event: 2017
Risk: Shoreline recession
Date: 12 May 2018

Integrated Coasts
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www.integratedcoasts.com
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Notes

No observable change from 2002 to 2017

Map

Hallett Cliffs 2:5

Erosion assessment

Event: 2002
Risk: Shoreline recession
Date: 12 May 2018

Integrated Coasts
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1300 767 333 (free call)

Notes

Not possible to quantity. The shingle ridge on the beach seems to be in the same location in later photographs.

Map

Hallett Cliffs 2:5

Erosion assessment

Event: 1949
Risk: Shoreline recession
Date: 12 May 2018

Seacliff sandstone underlying which seems an artificial slope. This material will continue to erode mostly from the top of the cliff. A relatively wide gravel beach offers protection against wave erosion at the cliff toe. In a 1-4 erosion resistance scale (1, highly vulnerable; 2, likely vulnerable; 3, likely resistant; 4, highly resistant) this section is 2, likely vulnerable, given the erodibility of the material sitting on top of the sandstone and the proximity of the Esplanade to the top of the cliff. This section should be further inspected for geotechnical properties given the proximity of the road/houses to the edge of the cliff

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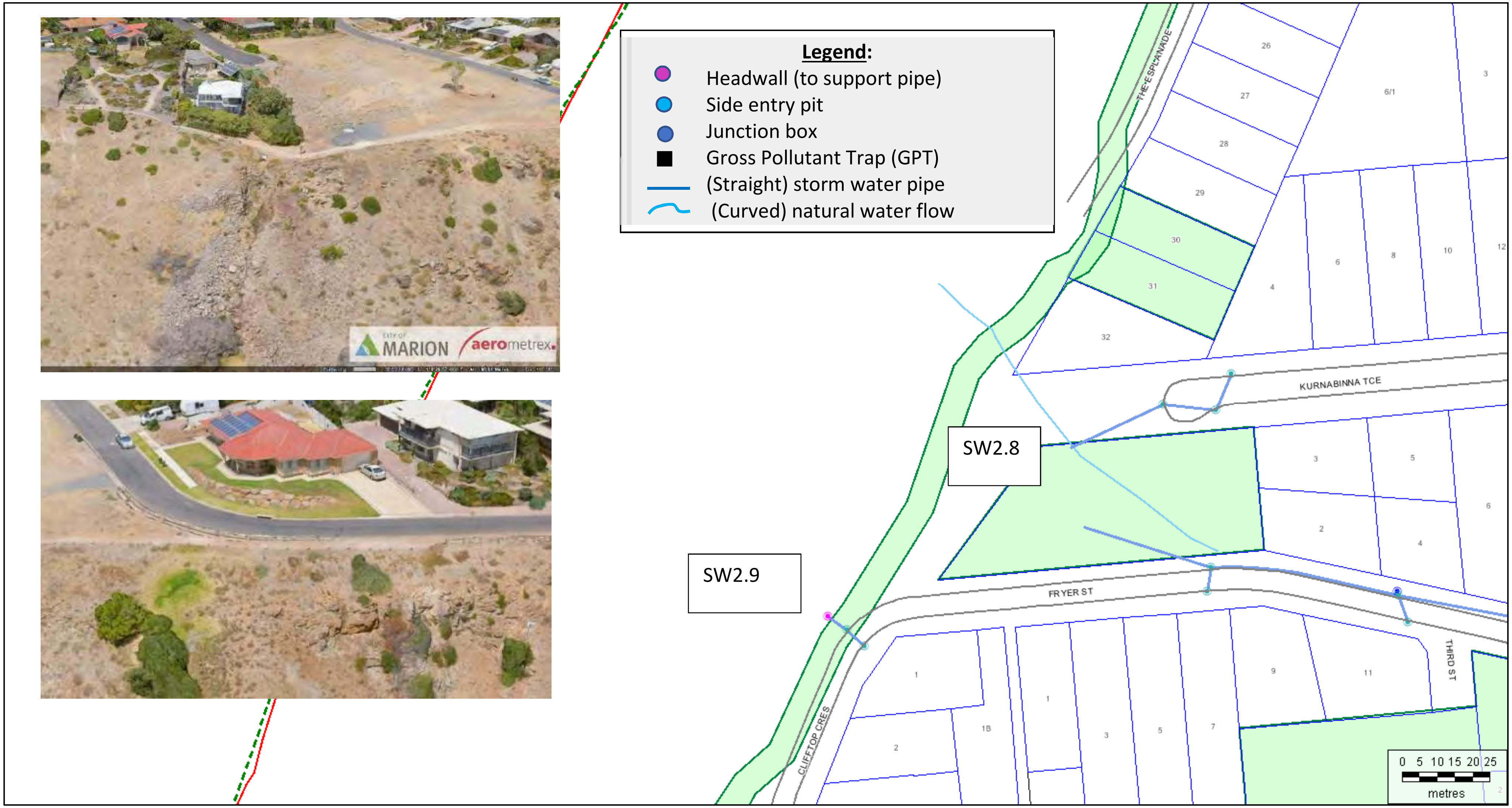
Notes

Map

Hallett Cliffs 2:5

Geological review

Event: Ongoing
Risk: Cliff stability
Date: 12 May 2018



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Notes

SW2.7 The Esplanade- cliff slump area. (what is blue line?)old pipe (prob not there)
SW2.8 Kurnabinna and Fryer (reserve area). Diagram is inaccurate. Water is piped to headwall (see inset) Headwall not on diagram
SW2.9 Clifftop Cres – side entry pit, but no headwall evident (perhaps headwall dot is in wrong place?)

Map

Hallett Cliffs 2:5

Stormwater assessment

Event: Ongoing
Risk: Cliff erosion
Date: 12 May 2018

Risk assessment: Hallett Cove Cliffs (2:5)

Risk identification: Erosion is, or may in the future, impact the base of the cliffs so that they become unstable and/or recede.

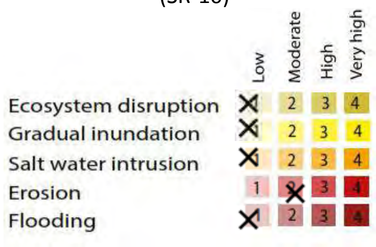
Coastal processes	Seacliff sandstone underlying which seems an artificial slope. This material will continue to erode mostly from the top of the cliff. A relatively wide gravel beach offers protection against wave erosion at the cliff toe. This section is 2, *likely vulnerable*, given the erodibility of the material sitting on top of the sandstone and the proximity of the Esplanade to the top of the cliff.

Are any strategies employed to mitigate the risk? No (and the assessment assumes that no action is taken to mitigate the risk)

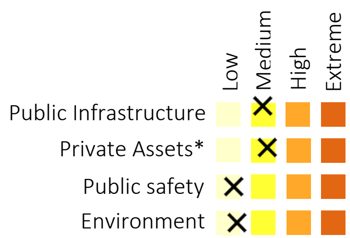
Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	The Esplanade (2m from the escarpment) and the northern end of Clifftop Cres (5m from the escarpment) (and associated infrastructure and street furniture)	current	*Rare*	*Major*	medium
		2100	*Unlikely*	*Major*	high
Private assets	9 allotments (7 houses) sit behind the Esplanade. 3 houses (close to the escarpment) sit behind Clifftop Cres. 1 house and 1 allotment directly front the cliff.	current	*Rare*	*Major*	medium
		2100	*Unlikely*	*Major*	high
Safety of people	People use the walking trail. It is extremely unlikely that an event would occur without any warning and that someone might be impacted (events such as earthquakes are excluded from this assessment)	current	*Rare*	*Insignificant*	low
		2100	*Rare*	*Insignificant*	low
Environment	Inter-tidal zone is rocky beach, backed by hard rock/ soft rock cliffs.	current	*Rare*	*Moderate*	low
		2100	*Possible*	*Moderate*	medium

Inherent Hazard Rating

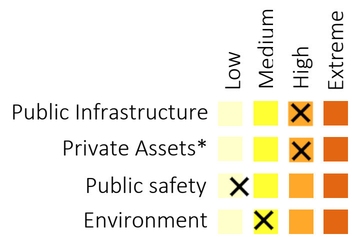
Soft rock sloping shores (SR-10)



Erosion Hazard Rating (current outlook)



Erosion Hazard Rating (future outlook)



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

*CoM is not necessarily liable for private assets

Summary	The geological hazard rating in this classified as 'likely vulnerable' mainly due to the material at the top of the cliff, rather than at the bottom (therefore coastal processes and increased sea level rise are not necessarily the prime impacts, but rather the control of storm water) It is recommendation that further assessment be undertaken.

Hallett Cliffs (2:5)
Erosion outlook and recommended actions (draft)

Geological review: Seacliff sandstone underlying which seems an artificial slope. This material will continue to erode mostly from the top of the cliff. A relatively wide gravel beach offers protection against wave erosion at the cliff toe. Therefore 'likely vulnerable' at the top of the cliff is the key issue.

Historical recession: Based on photographic analysis, there appears to be no significant recession of the cliff since 2002. It is not possible to determine any recession from the 1949 photograph except to notice that the shingle ridge appears in much the same location.

Exposure:	**Routine tidal impact (bi-monthly)**	**Storm surge impact (1 in 100 ARI)**
Historical event - 2016	NA	Unlikely to have been impact from storm surge or wave run up upon the toe of the cliff
Current	Routine tidal action does not impact the base of the cliff.	The wave run up of storm surge 2.60m will interact with minimal impact with the base of the cliff.
2050	Routine tidal action is unlikely to impact the base of the cliff	The wave run up of storm surge 2.90m will interact with some impact with the base of the cliff.
2100	Some routine tidal action is likely (wave run up)	The base of the cliff will come under high impact direct wave attack from storm surge of 3.60m

Storm water: Storm water flows over the cliff area in two locations.

Risk Assessment: This area is subjected to less action from the sea, but is vulnerable for erosion at the top of the cliff (storm water).

Recommended actions (draft):

Number	Action	Comments	Time frame
2:5 (1)	Review nature of storm water outflows and monitor impacts (esp in relation to this cliff area)	Routine inspections are taken of the outfall areas. Recommend that staff incorporate review of scouring impacts (use photography)	1-2 years
2:5 (2)	Quantify more accurately the nature of routine and storm surge interaction with cliff base.	Monitor tidal regime for period of three months (winter). Monitor the impact of storm surge events (if, and when they occur)	1-2 years
2:5 (3)	Recapture digital model as basis for comparison	Use appropriate software to quantify changes in the coastal environment.	3-5 years

Cell 2: Hallett Cliffs (2:6)

Clifftop Road is set back only five metres from the top of the escarpment. Two houses near the corner are set back about 15m from the clifftop. The remainder of the houses on Clifftop Cres are set back in excess of 30m. The base of the cliff in this area does not appear to be receiving constant wave action. High tide was 2.03CD (high tides can be 2.30 to 2.50). (See hotspot risk assessment below)

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Notes

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Map

Hallett Cliffs 2:6

Initial view

Event: None
Risk: NA
Date: 12 May 2018

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www.integratedcoasts.com
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Notes

On 9th May 2016 the highest level of water was recorded at Outer Harbor in 80 years at 3.80 CD (2.36 AHD). To calculate the storm surge height at Hallett Cove: secondary port relationship methodology was used with Port Stanvac (calculated at 90%) and wave height of 0.30m added in accordance with storm surge allowance allocated by Coast Protection Board for the Kingston Park Region. The height of this flood map is depicted at 2.43 (AHD). Wave run up has been drawn 1m higher. Historical photographs at The Esplanade, Marino and Field River, Hallett Cove tend to support an inundation of this height.

Map

Hallett Cliffs 2:6

Sea-flood 2.43m AHD

Event: 9 May 2016
Risk: Historical benchmark
Date: 12 May 2018

Integrated Coasts
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Notes

DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has been mapped at 1.0m higher and is depicted by way of dotted blue line. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Hallett Cliffs 2:6

Sea-flood 2.60m AHD

Event: Scenario: current

Risk: 1 in 100 ARI

Date: 12 May 2018

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Notes

DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has been mapped at 1.0m higher and is depicted by way of dotted blue line. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Hallett Cliffs 2:6

Sea-flood 2.90m AHD

Event: Scenario: 2050
Risk: 1 in 100 ARI
Date: 12 May 2018

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Notes

DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has been mapped at 1.0m higher and is depicted by way of dotted blue line. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Hallett Cliffs 2:6

Sea-flood 3.60m AHD

Event: Scenario: 2100
Risk: 1 in 100 ARI
Date: 12 May 2018

Integrated Coasts
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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been included at 0.7m higher and depicted by way of a dotted blue line. Sea level rise of 0.0 has been added.

Map

Hallett Cliffs 2:6

High tide 1.6m AHD

Event: Scenario: current
Risk: Escarpment erosion
Date: 12 May 2018

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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been included at 0.7m higher and depicted by way of a dotted blue line. Sea level rise of 0.0 has been added.

Map

Hallett Cliffs 2:6

High tide 1.9m AHD

Event: Scenario: 2050
Risk: Escarpment erosion
Date: 12 May 2018

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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been included at 0.7m higher and depicted by way of a dotted blue line. Sea level rise of 1.0 has been added.

Map

Hallett Cliffs 2:6

High tide 2.6m AHD

Event: Scenario: 2100
Risk: Escarpment erosion
Date: 12 May 2018

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Notes

To analyse the rate of shoreline recession over the last seventy years, comparative analysis was conducted using georeferenced aerial photographs from 1949, 2002, and 2017. This analysis provides a long-term review (70 years), and a shorter term review (15 years). The longer term review is dependent on black and white photographs that are often difficult to decipher.

Map

Hallett Cliffs 2:6

Erosion assessment

Event: 2017
Risk: Shoreline recession
Date: 12 May 2018

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www.integratedcoasts.com
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Notes

There appears to be minimal change from 2002 to 2017.

Map

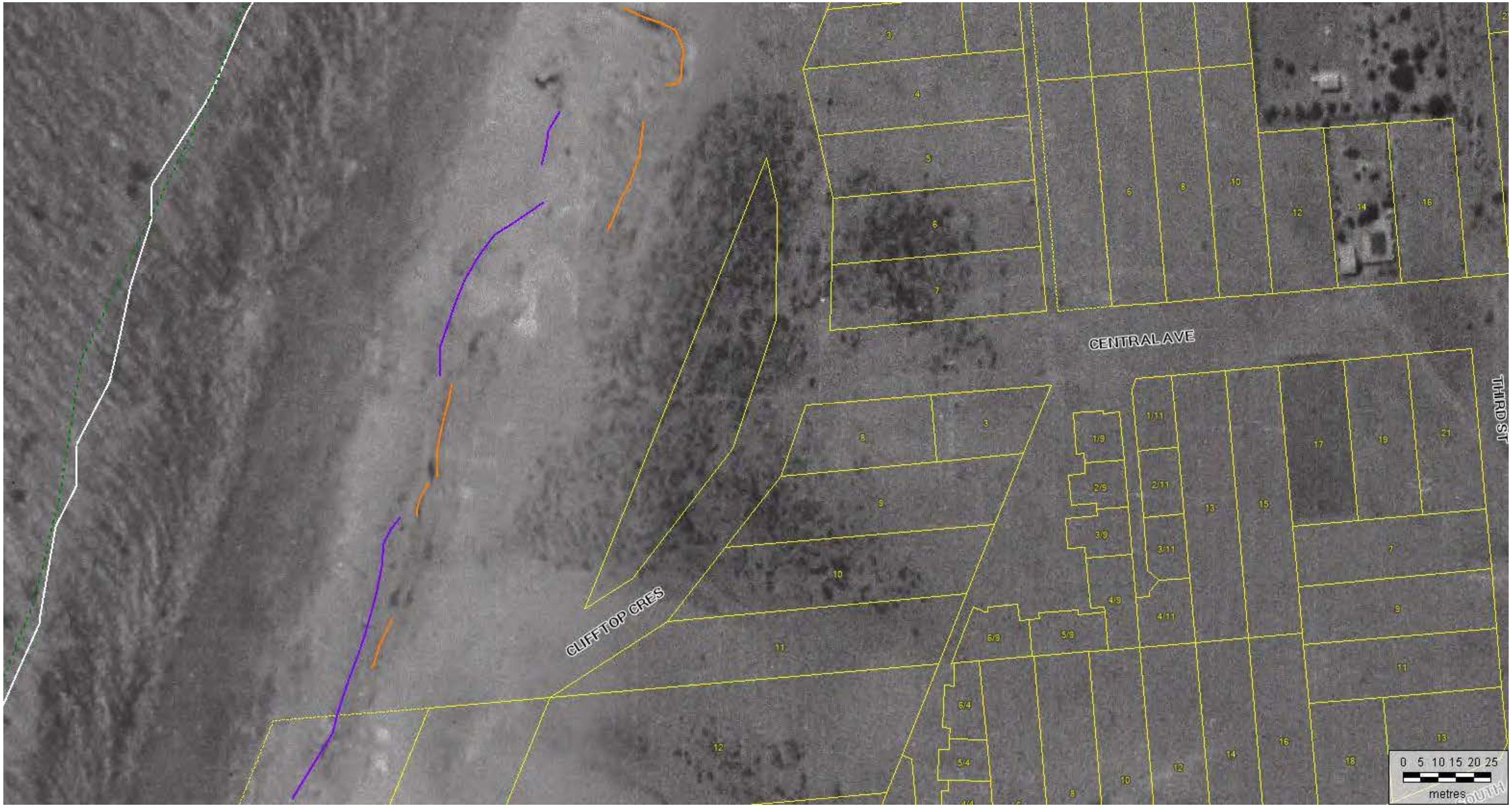
Hallett Cliffs 2:6

Erosion assessment

Event: 2002

Risk: Shoreline recession

Date: 12 May 2018



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www.integratedcoasts.com
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Notes

It is not possible to determine nature of cliff in this region. The shingle beach appears to be situated in same location.

Map

Hallett Cliffs 2:6

Erosion assessment

Event: 1949

Risk: Shoreline recession

Date: 12 May 2018

Relatively resistant Seacliff sandstone on the bottom of the cliff but the top is covered by friable material, perhaps Permian Cape Jervis formation (poorly consolidated glacio-marine and fluvioglacial sediments). Erosion seems mostly subaerial rather than wave-driven. In a 1-4 erosion resistance scale (1, highly vulnerable; 2, likely vulnerable; 3, likely resistant; 4, highly resistant) this section is 2, likely vulnerable, especially to stormwater flow and other subaerial factors removing material from the top of the cliff.

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Notes

Map

Hallett Cliffs 2:6

Geological review

Event: Ongoing
Risk: Cliff stability
Date: 12 May 2018

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Notes

Sw2.10 – Cliff top Cres and Central Ave (run off). Junction box and headwall (but appears rock installed to cater for overflow?)

Map

Hallett Cliffs-6

Stormwater assessment

Event: Ongoing
Risk: Cliff erosion
Date: 12 May 2018

Hotspot Assessment: The Esplanade/ Cliff Pde

Historical context	The Esplanade subdivision was originally completed in England (1912) It is likely that Clifftop was drawn at the same time. Houses and roads were likely constructed in 1980s. In 1996-1997 a land slip occurred that was deemed to have underlying cause as an agent fault that gave way after a very wet winter, and not as a result of any coastal processes. Neither Council nor the State was deemed legally responsible. The slope was collapsed to increase stability and some houses were acquired (check this). CPB advised that the base of the remedial works would likely to be subject to some wave action (in high events), and that the locality should be monitored.
Technical context	Golder and Associates (engineers) completed extensive geotechnical study of the locality and determined that the underlying causes were geological combined with wet winter.
Coastal context	CHZ assigned this section of coast as 'Soft rock sloping shores' with Moderate Erosion Hazard rating. Intertidal zone is rock and shingle beach, and subtidal is rock shelf. The high tide marks on 30th Aug/ 17th Sept demonstrate tidal range of 2.0CD to 2.2CD (high tide can be 2.5CD). Some erosion action is observed at the base, likely related to extreme events.
Climate context	SLR is rising in the Gulf and projected to rise faster. Over the course of this century the base of these cliffs will receive much more constant wave action.

Risk assessment: Hallett Cove 2:6

Risk identification: Erosion is, or may in the future, impact the base of the cliffs so that they become unstable and/or recede.

Coastal processes	Relatively resistant Seacliff sandstone on the bottom of the cliff but the top is covered by friable material, perhaps Permian Cape Jervis formation. The toe of the cliff has limited interaction with coastal processes. Therefore the rating of 'likely vulnerable' applies to the top of the cliff.

Are any strategies employed to mitigate the risk? No (and the assessment assumes that no action is taken to mitigate the risk)

Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	The Esplanade (2m from the escarpment) and the northern end of Clifftop Cres (5m from the escarpment) (and associated infrastructure and street furniture)	current	*Rare*	*Major*	medium
		2100	*Unlikely*	*Major*	high
Private assets*	9 allotments (7 houses) sit behind the Esplanade. 3 houses (close to the escarpment) sit behind Clifftop Cres. 1 house and 1 allotment directly front the cliff.	current	*Rare*	*Major*	medium
		2100	*Unlikely*	*Major*	high
Safety of people	People use the walking trail. It is extremely unlikely that an event would occur without any warning and that someone might be impacted (events such as earthquakes are excluded from this assessment)	current	*Rare*	*Insignificant*	low
		2100	*Rare*	*Insignificant*	low
Ecosystem disruption	Inter-tidal zone is rocky beach, backed by hard rock/ soft rock cliffs. This section contains threatened priority remnant vegetation and may provide habitat for threatened fauna. The subtidal reef and seagrass are vulnerable to change.	current	*Rare*	*Moderate*	low
		2100	*Possible*	*Moderate*	medium

Inherent Hazard Rating

Soft rock sloping shores
(SR-10)

	Low	Moderate	High	Very high
Ecosystem disruption	X	2	3	4
Gradual inundation	X	2	3	4
Salt water intrusion	X	2	3	4
Erosion	1	X	3	4
Flooding	X	2	3	4

Erosion Hazard Rating
(current outlook)

	Low	Medium	High	Extreme
Public Infrastructure		X		
Private Assets*		X		
Public safety	X			
Ecosystem disruption	X			

Erosion Hazard Rating
(future outlook)

	Low	Medium	High	Extreme
Public Infrastructure			X	
Private Assets*			X	
Public safety	X			
Ecosystem disruption		X		

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

*CoM is not necessarily liable for private assets

Summary	The proximity of assets in relation to a friable (crumbly) cliff escarpment at the top sees this location given a higher risk rating. Controlling storm water flows will be important. The bottom of the cliff is likely to be rated as 'likely resistant' in the view that coastal processes do not appear to be interacting with the base of the cliff.

Hallett Cliffs (2:6)
Erosion outlook and recommended actions (draft)

Geological review: Relatively resistant Seacliff sandstone on the bottom of the cliff but the top is covered by friable material, perhaps Permian Cape Jervis formation.

Historical recession: Based on photographic analysis, there appears to be no recession of the cliff since 2002. Photographic evidence from 1949 is difficult to analyse

Exposure:	**Routine tidal impact (bi-monthly)**	**Storm surge impact (1 in 100 ARI)**
Historical event - 2016	NA	Likely to have interacted with the base of the cliff with minor escarpment created.
Current	Unlikely that routine tidal action is interelating with the base of the cliff (apart from harder rock sections at either end)	The wave run up of storm surge and wave height of 2.70m will interact significantly with the base of the cliff (with wave run up only)
2050	Some routine tidal action will interelate with the base of the cliff (wave run up only)	The wave run up of storm surge and wave height of 3.00m will interact significantly with the base of the cliff (with wave run up only)
2100	Significant routine wave and wave run-up action will interelate with the base of the cliff	The base of the cliff will come under high impact direct wave attack from storm surge of 3.70m

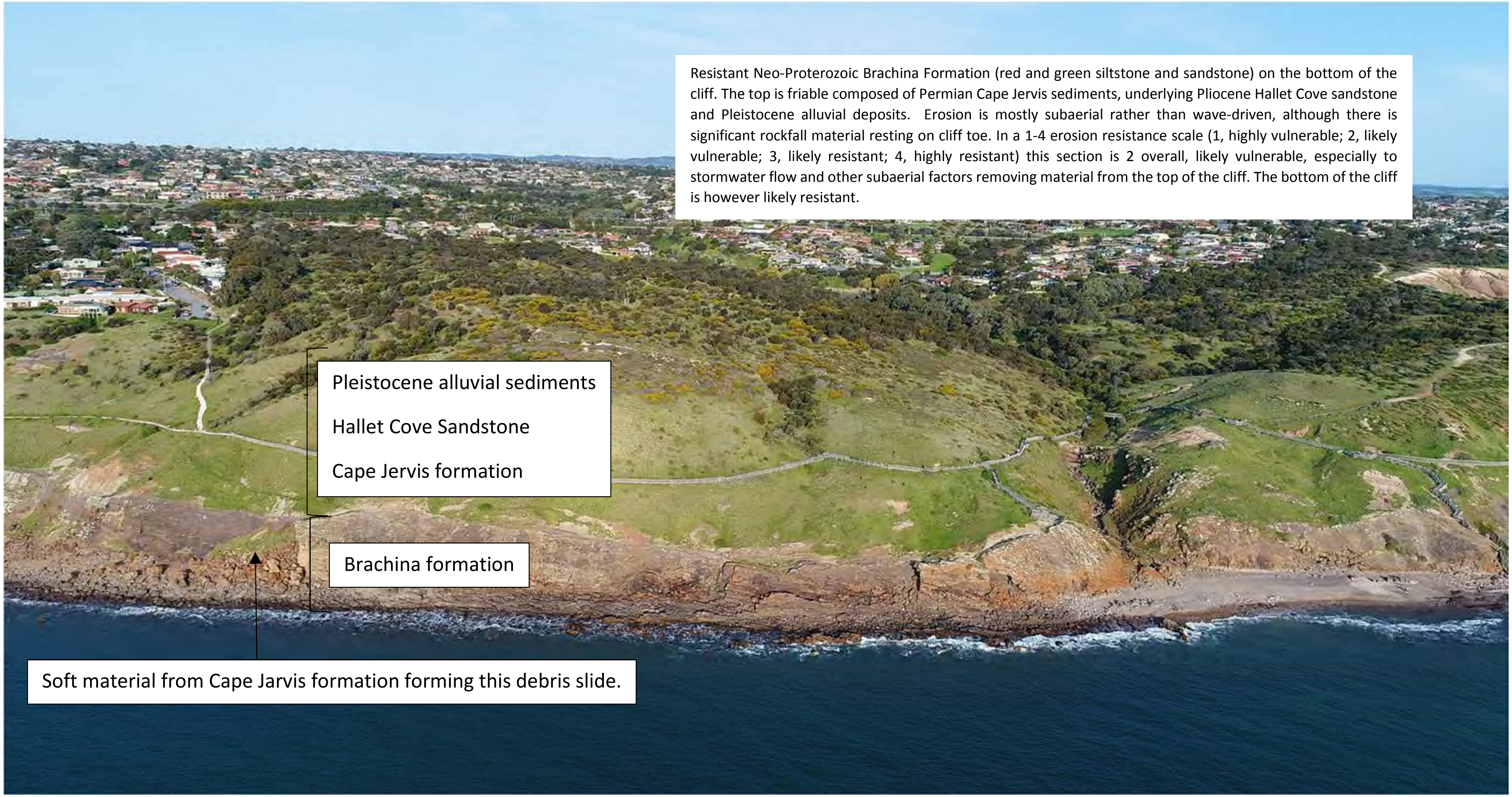
Storm water: Water flows north west from end of Clifftop Parade through rocks (to dissipate and slow flow) and then flows over the cliff.

Risk Assessment: The proximity of assets in relation to a friable (crumbly) cliff escarpment at the top sees this location given a higher risk rating.

Recommended actions (draft):

Number	Action	Comments	Time frame
1:1 (1)	Review nature of storm water outflows and monitor impacts	Routine inspections are taken of the outfall areas. Recommend that staff incorporate review of scouring impacts (use photography)	1-2 years
1:1 (2)	Quantify more accurately the nature of routine and storm surge interaction with cliff base.	Monitor tidal regime for period of three months (winter). Monitor the impact of storm surge events (if, and when they occur)	1-2 years
1:1 (3)	Recapture digital model as basis for comparison	Use appropriate software to quantify changes in the coastal environment.	3-5 years

Cell2: Hallett Cliffs (2:7)



Integrated Coasts
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1300 767 333 (free call)

Notes

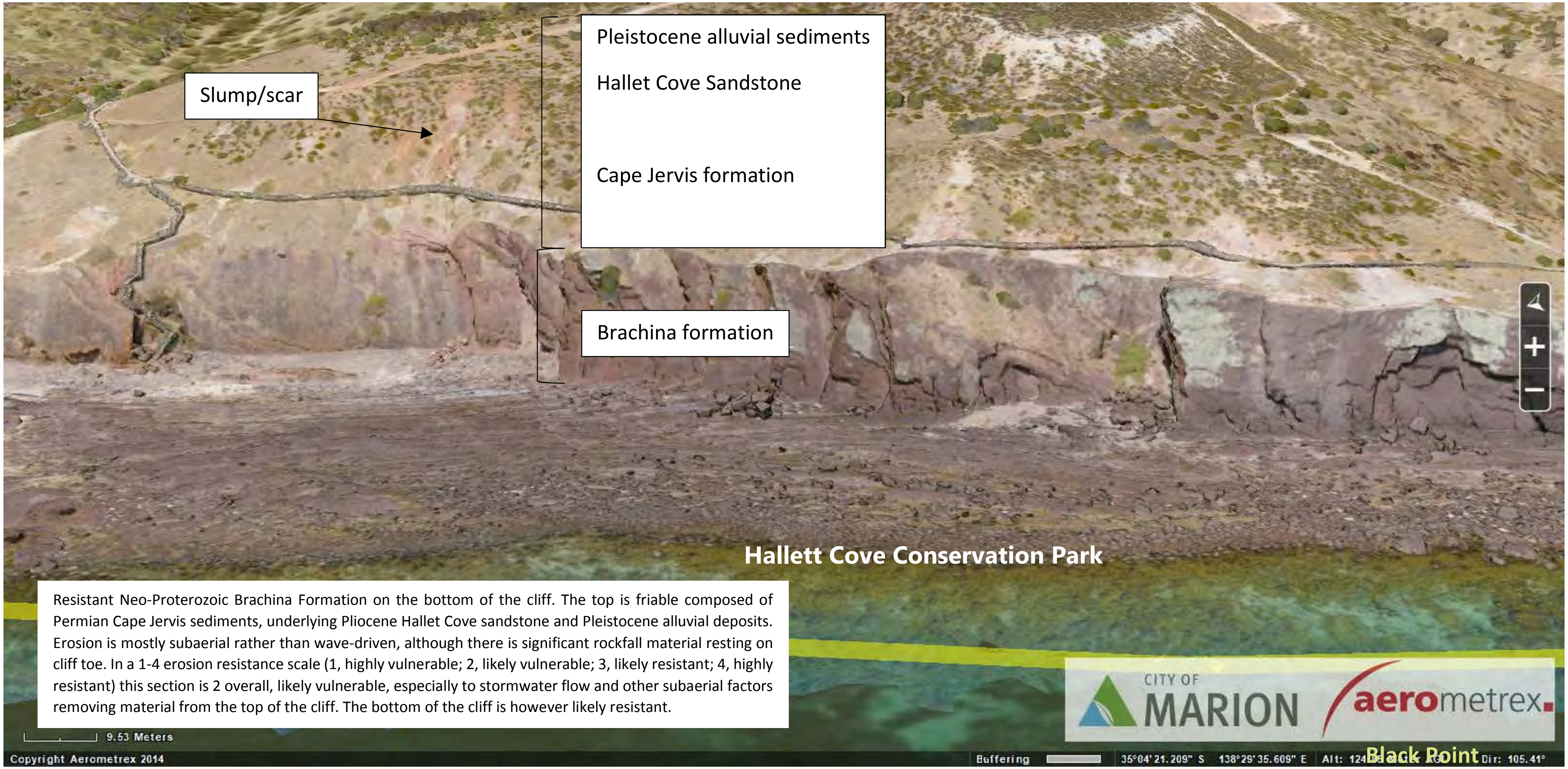
Map

Hallett Cliffs 2:7

Geological review

Event: Ongoing
Risk: Cliff stability
Date: 12 May 2018

Cell 2: Hallett Cliffs (2:8)



Resistant Neo-Proterozoic Brachina Formation on the bottom of the cliff. The top is friable composed of Permian Cape Jervis sediments, underlying Pliocene Hallet Cove sandstone and Pleistocene alluvial deposits. Erosion is mostly subaerial rather than wave-driven, although there is significant rockfall material resting on cliff toe. In a 1-4 erosion resistance scale (1, highly vulnerable; 2, likely vulnerable; 3, likely resistant; 4, highly resistant) this section is 2 overall, likely vulnerable, especially to stormwater flow and other subaerial factors removing material from the top of the cliff. The bottom of the cliff is however likely resistant.

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Notes

Map

Hallett Cliffs 2:8

Geological review

Event: Ongoing
Risk: Cliff stability
Date: 12 May 2018

Cell 2: Hallett Cliffs (2:9)

Resistant Neo-Proterozoic Brachina Formation composing most of the cliff. The top is friable Permian Cape Jervis sediments, but further inland than previous 2 sections. Erosion is mostly subaerial rather than wave-driven. In a 1-4 erosion resistance scale (1, highly vulnerable; 2, likely vulnerable; 3, likely resistant; 4, highly resistant) this section is 3, likely resistant.

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Notes

Map

Hallett Cliffs 2:9

Geological review

Event: Ongoing
Risk: Cliff stability
Date: 12 May 2018


Coastal Tour and
Preliminary Assessment
Cell 3:
Hallett Beach
Seaview Downs
Marino
CC MARION
Seacliff Park
Southern Exp
O'Halloran Hill
Trott Park
Hallett Cove
Sheidow Park
Main South Rd
Lonsdale Rd
Reynella

Section 3: Hallett Beach (3:1)

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Notes

On 9th May 2016 the highest level of water was recorded at Outer Harbor in 80 years at 3.80 CD (2.36 AHD). To calculate the storm surge height at Hallett Cove: secondary port relationship methodology was used with Port Stanvac (calculated at 90%) and wave height of 0.30m added in accordance with storm surge allowance allocated by Coast Protection Board for the Kingston Park Region. The height of this flood map is depicted at 2.43 (AHD). Wave run up has drawn 1.0m higher. Historical photographs at The Esplanade, Marino and Field River, Hallett Cove tend to support an inundation of this height.

Map

Hallett Beach3:1

Historical storm event

Event: 9th May 2016: 2.43 AHD
Risk: Historical benchmark
Date: 12 May 2018

Typical wave-run up for this region

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Notes

DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has been mapped at 1.0m higher and depicted by way of dotted blue line.. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Hallett Beach 3:1

Sea-flood 2.60m AHD

Event: Scenario: current
Risk: 1 in 100 ARI
Date: 12 May 2018

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Notes

DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has been mapped at 1.0m higher and depicted by way of dotted blue line.. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Hallett Beach 3:1

Sea-flood 2.90m AHD

Event: Scenario 2050

Risk: 1 in 100 ARI

Date: 12 May 2018

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Notes

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Map

Hallett Beach 3:1
Sea-flood 3.6m AHD
Event: Scenario 2100
Risk: 1 in 100 ARI
Date: 12 May 2018

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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been included at 0.7m higher and depicted by way of a dotted blue line. Sea level rise of 0.0 has been added.

Map

Hallett Beach 3:1

High Tide 1.60m AHD

Event:	Scenario: current
Risk:	Escarpment Erosion
Date:	12 May 2018

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Notes

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Map

Hallett Beach 3:1

High Tide 1.9m AHD

Event: Scenario 2050
Risk: Escarpment erosion
Date: 12 May 2018

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Notes

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Map

Hallett Beach 3:1

High tide 2.6m AHD

Event: Scenario 2100
Risk: Escarpment erosion
Date: 12 May 2018

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Notes

To analyse the rate of shoreline recession over the last seventy years, comparative analysis was conducted using georeferenced aerial photographs from 1949, 2002, and 2017. This analysis provides a long-term review (70 years), and a shorter term review (15 years). The longer term review is dependent on black and white photographs that are often difficult to decipher.

Map

Hallett Beach 3:1

Erosion assessment

Event: Oct 2017

Risk: Shoreline recession

Date: 12 May 2018

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Notes

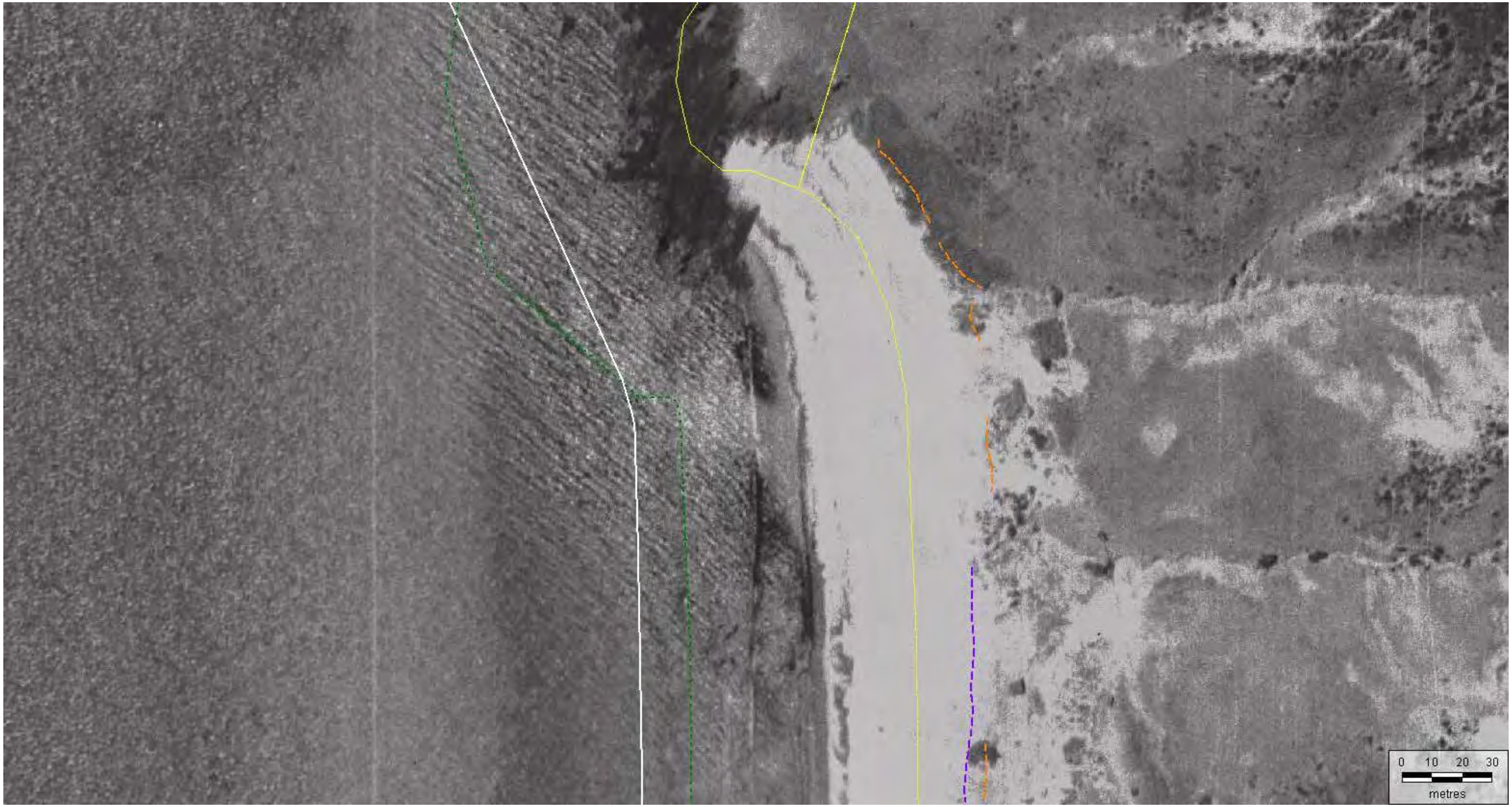
Comparing this photograph with 2017 suggests a recession of dunes by approx 1 metres and slightly less volume of sand on the beach.

Map

Hallett Beach 3:1

Erosion assessment

Event: 2002
Risk: Shoreline recession
Date: 12 May 2018



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Notes

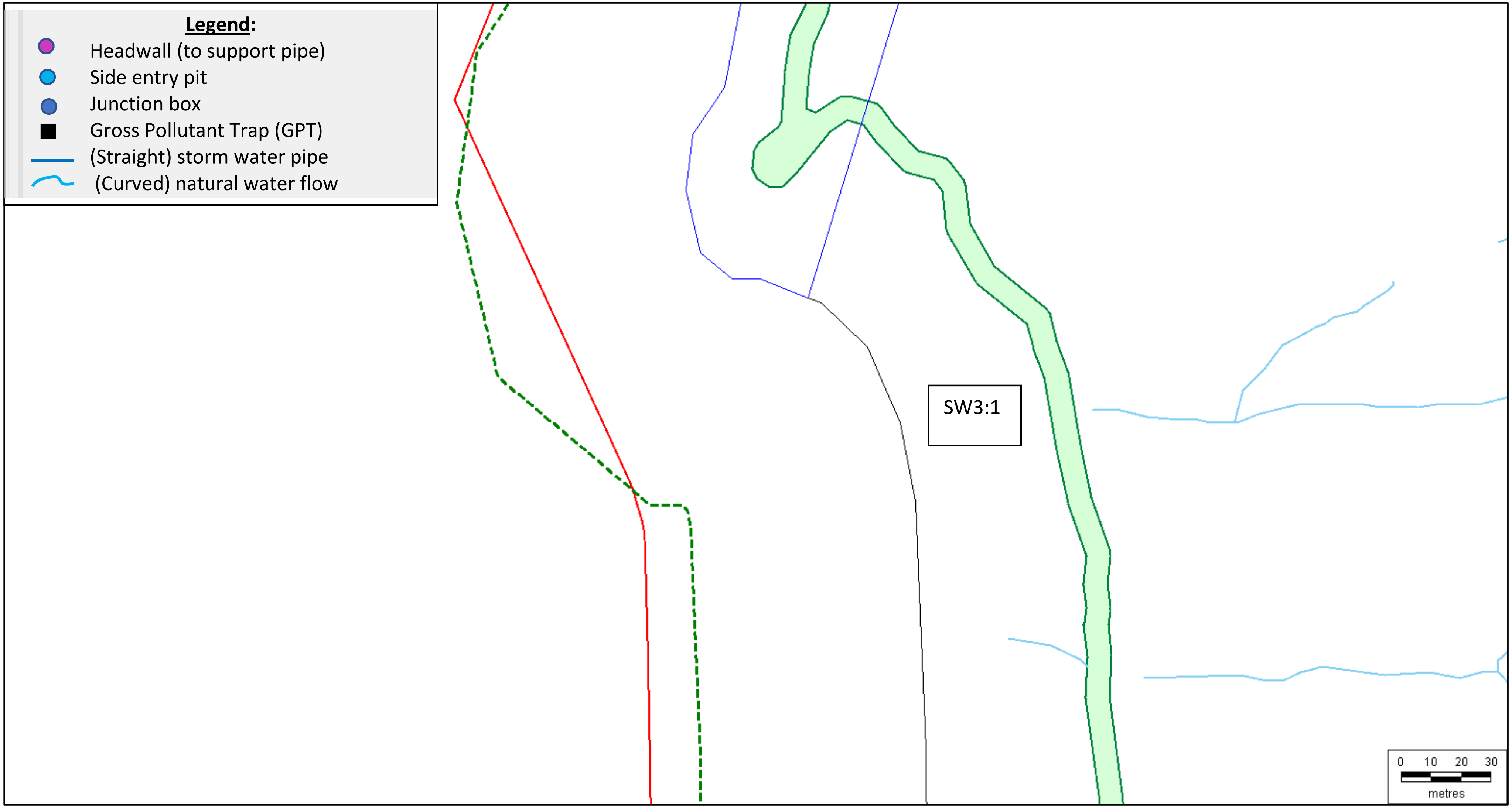
Erosion appears to have occurred on the northern end of the beach (2-3 metres) (based on vegetation line). Compared to photographs of 2002/2017 there is significantly more sand on the beach.

Map

Hallett Beach 3:1

Erosion assessment

Event: 1949
Risk: Shoreline recession
Date: 12 May 2018



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Notes

SW3:1 Water drains through national park. DEWNR is responsible for managing this location. Some storm water erosion from natural runoff is evident through frontal dunes. The key issue here is to protect the frontal dunes (for long term coastal stability in view of SLR)

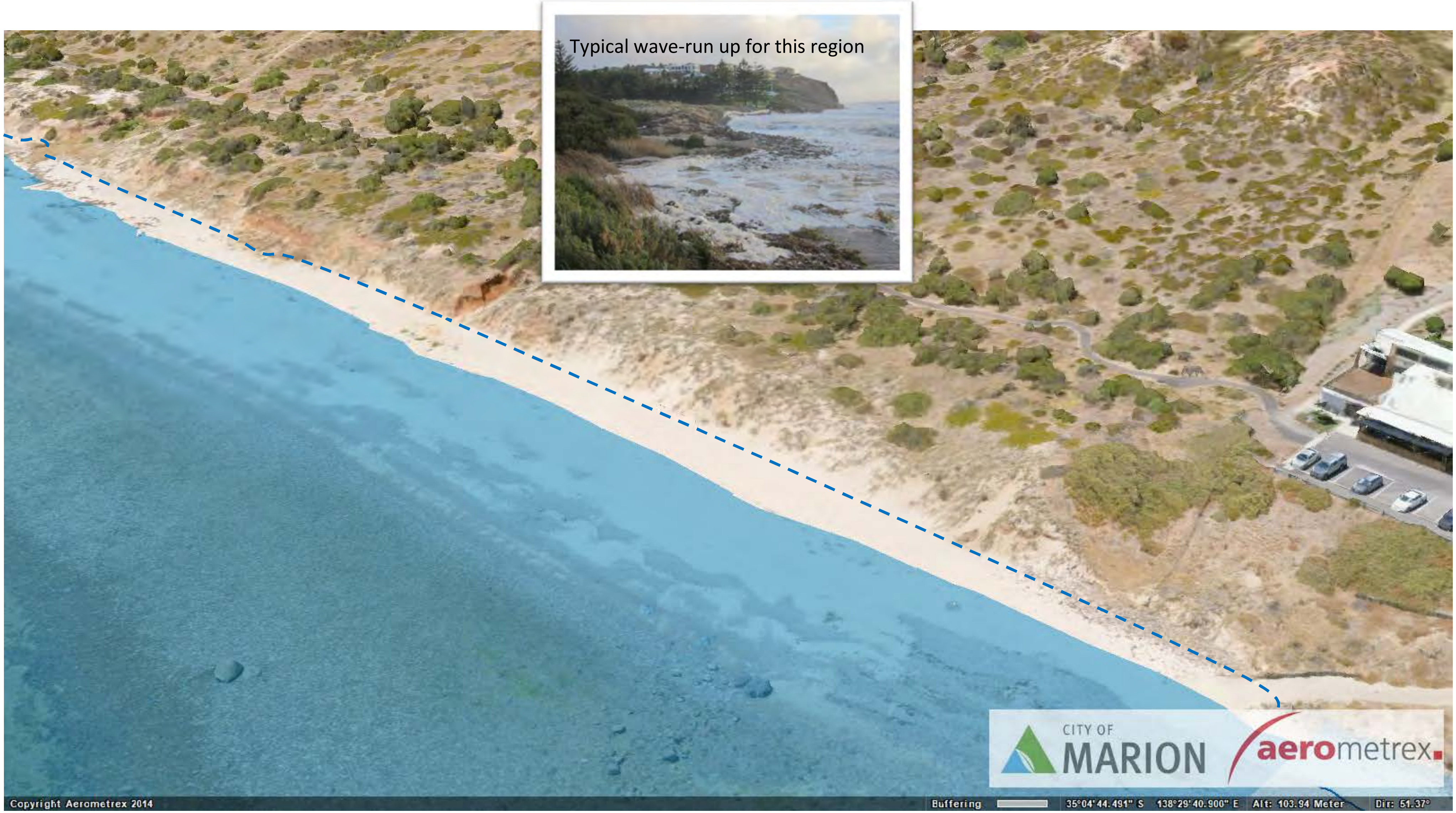
Map

Hallett Beach 3:1

Stormwater assessment

Event: Ongoing
Risk: Cliff erosion
Date: 12 May 2018

Cell 3: Hallett Beach (3:2)



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Map

Hallett Beach 3:2

Sea-flood 2.43m AHD

Event: 9 May 2016

Risk: Historical benchmark

Date: 12 May 2018

Integrated Coasts

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Notes

DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has been drawn at 1.0m higher and depicted by way of dotted blue line. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Hallett Beach 3:2

Sea-flood 2.60m AHD

Event: Scenario: current
Risk: 1 in 100 ARI
Date: 12 May 2018

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Notes

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Map

Hallett Beach 3:2

Sea-flood 2.90m AHD

Event: Scenario: 2050
Risk: 1 in 100 ARI
Date: 12 May 2018

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Notes

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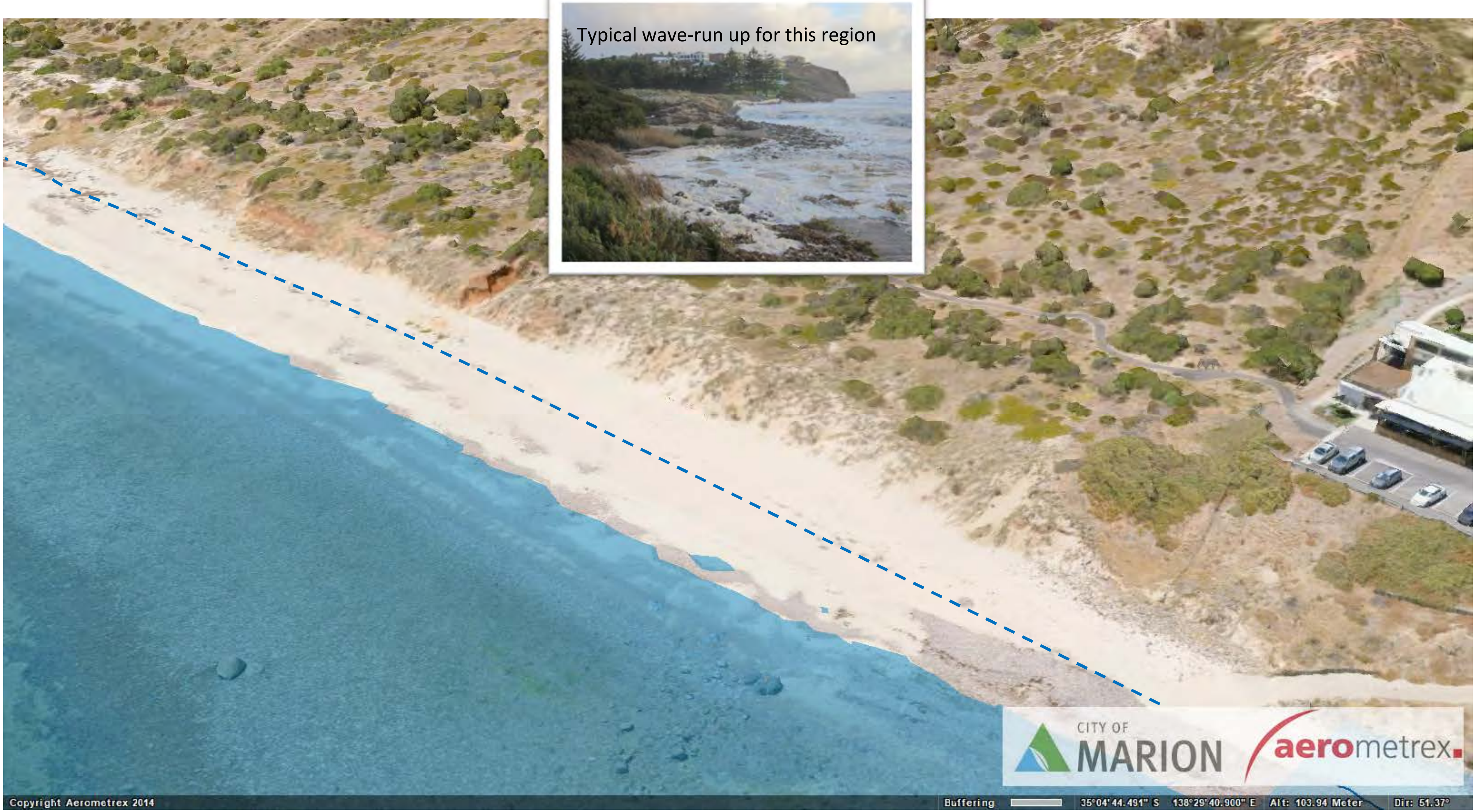
Map

Hallett Beach 3:2

Sea-flood 3.60m AHD

Event: Scenario: 2100
Risk: 1 in 100 ARI
Date: 12 May 2018



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Notes

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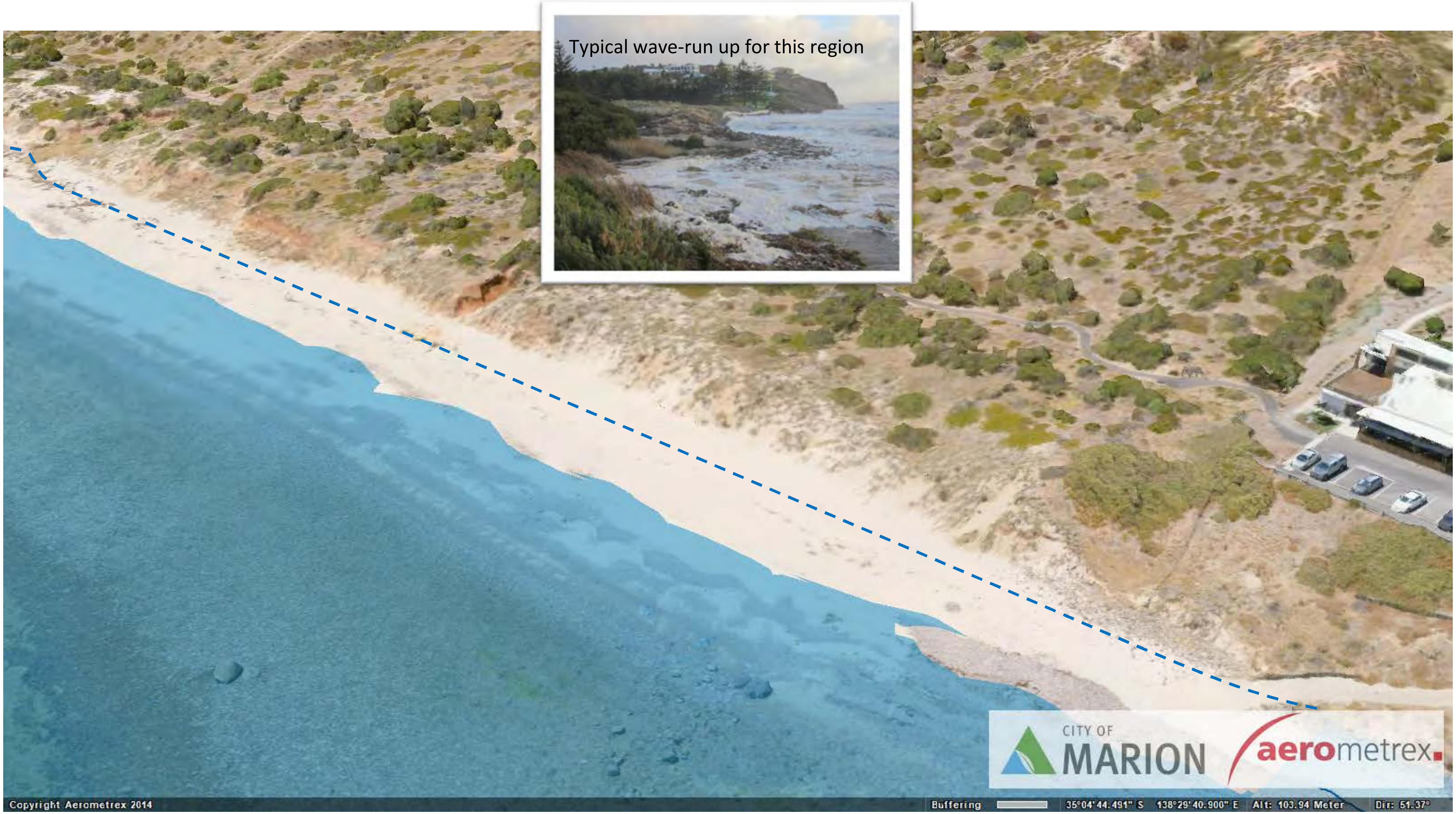
Map

Hallett Beach 3:2

High tide 1.6m AHD

Event: Scenario: current
Risk: Escarpment erosion
Date: 12 May 2018



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Notes

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Map

Hallett Beach 3:2

High tide 1.9m AHD

Event: Scenario: 2050
Risk: Escarpment erosion
Date: 12 May 2018

June 2018

Typical wave-run up for this region

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Notes

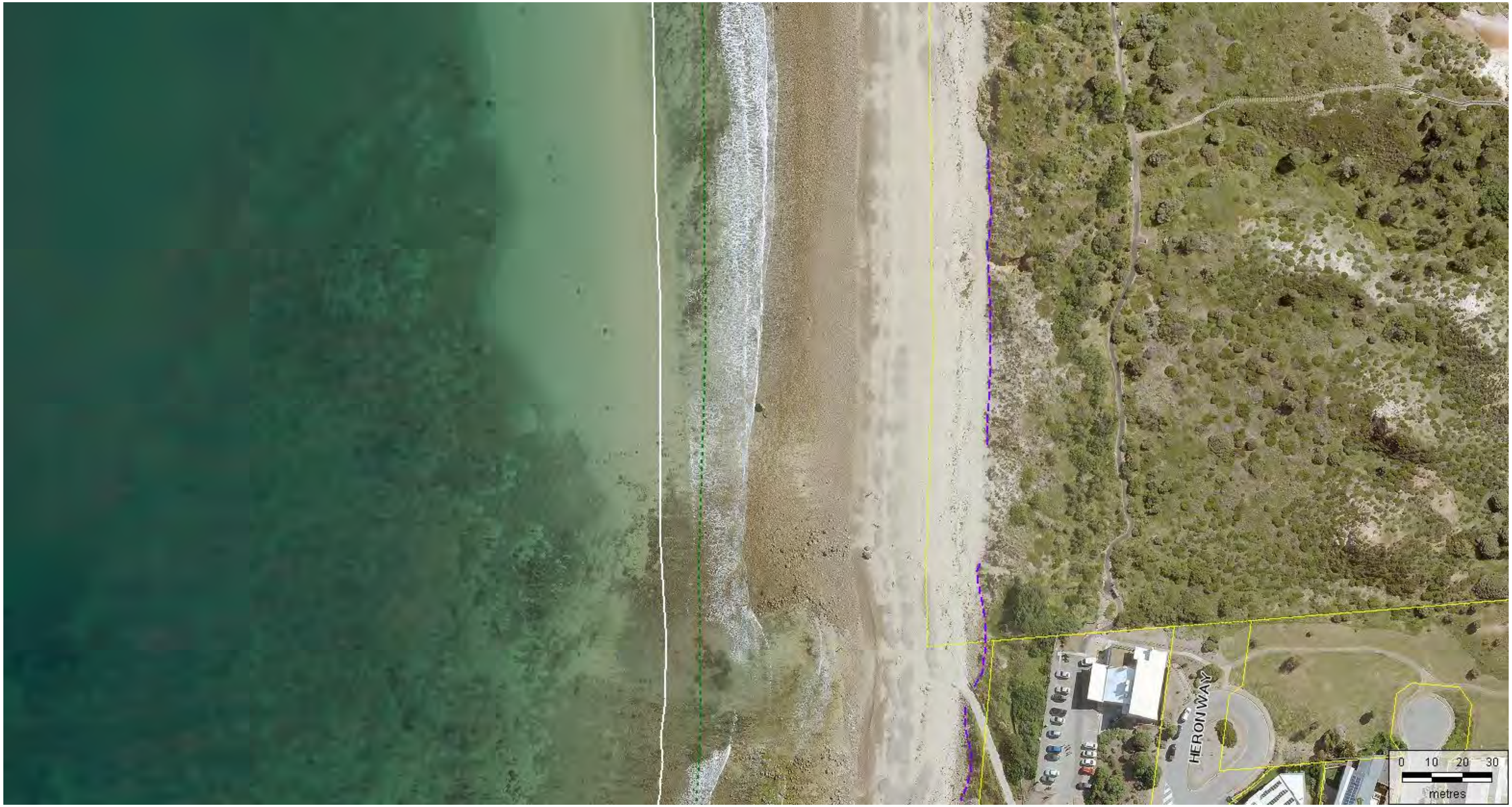
This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been drawn at 0.7m higher and depicted by way of a dotted blue line. Sea level rise of 1.0 has been added.

Map

Hallett Beach 3:2

High tide 2.6m AHD

Event: Scenario: 2100
Risk: Escarpment erosion
Date: 12 May 2018



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1300 767 333 (free call)

Notes

To analyse the rate of shoreline recession over the last seventy years, comparative analysis was conducted using georeferenced aerial photographs from 1949, 2002, and 2017. This analysis provides a long-term review (70 years), and a shorter term review (15 years). The longer term review is dependent on black and white photographs that are often difficult to decipher.

Map

Hallett Beach 3:2

Erosion assessment

Event: 2017
Risk: Shoreline recession
Date: 12 May 2018

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Notes

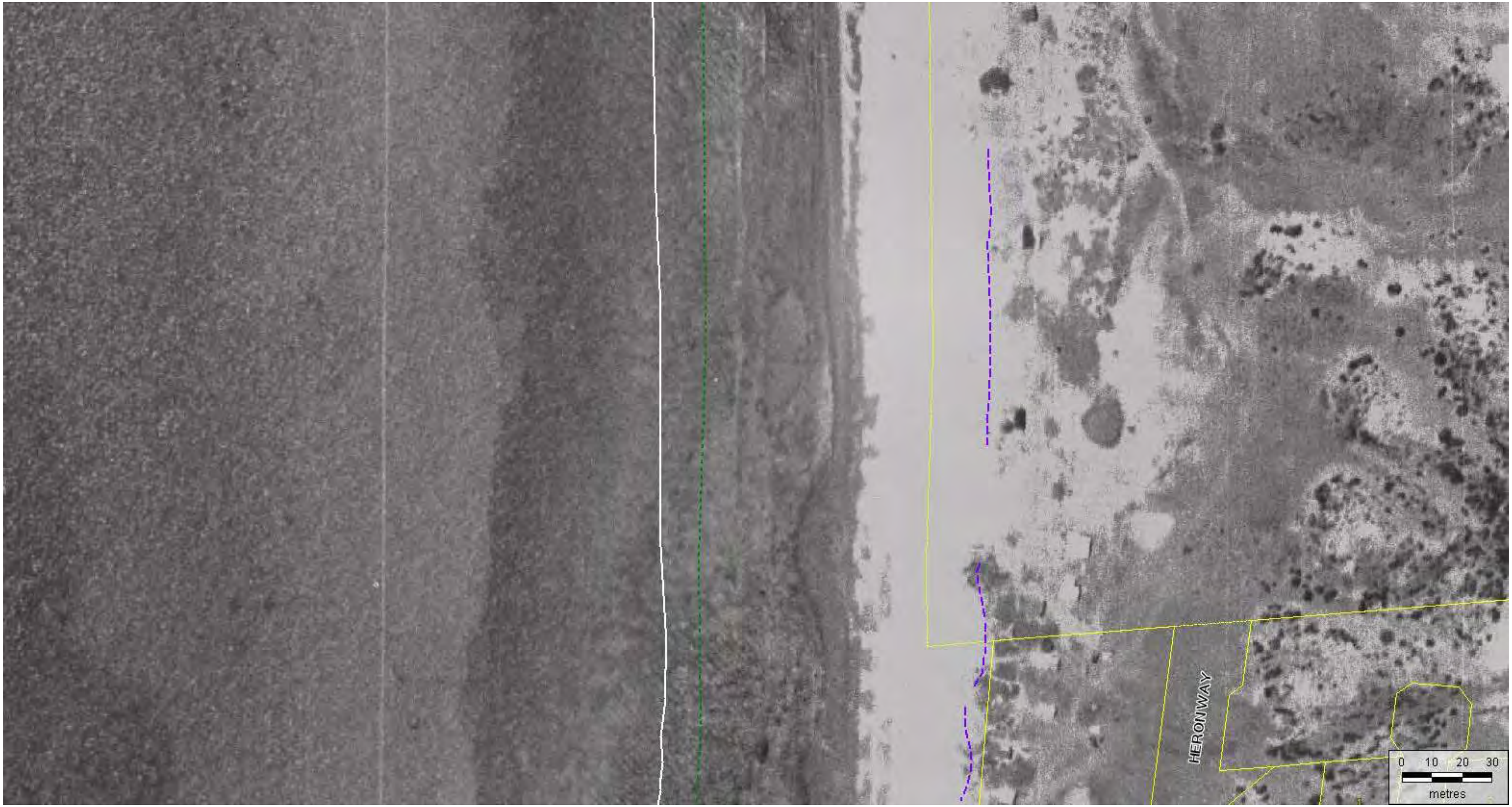
Some minor recession of the vegetation line at the base of the dunes is noted in places (1-2 m)

Map

Hallett Beach 3:2

Erosion assessment

Event: 2002
Risk: Shoreline recession
Date: 12 May 2018



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Notes

Sand dunes in 1949 were mostly devoid of vegetation (and this it isn't possible to ascertain dune movement from this photograph). Vegetation in the south of this picture appears to be in a similar position. Generally, the volume of sand is higher than 2002/2017.

Map

Hallett Beach 3:2

Erosion assessment

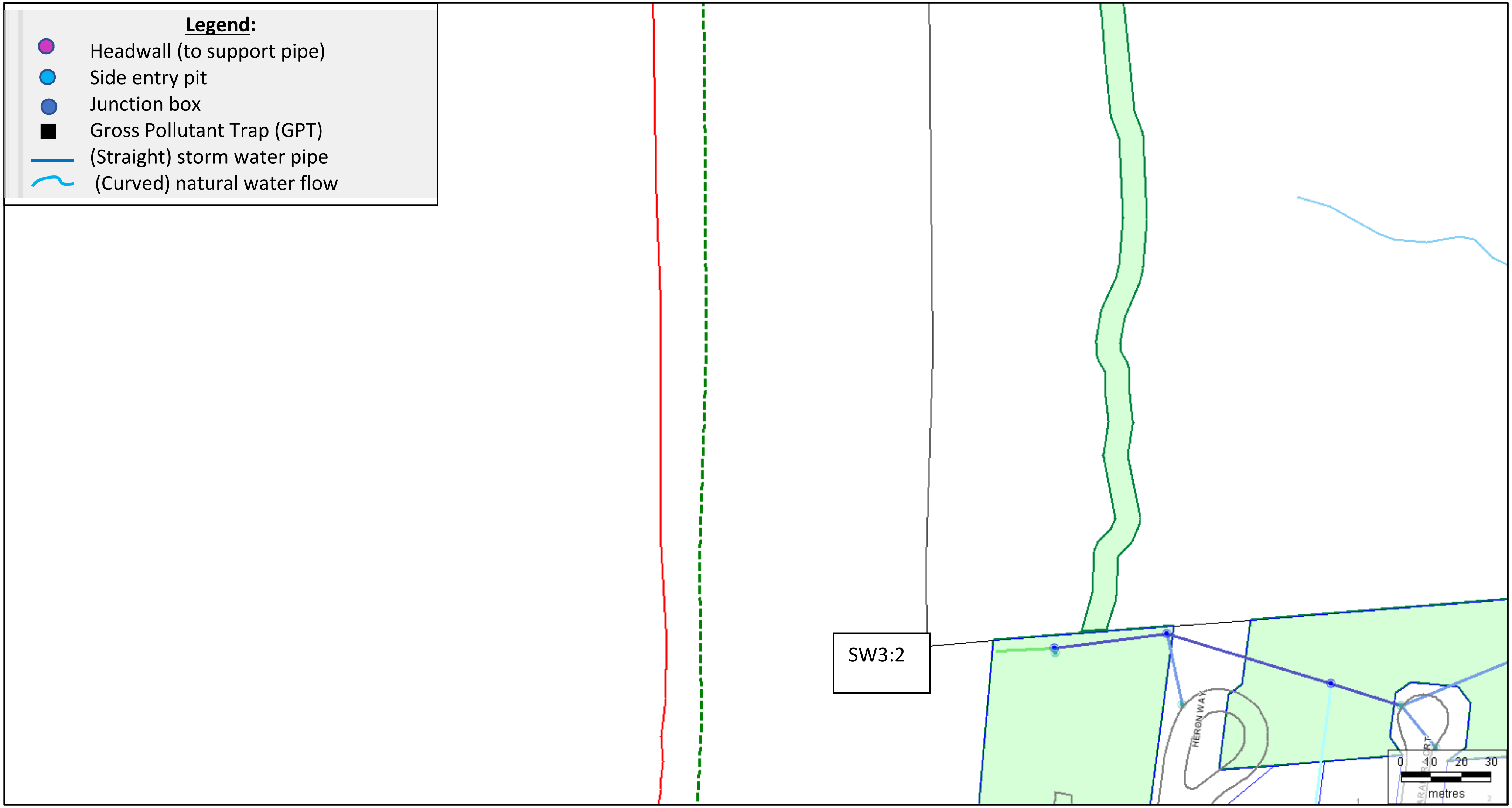
Event: 1947

Risk: Shoreline recession

Date: 12 May 2018

Legend:

- Headwall (to support pipe)
- Side entry pit
- Junction box
- Gross Pollutant Trap (GPT)
- (Straight) storm water pipe
- (Curved) natural water flow



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Notes

SW3:2 The configuration depicted here does not exist. Storm water infrastructure now flows south along Heron Way. Only natural flows from the national park. The dunes have been gullied in at least one location (pg 14). Should sea water enter this location (or others like it) then the dunes would break down quickly.

Map

Hallett Beach 3:2

Stormwater assessment

Event: Ongoing
Risk: Cliff erosion
Date: 12 May 2018

Section 3: Hallett Beach (north)

This section of beach is underlain by glacial clay and till deposits which extend from the back of the beach offshore to below the low tide limit. The beach has been relatively stable over time (but appears to have less sand than in the 1960s). The back-beach escarpment appears stable (based on limited survey information and vertical photography) (HCCMS, p. 12, 37,38).

Stormwater drains from the amphitheatre to the beach (nil water from urban environments). Storm water is compromising the dunes in three places. Combined with higher storm surges, the dunes are likely to degrade more quickly and impact the walking trail behind.

General erosion assessment

Risk assessment: Hallett Beach (3:1,2)

Risk identification: Erosion is currently, or may in the future, impact the integrity of the dune system and erode to the walking trail.

Coastal processes	The foreshores of Hallett Cove present as a slowly receding coastline, starved of sediment (HCCMS) Observation tour found little evidence of erosion activity at the base of the dune escarpment. Dunes are well vegetated. Three storm water outlets draining from the amphitheatre have eroded gullies through the dunes. Height of walking trail adjacent boatshed is 10m AHD (HCCMS, p.39) and on northern end of beach is 7.5m AHD. Storm surge policy level is set at 4.7m AHD in 2100.

Are any strategies employed to mitigate the risk? No (and the assessment assumes that no action is taken to mitigate the risk)

Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Walking trail and associated signs and furniture. HCCMS uses Bruin Rule and allows 25m recession by 2100 which suggests dunes will remain intact. But channels cut by storm water put this assessment in doubt at 2100 with intrusion of sea water.	current	*Rare*	*No risk*	No risk
		2100	*Possible*	*Moderate*	medium
Private assets	Nil	current	*Rare*	*No risk*	No risk
		2100	*Rare*	*No risk*	No risk
Safety of people	People movement is confined to the walk trail or the beach.	current	*Rare*	*No risk*	No risk
		2100	*Rare*	*No risk*	No risk
Environment	The distance from the dune escarpment to the walking trail varies between 32m to 45m. Increase sea levels into storm water gullies may exacerbate erosion rate.	current	*Possible*	*Minor*	medium
		2100	*Likely*	*Moderate*	High

Inherent Hazard Rating

Soft rock sloping shores (SR-10)

	Low	Moderate	High	Very high
Ecosystem disruption	X	2	3	4
Gradual inundation	X	2	3	4
Salt water intrusion	X	2	3	4
Erosion	1	X	3	4
Flooding	X	2	3	4

Erosion Hazard Rating (current outlook)

	Low	Medium	High	Extreme
Public Infrastructure	No	risk		
Private Assets	No	risk		
Public safety	No	risk		
Environment		X		

Erosion Hazard Rating (future outlook)

	Low	Medium	High	Extreme
Public Infrastructure		X		
Private Assets	No	risk		
Public safety				
Environment			X	

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	HCCMS evaluated the erosion of the dunes as low risk by 2100, and suggested allowing them to recede with increase of sea level. However, storm water has cut three gullies and combined with increases in sea level will increase the rate of erosion. The scenario modelling within the DEM suggests that the dunes will come under increasing wave attack over the course of the century.

Hallett Beach (3:1,2)
Summary and recommended actions (draft)

Geological review: This section of beach is underlain by glacial clay and till deposits which extend from the back of the beach offshore to below the low tide limit.

Historical recession: Minor recession is observed when comparing 2002 photograph with 2017 (1-2 metres, especially on northern end). Recession in order of 3-4 metres is observed on northern end of the beach. There appears to be minimal recession in southern section. (Mid section not assessible).

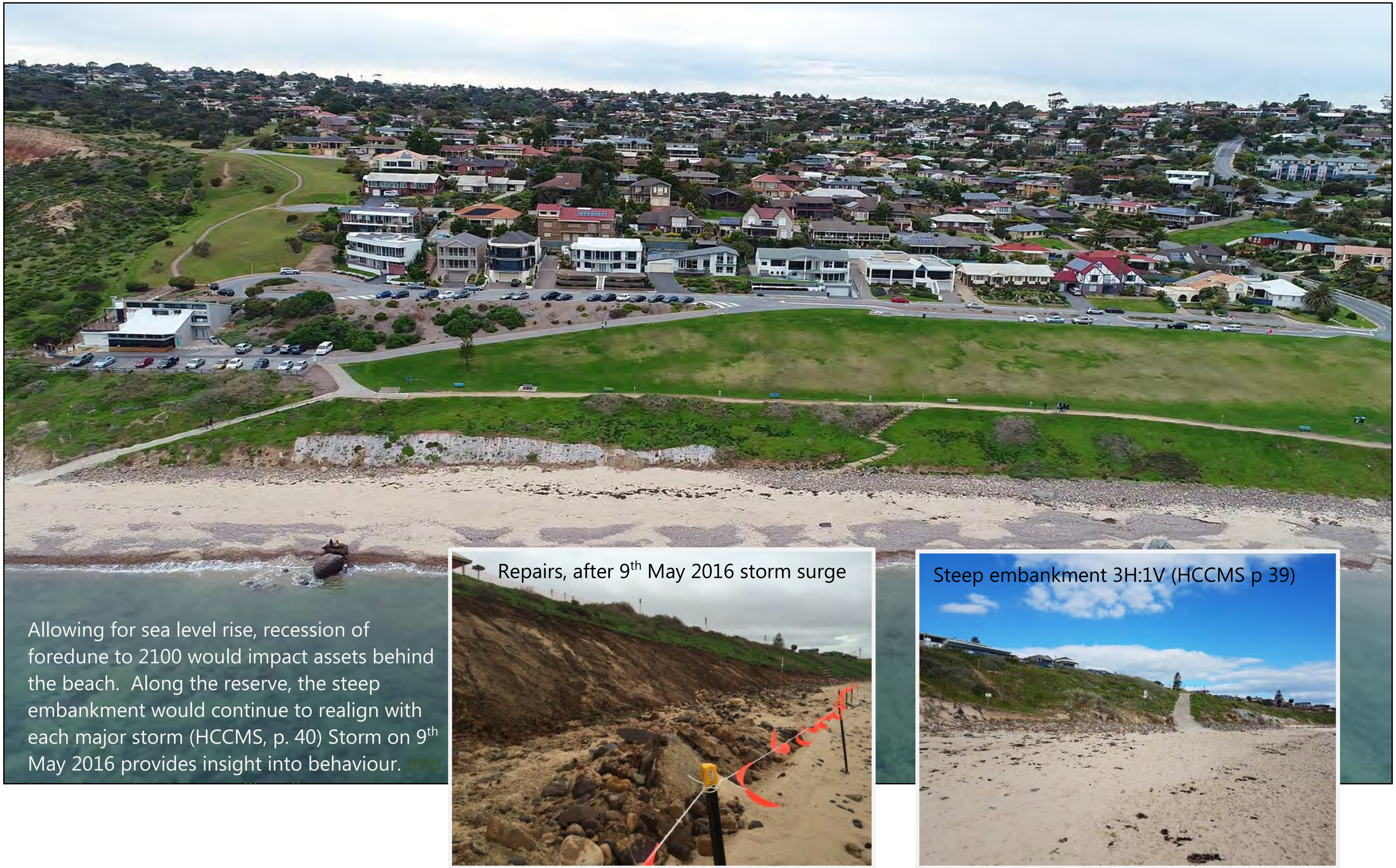
Exposure	Routine tidal impact (bi-monthly)	Storm surge impact (1 in 100 ARI)
Historical event - 2016	NA	Wave run-up from this event is likely just to interacted with the base of the dunes (especially in the north of the beach).
Current	The dunes on Hallett Cove Beach are not likely to be under impact from routine tidal action.	The wave run up of storm surge and wave height of 2.60m will interact with the base of the dunes (with wave run up only)**.
2050	The dunes on Hallett Cove Beach are not likely to come under significant impact from routine tidal action.	The wave run up of storm surge and wave height of 2.90m will interact significantly with the base of the cliff (with wave run-up)**
2100	Significant routine wave and wave run-up action will impact the dunes causing them to recede.	The base of the dunes will come under high impact with direct wave attack from storm surge of 3.60m

****Storm water:** **Water from non-urban environments is causing some gullying (see pictures above). If sea water enters these locations, the dunes will break down quite quickly**.

Risk Assessment: As a national park, there are no private assets. The walking trail is situated well back from the dunes and is unlikely to be impacted. However, later in the century the dunes are likely to have receded if projected sea level rise occur.

Recommended actions (draft):

Number	Action	Comments	Time frame
3:1 (1)	Consult with DEWNR re storm water gullying in dunes.	Consult with DEWNR who are responsible of storm water flows noting that if sea water enters these locations the dune system will break down quite quickly.	1-2 years
3:1 (2)	Quantify more accurately the nature of routine and storm surge interaction with dunes	Monitor tidal regime for period of three months (winter). Monitor the impact of storm surge events (if, and when they occur)	1-2 years
3:1 (3)	Recapture digital model as basis for comparison	Use appropriate software to quantify changes in the coastal environment.	3-5 years



Allowing for sea level rise, recession of foredune to 2100 would impact assets behind the beach. Along the reserve, the steep embankment would continue to realign with each major storm (HCCMS, p. 40) Storm on 9th May 2016 provides insight into behaviour. into

Repairs, after 9th May 2016 storm surge

Steep embankment 3H:1V (HCCMS p 39)

Integrated Coasts
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1300 767 333 (free call)

Notes

On 9th May 2016 the highest level of water was recorded at Outer Harbor in 80 years at 3.80 CD (2.36 AHD). To calculate the storm surge height at Hallett Cove: secondary port relationship methodology was used with Port Stanvac (calculated at 90%) and wave height of 0.30m added in accordance with storm surge allowance allocated by Coast Protection Board for the Kingston Park Region. The height of this flood map is depicted at 2.43 (AHD). Wave run up has been drawn 1.0m higher. Historical photographs at The Esplanade, Marino and Field River, Hallett Cove tend to support an inundation of this height.

Map

Hallett Beach 3:3

Sea-flood 2.43m AHD

Event: 9 May 2016
Risk: Historical benchmark
Date: 12 May 2018

Integrated Coasts
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www.integratedcoasts.com
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Notes

DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has been mapped at 1.0m higher and depicted by way of dotted blue line.. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Hallett Beach 3:3

Sea-flood 2.60m AHD

Event: Scenario: current
Risk: 1 in 100 ARI
Date: 12 May 2018

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Notes

DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has been mapped at 1.0m higher and depicted by way of dotted blue line.. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Hallett Beach 3:3

Sea-flood 2.90m AHD

Event: Scenario: 2050
Risk: 1 in 100 ARI
Date: 12 May 2018

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Notes

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Map

Hallett Beach 3:3

Sea-flood 3.60m AHD

Event: Scenario: 2100
Risk: 1 in 100 ARI
Date: 12 May 2018

Integrated Coasts
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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run-up has been mapped at 0.7m higher and depicted by way of dotted blue line.. Sea level rise of 0.0 has been added.

Map

Hallett Beach 3:3

High tide 1.6m AHD

Event: Scenario: current
Risk: Escarpment erosion
Date: 12 May 2018

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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run-up has been mapped at 0.7m higher and depicted by way of dotted blue line. Sea level rise of 0.3 has been added.

Map

Hallett Beach 3:3

High tide 1.9m AHD

Event: Scenario: 2050
Risk: Escarpment erosion
Date: 12 May 2018

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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been drawn at 0.7m higher and depicted by way of a dotted blue line. Sea level rise of 1.0 has been added.

Map

Hallett Beach 3:3

High tide 2.6m AHD

Event:	Scenario: 2100
Risk:	Escarpment erosion
Date:	12 May 2018

Integrated Coasts
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Notes

To analyse the rate of shoreline recession over the last seventy years, comparative analysis was conducted using georeferenced aerial photographs from 1949, 2002, and 2017. This analysis provides a long-term review (70 years), and a shorter term review (15 years). The longer term review is dependent on black and white photographs that are often difficult to decipher.

Map

Hallett Beach 3:3

Erosion assessment

Event: 2017
Risk: Shoreline recession
Date: 12 May 2018

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

Notes

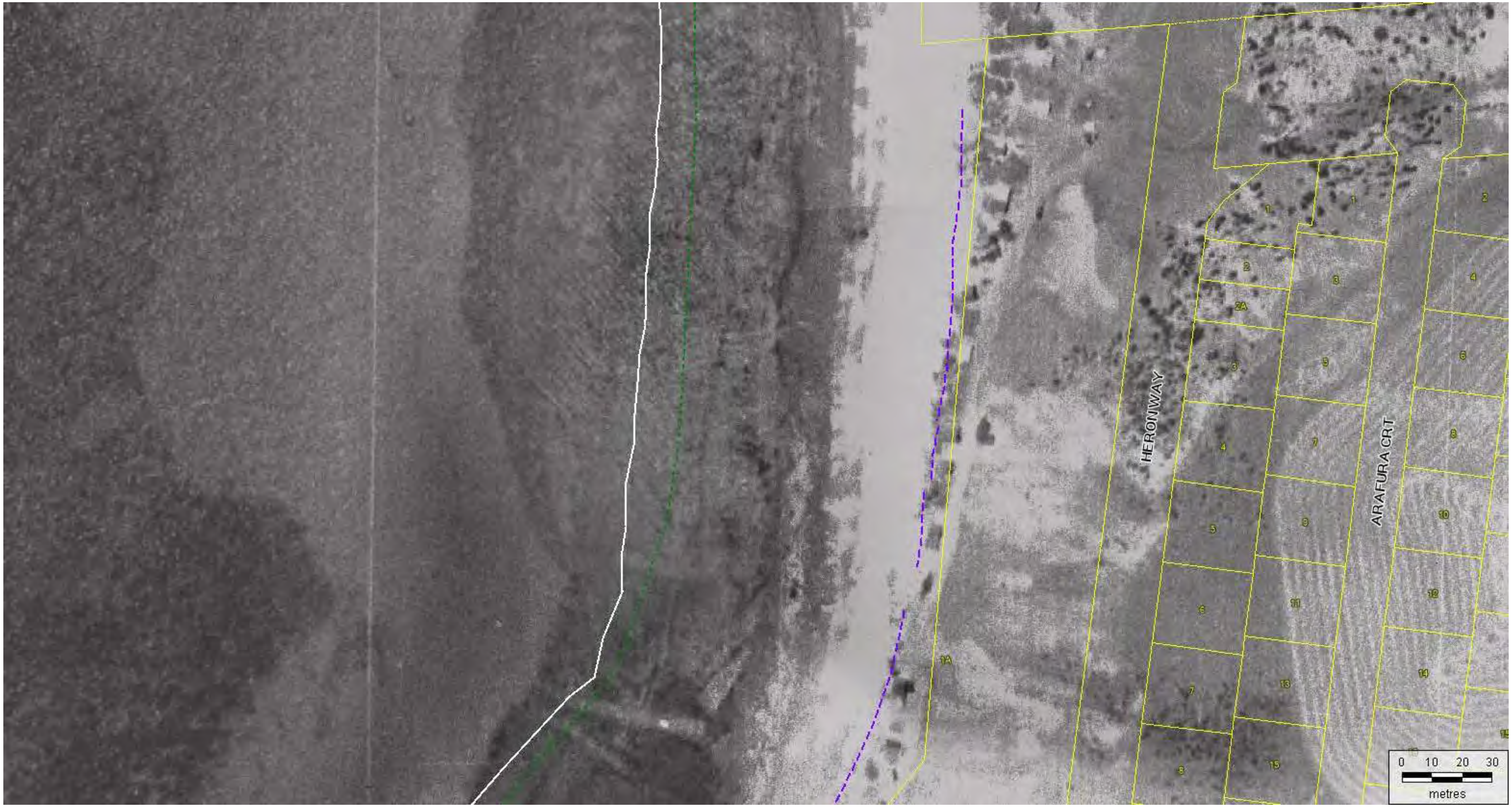
The base of the escarpment appears to be in the same location as 2017.

Map

Hallett Beach 3:3

Erosion assessment

Event: 2002
Risk: Shoreline recession
Date: 12 May 2018



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Notes

Using the photograph of 1949 it is not possible to determine where the base and top of the escarpment is positioned. Sand volumes are not as variant between the two eras as in the north of Hallett Cove Beach.

Map

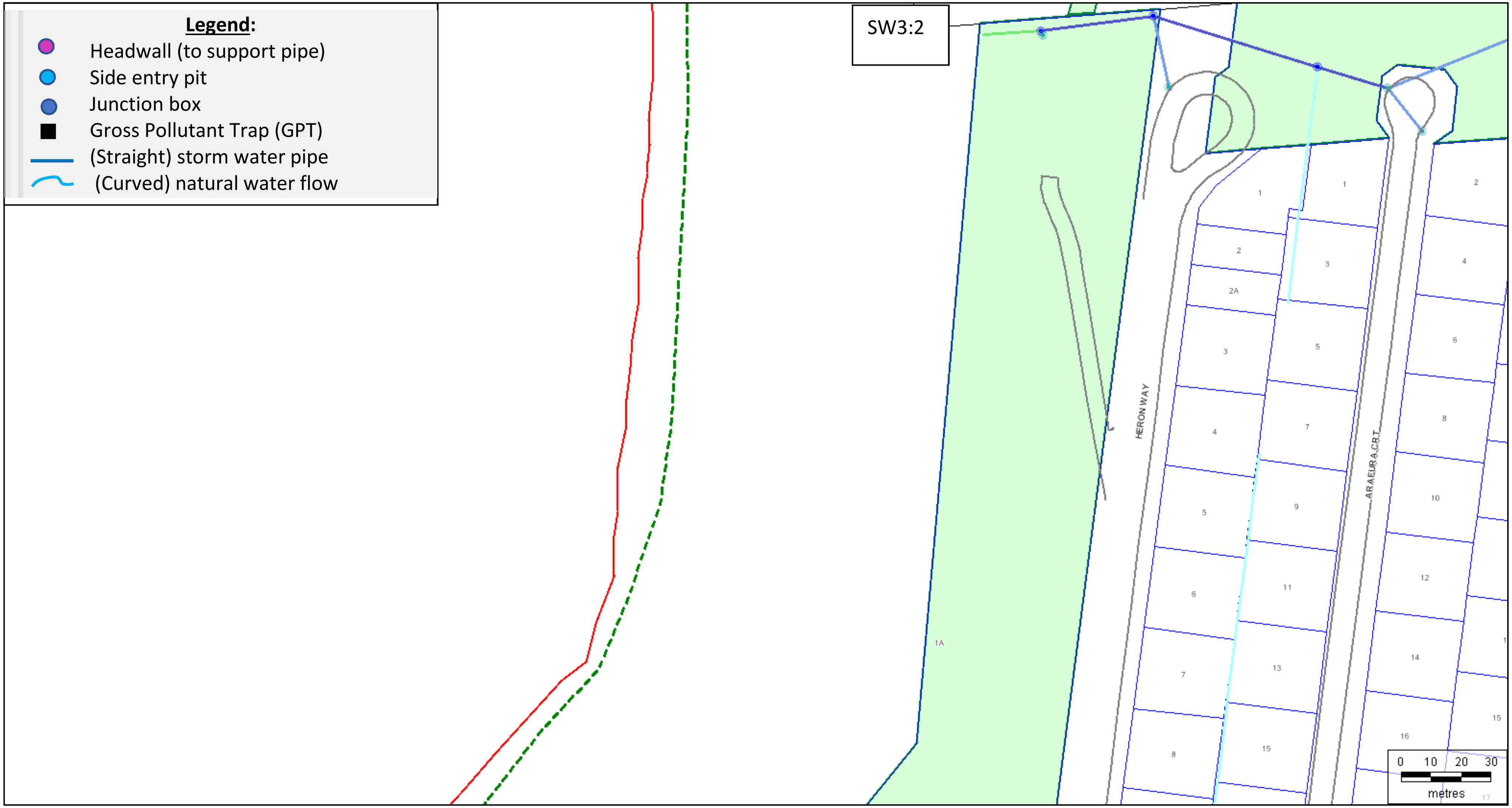
Hallett Beach 3:3

Erosion assessment

Event: 1949

Risk: Shoreline recession

Date: 12 May 2018



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Notes

SW3.2 See Hallett Beach 2 – storm water now flows south along Heron Way (not as depicted)

Map

Hallett Beach 3:3

Stormwater assessment

Event: Ongoing
Risk: Cliff erosion
Date: 12 May 2018

Cell 3: Hallett Beach (3:4)

The beach narrows to the south as the back-beach curves further seaward. The slope of the embankment is steeper (1.5H: 1V) Part of this section has been reinforced with rock armour. (HCCMS, p. 40).

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Notes

On 9th May 2016 the highest level of water was recorded at Outer Harbor in 80 years at 3.80 CD (2.36 AHD). To calculate the storm surge height at Hallett Cove: secondary port relationship methodology was used with Port Stanvac (calculated at 90%) and wave height of 0.30m added in accordance with storm surge allowance allocated by Coast Protection Board for the Kingston Park Region. The height of this flood map is depicted at 2.43 (AHD). Wave run up has been included at 1.0m. Historical photographs at The Esplanade, Marino and Field River, Hallett Cove tend to support an inundation of this height.

Map

Hallett Beach 3:4

Sea-flood 2.43m AHD

Event: 9 May 2016

Risk: Historical benchmark

Date: 12 May 2018

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Map

Hallett Beach 3:4

Sea-flood 2.60m AHD

Event: Scenario: current
Risk: 1 in 100 ARI
Date: 12 May 2018

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Notes

DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has not been mapped but the need to consider this factor is indicated schematically by way of dotted blue line. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Hallett Beach 3:4

Sea-flood 2.90m AHD

Event: Scenario: 2050
Risk: 1 in 100 ARI
Date: 12 May 2018

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Notes

DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has not been mapped but the need to consider this factor is indicated schematically by way of dotted blue line. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Hallett Beach 3:4

Sea-flood 3.60 AHD

Event: Scenario: 2100
Risk: 1 in 100 ARI
Date: 12 May 2018

Integrated Coasts
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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been drawn at 0.7m higher and depicted by way of a dotted blue line.. Sea level rise of 0.0 has been added.

Map

Hallett Beach 3:4

High tide 1.6m AHD

Event: Scenario: current
Risk: Escarpment erosion
Date: 12 May 2018

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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been drawn at 0.7m higher and depicted by way of a dotted blue line.. Sea level rise of 0.3 has been added.

Map

Hallett Beach 3:4

High tide 1.90m AHD

Event: Scenario: 2050
Risk: Escarpment erosion
Date: 12 May 2018

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Map

Hallett Beach3:4

High tide 2.6m AHD

Event: Scenario: 2100
Risk: Escarpment erosion
Date: 12 May 2018

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Notes

To analyse the rate of shoreline recession over the last seventy years, comparative analysis was conducted using georeferenced aerial photographs from 1949, 2002, and 2017. This analysis provides a long-term review (70 years), and a shorter term review (15 years). The longer term review is dependent on black and white photographs that are often difficult to decipher.

Map

Hallett Beach 3:4

Erosion assessment

Event: 2017
Risk: Shoreline recession
Date: 12 May 2018

Integrated Coasts
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1300 767 333 (free call)

Notes

Some minor recession of the toe of the escarpment is visible (compared to 2017 photograph) (1m to 2m)

Map

Hallett Beach 3:4

Erosion assessment

Event: 2002

Risk: Shoreline recession

Date: 12 May 2018

Integrated Coasts
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1300 767 333 (free call)

Notes

Since 1949, fill has been imported to form the present headland. The photographs from 1949 (including oblique aerial photographs) suggest that a more natural dune was located in this region.

Map

Hallett Beach 3:4

Erosion assessment

Event: 1949
Risk: Shoreline recession
Date: 12 May 2018

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Notes

Since 1949, fill has been imported to form the present headland. The photographs from 1949 (including oblique aerial photographs) suggest that a more natural dune was located in this region.

Map

Hallett Beach 3:4

Erosion assessment

Event: 1949

Risk: Shoreline recession

Date: 12 May 2018

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Notes

SW3:3 GPT installed at ‘pink dot’. Headwall to ocean outfall. Some evidence of erosion on beach (rocks installed to limit erosion)
SW3.4 Southpoint (2012) recommended GPT to be installed. CoM not yet installed (unsure of priority) (MW…can’t locate outfall…in rock area?)

Map

Hallett Beach 3:4
Stormwater assessment
Event: Ongoing
Risk: Cliff erosion
Date: 12 May 2018

Cell 3: Hallett Beach (3:3,4)

Risk assessment: Hallett Beach (3:3,4)

General erosion assessment

Risk identification: Erosion is currently, or may in the future, undermine the integrity of the Heron Reserve

Coastal processes	Storm surge and wave action hits this part of the shoreline obliquely. HCCMS assesses the slope of the embankment at 1V to 3H at boatshed end, and 1V to 1.5H at southern end. At the base of the sloping embankment, erosion has left a vertical and unstable slope along sections of the beachfront. Storm event of 9th May, 2016, eroded the embankment in three places (see ps 67.68.69) which have been remediated with soil and compacted.

Are any strategies employed to mitigate the risk? Rock armour is situated adjacent the access ramp to the beach.

Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Consists of – Embankment (with rock armour in places) behind which are situated Boatshed Café and carpark, Heron Reserve, s/w infrastructure, walking path, playground and shelter (s).	current	*Rare*	*Moderate*	low
		2100	*Possible*	*Major*	high
Private assets	All houses sit back behind Heron Way and are not likely to be subject to any risk within this century	current	*Rare*	*Moderate*	low
		2100	*Unlikely*	*Major*	medium
Safety of people	People recreate in the region on Heron Reserve and the beach. Coastal processes are unlikely to present any risk to safety of people (above normal activities)	current	*Rare*	*Insignificant*	low
		2100	*Rare*	*Insignificant*	low
Environment	Inter-tidal zone is shingle/ sand beach (underlain by clay), and backed by sloping earthen embankment, rock armoured in places. Intertidal reef and subtidal is at threat.	current	*Unlikely*	*Minor*	low
		2100	*Possible*	*Moderate*	medium

Inherent Hazard Rating

Soft rock sloping shores (SR-10)

	Low	Moderate	High	Very high
Ecosystem disruption	X	2	3	4
Gradual inundation	X	2	3	4
Salt water intrusion	X	2	3	4
Erosion	1	X	3	4
Flooding	X	2	3	4

Erosion Hazard Rating (current outlook)

	Low	Medium	High	Extreme
Public Infrastructure			X	
Private Assets	No risk			
Public safety	X			
Environment	X			

Erosion Hazard Rating (future outlook)

	Low	Medium	High	Extreme
Public Infrastructure				X
Private Assets	No risk			
Public safety	X			
Environment		X		

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	Scenario modelling suggests that the clay embankment will come under increasing pressure from wave action and as the century progresses, routine tidal action.

Hallett Beach (3:3,4)
Summary and recommended actions (draft)

Geological review: This section of beach is underlain by glacial clay and till deposits which extend from the back of the beach offshore to below the low tide limit. The beach is backed by steeped sloped sediment escarpment. It is likely that clay fill has been imported to create a 'headland' in the south (rather than dune).

Historical recession: Minor recession of the toe of the escarpment is observed on the southern end of the beach when comparing 2002 photograph with 2017. It isn't possible to identify movement in relation to photograph from 1949 except to note that the location was a more natural dune system in the south.

Exposure	Routine tidal impact (bi-monthly)	Storm surge impact (1 in 100 ARI)
Historical event - 2016	NA	Wave run-up from this event is likely just to interacted with the base of the dunes (especially in the north of the beach).
Current	The dunes on Hallett Cove Beach are not likely to be under impact from routine tidal action.	The wave run up of storm surge and wave height of 2.60m will interact with the base of the dunes (with wave run up only).
2050	The dunes on Hallett Cove Beach are not likely to come under significant impact from routine tidal action.	The wave run up of storm surge and wave height of 2.90m will interact significantly with the base of the cliff (with wave run-up)
2100	Significant routine wave and wave run-up action will impact the dunes causing them to recede.	The base of the dunes will come under high impact with direct wave attack from storm surge of 3.60m

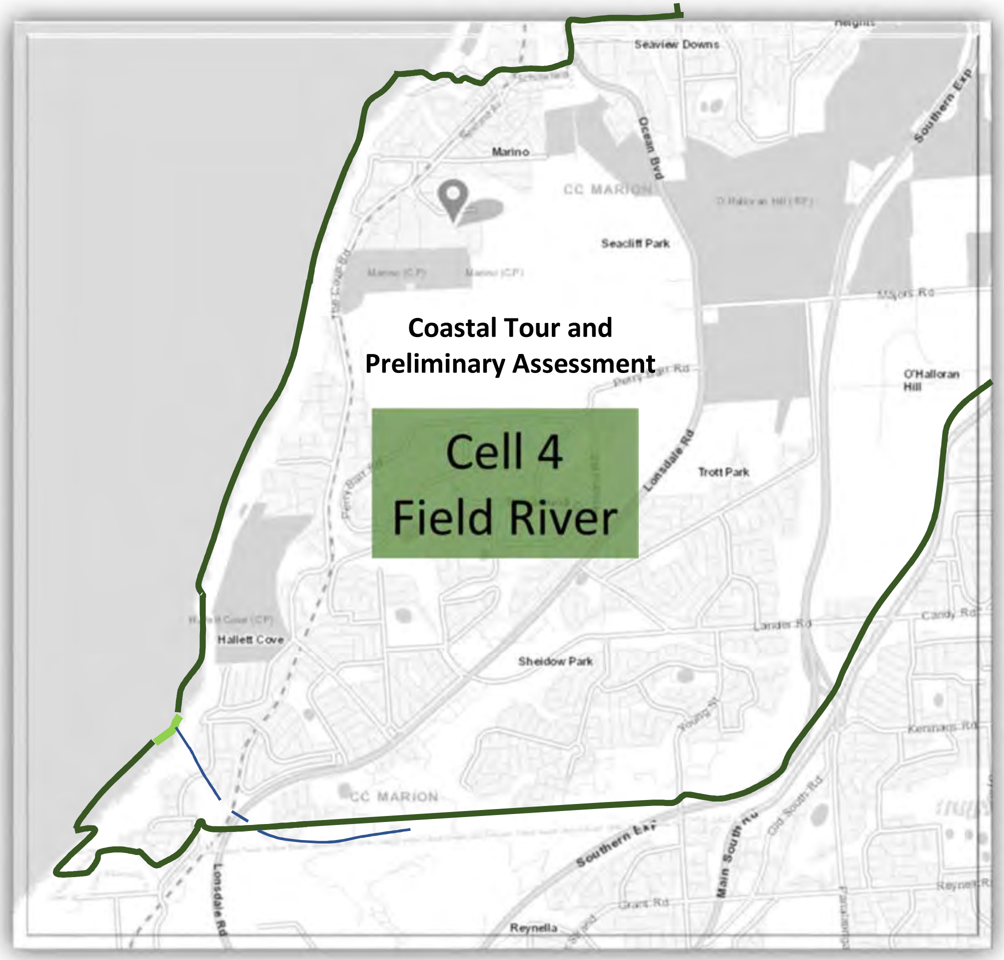
Storm water: Storm water from urban environments does not flow over the escarpment/ beach area.

Risk Assessment: There are no private assets. Public assets (the public park) is at increasing risk as the slope of the escarpment increases. Existing protection works can be expected to fail (see also Hallett Cove Coastal Management Study).

Recommended actions (draft):

Number	Action	Comments	Time frame
3:2 (1)	Solutions are required for to cater for the steep and unstable slope that is expected to come under increasing pressure from current and future storm events.	CoM is currently reviewing Hallett Cove Beach foreshore in preparation for a master plan for this region. It is recommended that CoM considers the flood modelling over the century so as to ensure that designs cope with projected sea level rises.	1-2 years
3:1 (2)	Quantify more accurately the nature of routine and storm surge interaction with escarpment	Monitor tidal regime for period of three months (winter). Monitor the impact of storm surge events (if, and when they occur)	1-2 years
3:1 (3)	Recapture digital model as basis for comparison	Use appropriate software to quantify changes in the coastal environment.	3-5 years

Cell 4: Field River (4:1)




River Parade
Field River

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

Notes

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Map

Field River 4:1

Historical Event

Event: 9th May 2016: 2.43 AHD
Risk: Historical benchmark
Date: 12 May 2018

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

Photographs taken by Damian Landrigan at observed height of the storm, approximately between17:50 and 18:15 (although colour in sky suggests it may have been slightly earlier). (Photographs used with permission). The pattern in the photograph above is effectively reproduced with a storm surge and wave height of 2.43m AHD, with wave run-up elevating the storm tide further up the beach.

Map

Field River 4:1

Historical Event

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Date: 12 May 2018

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Map

Field River 4:1

Historical Event

Event: 9th May 2016: 2.43 AHD
Risk: Historical benchmark
Date: 12 May 2018

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Map

Field River 4:2

Historical Event

Event: 9th May 2016: 2.43 AHD
Risk: Historical benchmark
Date: 12 May 2018

Integrated Coasts
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www.integratedcoasts.com
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Notes

Photographs taken by Damian Landrigan at observed height of the storm, approximately between17:50 and 18:15 (although colour in sky suggests it may have been slightly earlier). (Photographs used with permission). Sea-water flowed into Field River (this height could be estimated from the survey data but not from the digital model. Photogrammetry does not handle vegetation well)

Map

Field River 4:2

Historical Event

Event: 9th May 2016: 2.43 AHD
Risk: Historical benchmark
Date: 12 May 2018

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Notes

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Map

Field River 4:1

Historical storm event

Event: 9th May 2016: 2.43 AHD
Risk: Historical benchmark
Date: 12 May 2018

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Notes

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Map

Field River 4:1

Sea-flood 2.60m AHD

Event: Scenario: current
Risk: 1 in 100 ARI
Date: 12 May 2018

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Map

Field River 4:1

Sea-flood 2.9m AHD

Event: Scenario 2050
Risk: 1 in 100 ARI
Date: 12 May 2018

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

Notes

DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has not been mapped but the need to consider this factor is indicated schematically by way of dotted blue line. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Field River 4:1

Sea-flood 3.6m AHD

Event: Scenario 2100
Risk: 1 in 100 ARI
Date: 12 May 2018

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

Notes

To analyse the rate of shoreline recession over the last seventy years, comparative analysis was conducted using georeferenced aerial photographs from 1949, 2002, and 2017. This analysis provides a long-term review (70 years), and a shorter term review (15 years). The longer term review is dependent on black and white photographs that are often difficult to decipher.

Map

Field River 4:1

Erosion assessment

Event: Oct 2017
Risk: Shoreline recession
Date: 12 May 2018

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1300 767 333 (free call)

Notes

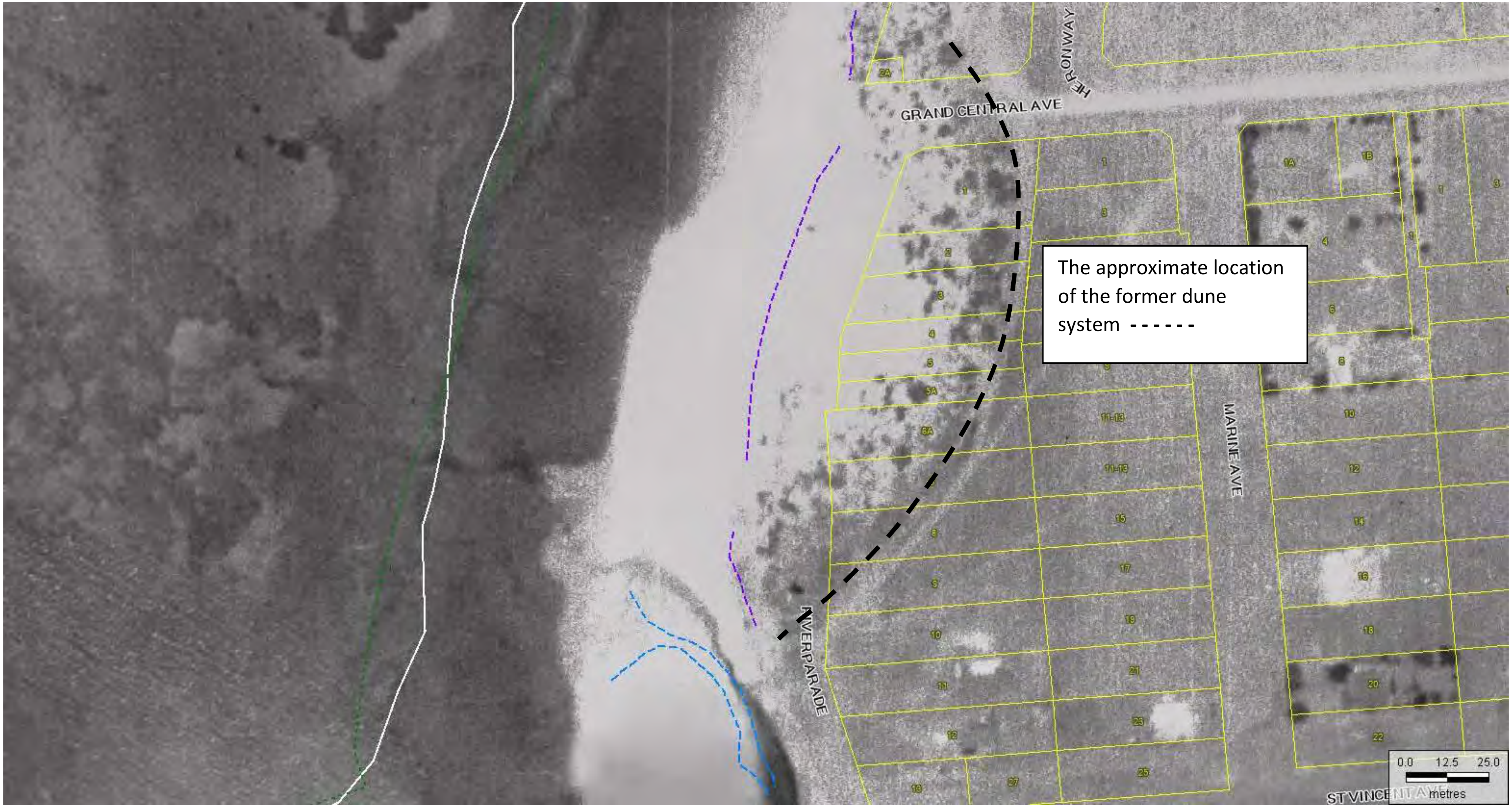
Shoreline is similar to 2017. The dune fencing is maintaining the line of dunes in a similar position. The volume of sand is slightly larger in 2002 than in 2017.

Map

Field River 4:1

Erosion assessment

Event: Oct 2002
Risk: Shoreline recession
Date: 12 May 2018



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Notes

The shoreline is substantially different to later photographs 2002, 2017. About seven allotments appear to have been placed into what was in 1949 part of the dune system. The flow of the river appears to be further north than its current path. There is substantially more sand within the dune system (see photographs on next page for oblique comparison).

Map

Field River 4:1

Erosion assessment

Event: Oct 1949

Risk: Shoreline recession

Date: 12 May 2018

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Notes

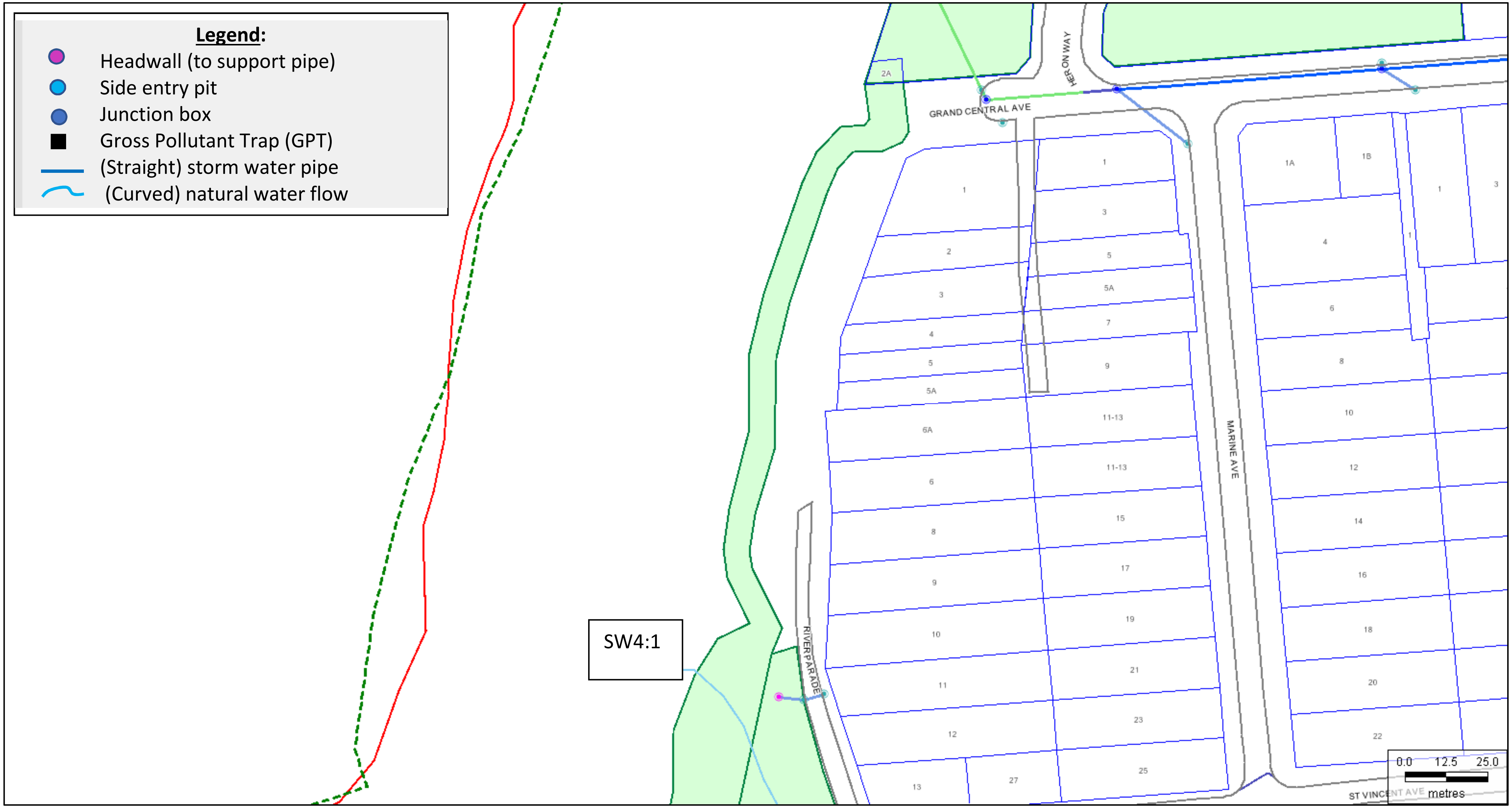
Aerial photographs demonstrate that the area of River Parade was formerly a dune system that would have interacted naturally with the ocean environment (allowing for natural accretion and recession). The introduction of the rigidity of urban settlements has stopped the ability of this section of coast to react to normal processes of the ocean.

Map

Field River 4:1

Erosion assessment

Event: Ongoing
Risk: Cliff erosion
Date: 12 May 2018



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Notes

SW4.1 River parade...drains into Field River...PINK DOT HEAD WALL.. ..NO GPT (SMALL CATCHMENT?)...

Map

Field River 4:1

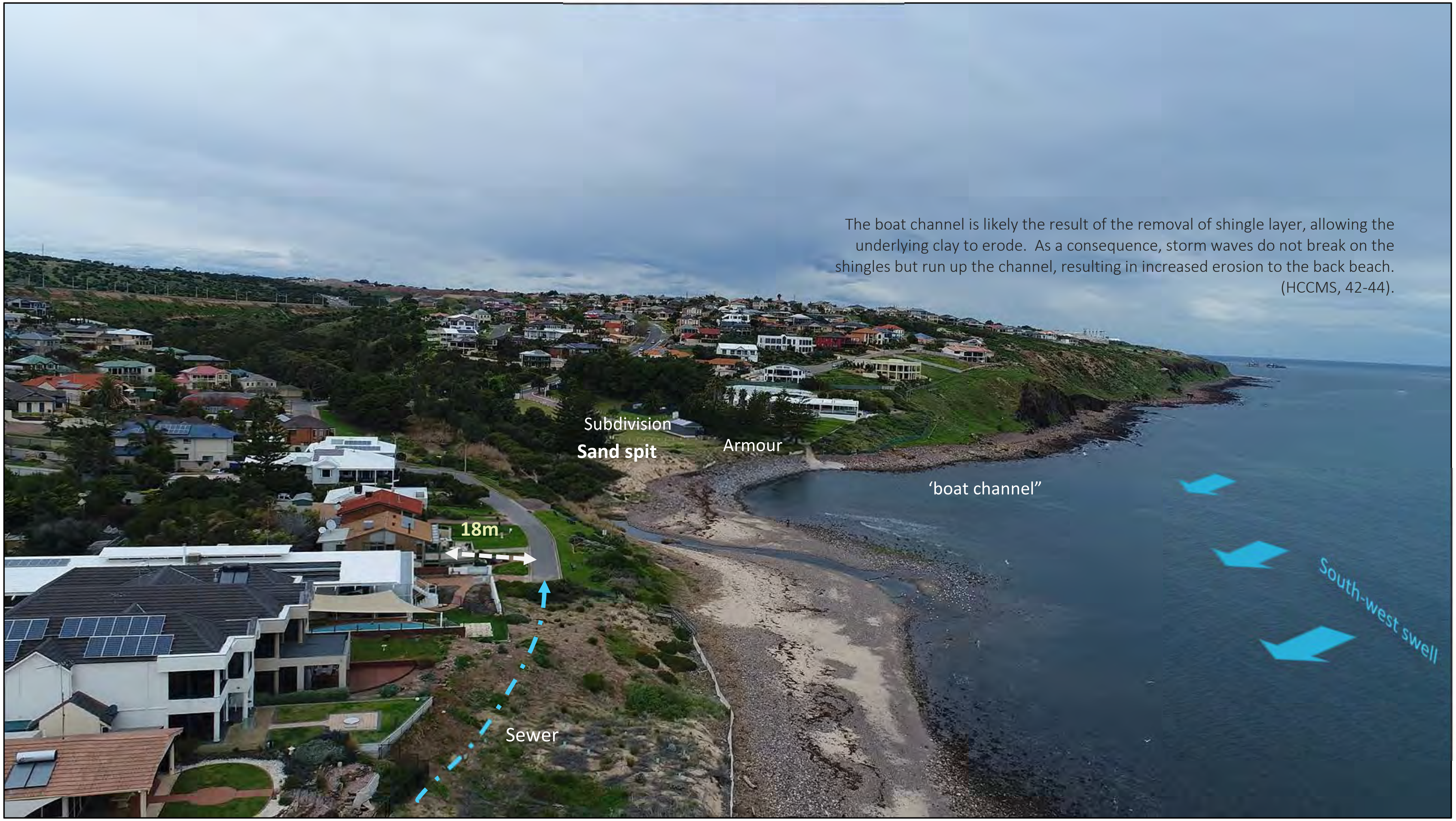
Stormwater assessment

Event: Ongoing
Risk: Cliff erosion
Date: 12 May 2018

Cell 4: Field River (4:2)

There are twelve beachfront properties, six of which have frontage to the low dunes, and six which have frontage to River Parade. HCCMS (p.42) states that sewer infrastructure is located on the seaward side of the properties. Allowing for 25m of recession by 2100, HCCMS states that these properties and associated infrastructure would be vulnerable to coastal processes.

Cell 4: Field River (4:2)



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Notes

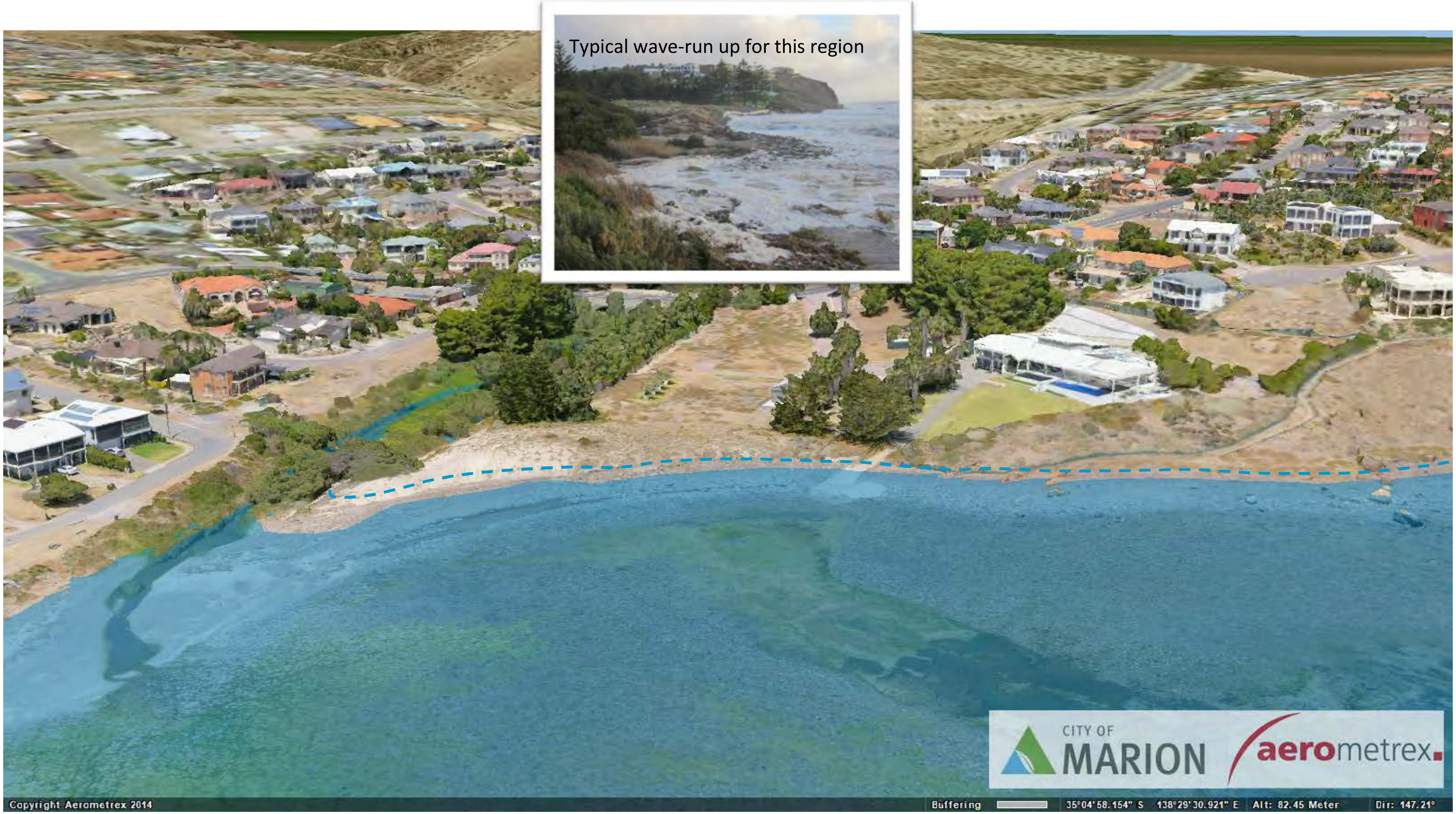
On 9th May 2016 the highest level of water was recorded at Outer Harbor in 80 years at 3.80 CD (2.36 AHD). To calculate the storm surge height at Hallett Cove: secondary port relationship methodology was used with Port Stanvac (calculated at 90%) and wave height of 0.30m added in accordance with storm surge allowance allocated by Coast Protection Board for the Kingston Park Region. The height of this flood map is depicted at 2.43 (AHD). Wave run up is drawn at 1.0m higher and depicted by dotted line.

Map

Field River 4:2

Sea-flood 2.43m AHD

Event: 9 May 2016
Risk: 1 in 100 ARI
Date: 12 May 2018



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Notes

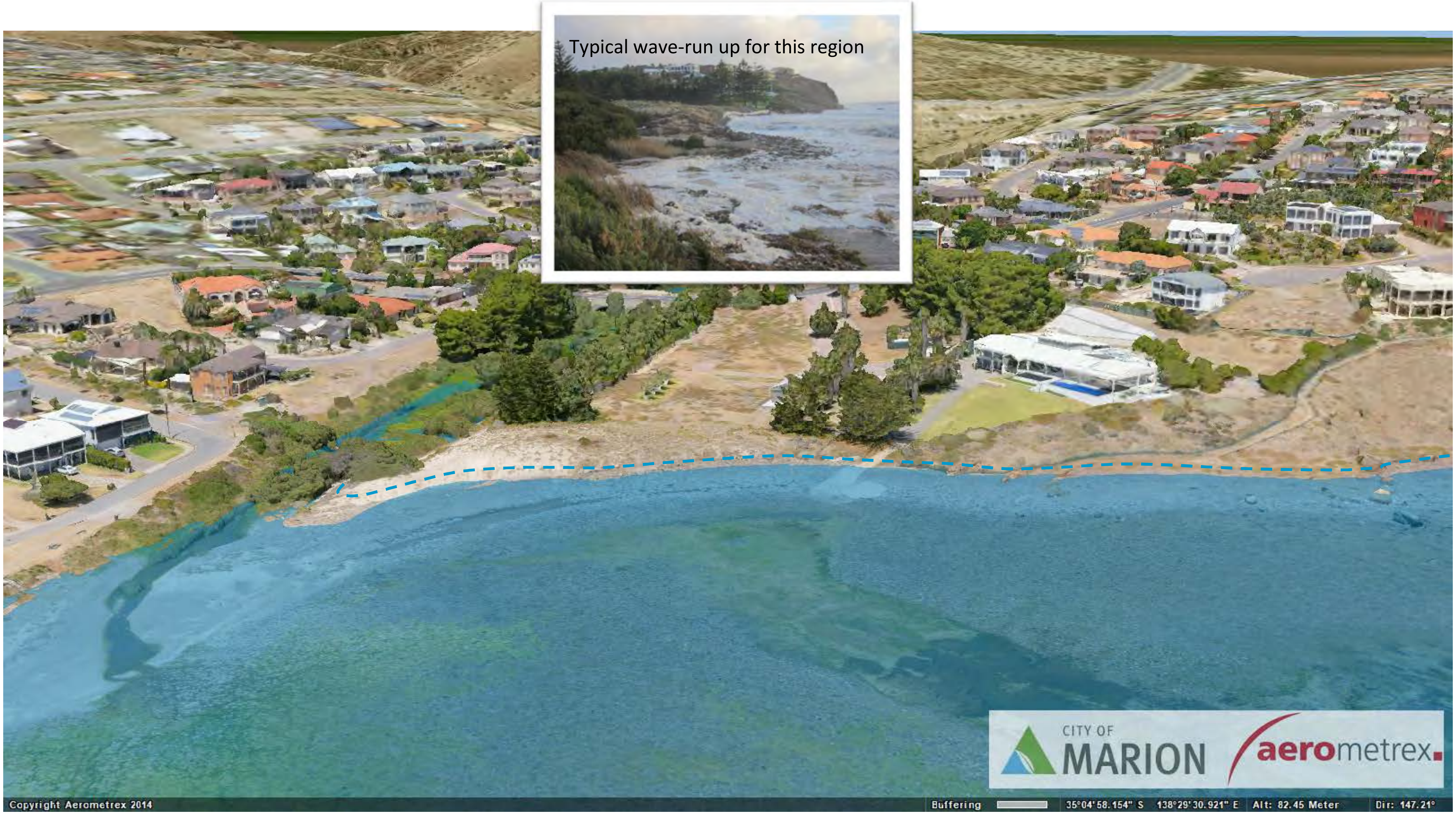
DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has been mapped at 1.0m higher depicted by way of dotted blue line. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Field River 4:2

Sea-flood 2.6m AHD

Event: Scenario: current
Risk: 1 in 100 ARI
Date: 12 May 2018



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Map

Field River 4:2

Sea-flood 2.9m AHD

Event: Scenario 2050
Risk: 1 in 100 ARI
Date: 12 May 2018

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Notes

DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has been mapped at 1.0m higher depicted by way of dotted blue line.. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

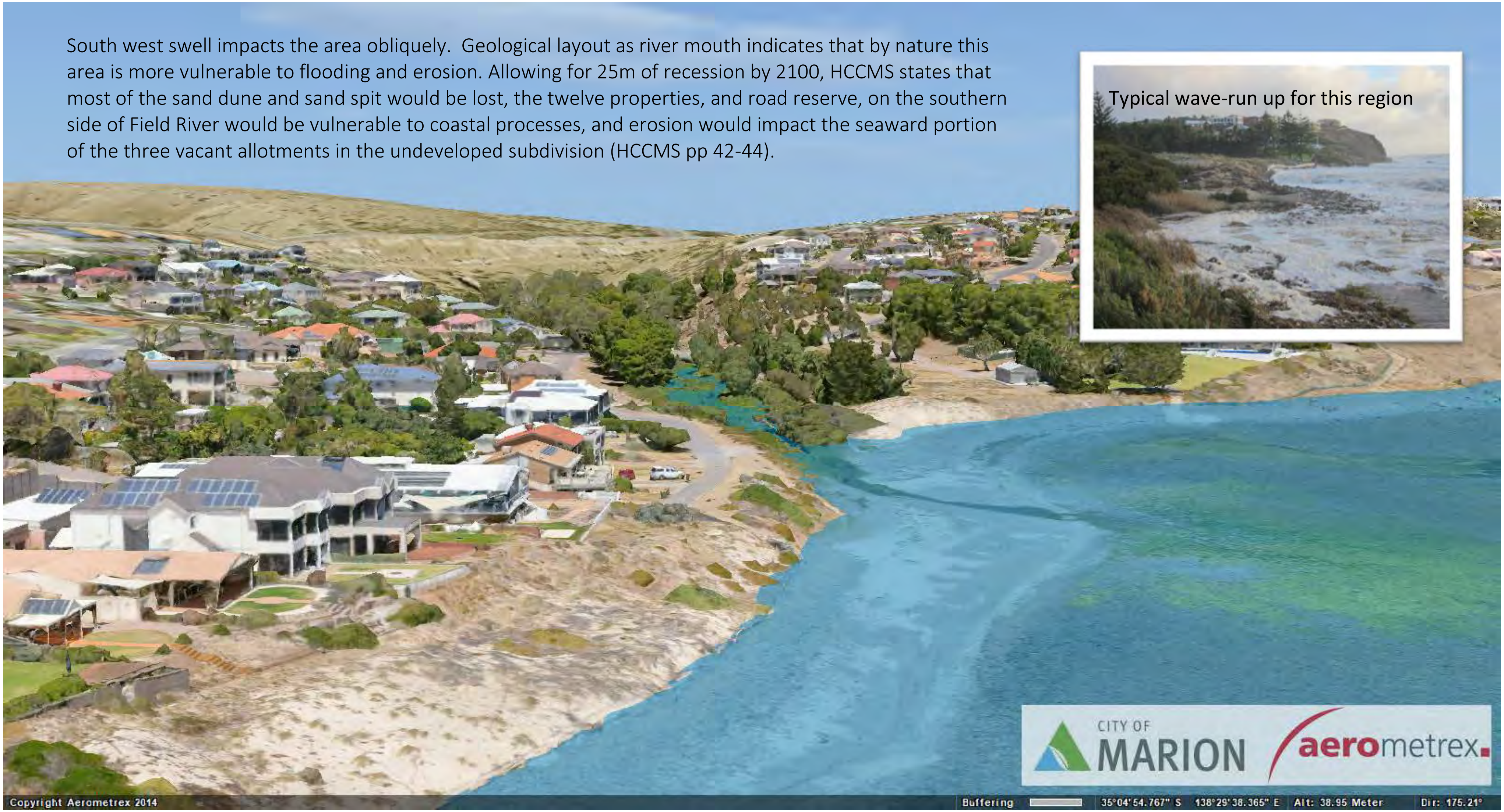
Map

Field River 4:2

Sea-flood 3.6m AHD

Event: Scenario 2100
Risk: 1 in 100 ARI
Date: 12 May 2018

South west swell impacts the area obliquely. Geological layout as river mouth indicates that by nature this area is more vulnerable to flooding and erosion. Allowing for 25m of recession by 2100, HCCMS states that most of the sand dune and sand spit would be lost, the twelve properties, and road reserve, on the southern side of Field River would be vulnerable to coastal processes, and erosion would impact the seaward portion of the three vacant allotments in the undeveloped subdivision (HCCMS pp 42-44).



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Notes

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Map

Field River 4:2

Sea-flood 3.6m AHD

Event: Scenario 2100
Risk: 1 in 100 ARI
Date: 12 May 2018

Typical wave-run up for this region

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Notes

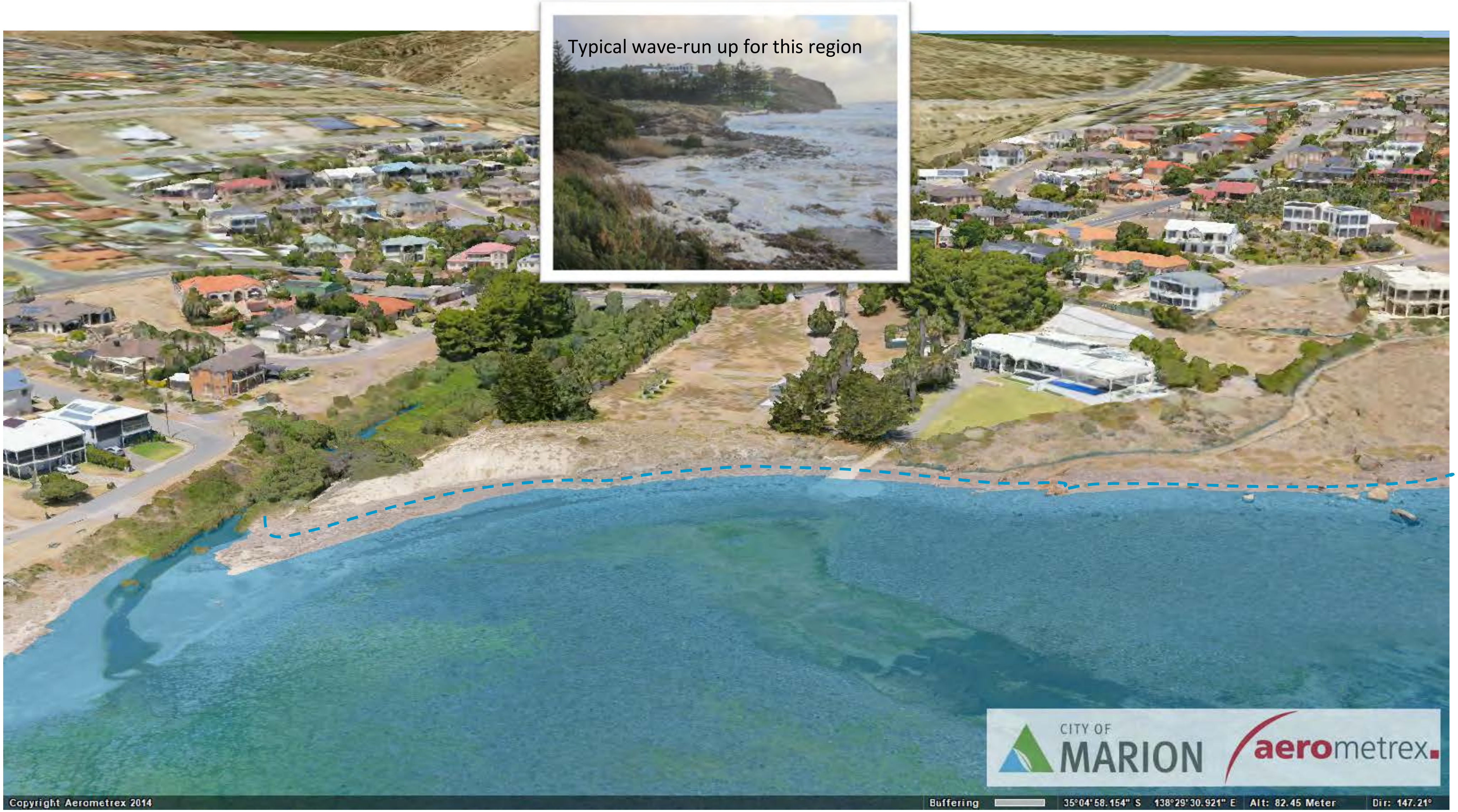
This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been drawn at 0.7m higher as depicted by the dotted blue line. Sea level rise of 0.0 has been added.

Map

Field River 4:2

High Tide 1.60m AHD

Event:	Scenario: current
Risk:	Escarpment Erosion
Date:	12 May 2018



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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been drawsn at 0.7m higher and depicted by way of a dotted blue line. Sea level rise of 0.3 has been added.

Map

Field River 4:2

High Tide 1.9m AHD

Event: Scenario 2050
Risk: Escarpment erosion
Date: 12 May 2018

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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been drawn 0.7m higher and depicted by way of a dotted blue line. Sea level rise of 1.0 has been added.

Map

Field River4:2

High tide 2.6m AHD

Event: Scenario 2100
Risk: Escarpment erosion
Date: 12 May 2018

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Notes

To analyse the rate of shoreline recession over the last seventy years, comparative analysis was conducted using georeferenced aerial photographs from 1949, 2002, and 2017. This analysis provides a long-term review (70 years), and a shorter-term review (15 years). The longer-term review is dependent on black and white photographs that are often difficult to decipher.

Map

Field River 4:2

Erosion assessment

Event: Oct 2017
Risk: Shoreline recession
Date: 12 May 2018

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www.integratedcoasts.com
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Notes

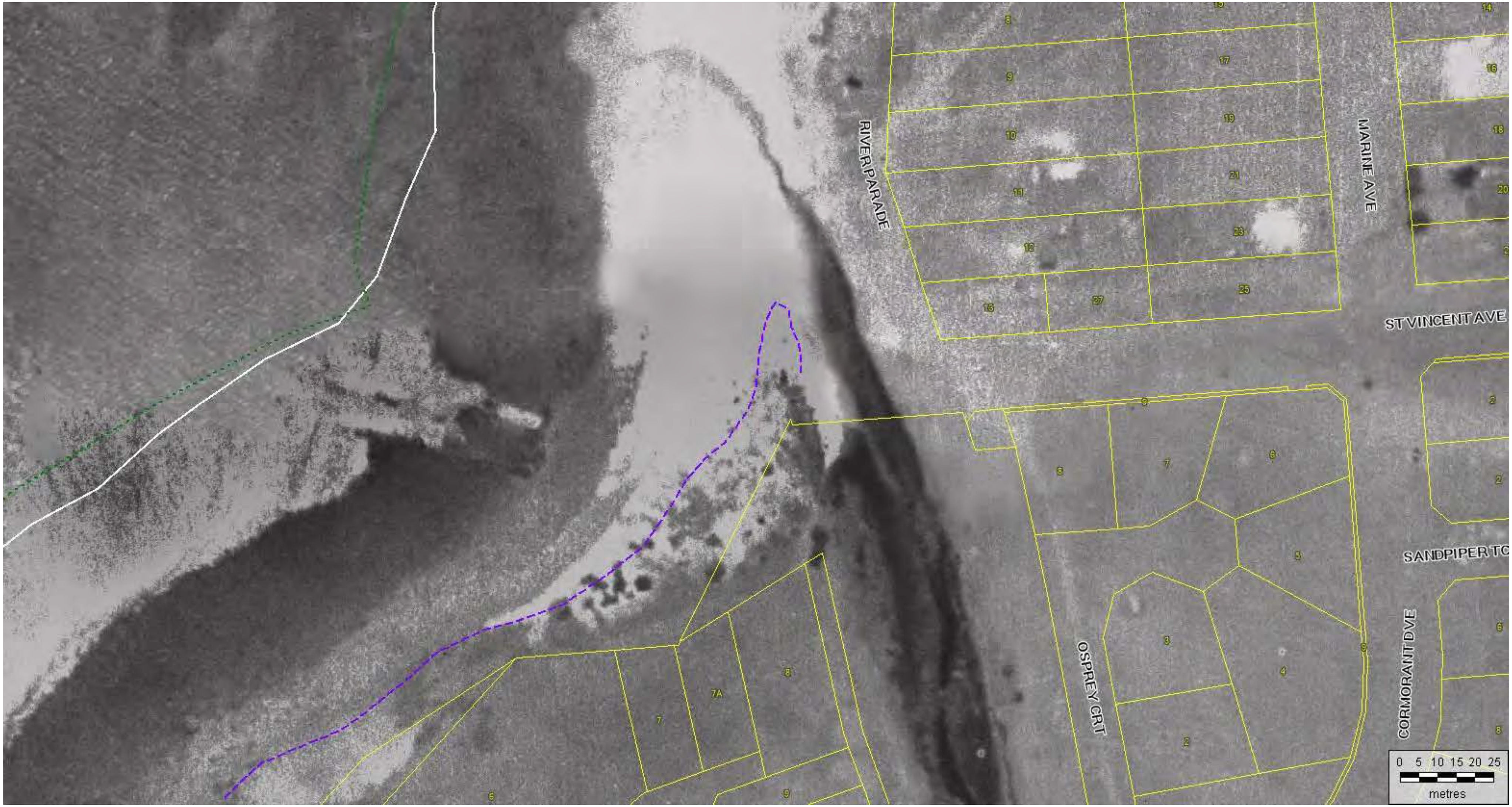
Noticeable recession to the sand dune over fifteen years.

Map

Field River 4:2

Erosion assessment

Event: 2002
Risk: Shoreline recession
Date: 12 May 2018



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Notes

Large recession to the foreshore and sand dune over 70 years.. See also oblique photographs above.

Map

Field River 4:2

Erosion assessment

Event: 1949

Risk: Shoreline recession

Date: 12 May 2018

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www.integratedcoasts.com
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Notes

SW4.1 Small catchment area drains to Field River via stormwater pipe with headwall. (Can't locate headwall)

Map

Field River 4:2

Stormwater assessment

Event: Ongoing
Risk: Cliff erosion
Date: 12 May 2018

Risk assessment: Field River 4:1,2

General erosion assessment

Risk identification: Erosion is currently, or may in the future, threaten the dunes and infrastructure behind the dunes.

Coastal processes	Storm surge and wave action hits this part of the shoreline obliquely. The removal of shingles to form boat channel has exacerbated the erosion of shoreline and dune spit. The underlying geological classification is River Mouth (TSR). How peak river flows relate to sea storm surges is unknown. Storm event of 9th May, 2016, would provide insight into the nature of coastal processes in a storm surge event and provide a context from which to assess the impacts of future sea level rise.

Are any strategies employed to mitigate the risk? Dune fencing to dunes and sand spit, minor rock armour to southern side of sand spit.

Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	River Parade and associated infrastructure (sewer, furniture, signs)	current	*Possible*	*Minor*	medium
		2100	*Likely*	*Major*	high
Private assets	Six houses with dune frontage, six houses situated behind River Road (protected as long as Council defends the road), allotments behind the sand spit (undeveloped).	current	*Unlikely*	*Minor*	medium
		2100	*Likely*	*Major*	high
Safety of people	The beach in this location is not used to a great extent by the public. There is no walking trail to connect north and south of Field River.	current	*Rare*	*Insignificant*	low
		2100	*Rare*	*Insignificant*	low
Environment	Inter-tidal zone is shingle/ sand beach (underlain by clay), and backed by low dunes. Should seas rise as projected, the estuary system could come under threat. Intertidal and subtidal environments are also under threat.	current	*Rare*	*Moderate*	low
		2100	*Possible*	*Moderate*	medium

Inherent Hazard Rating

River mouth, sand spit (TSR)

	Low	Moderate	High	Very high
Ecosystem disruption	1	X	3	4
Gradual inundation	1	X	3	4
Salt water intrusion	1	2	X	4
Erosion	1	2	3	X
Flooding	1	X	3	4

Erosion Hazard Rating (current outlook)

	Low	Medium	High	Extreme
Public Infrastructure		X		
Private Assets		X		
Public safety	X			
Environment	X			

Erosion Hazard Rating (future outlook)

	Low	Medium	High	Extreme
Public Infrastructure			X	
Private Assets			X	
Public safety	X			
Environment		X		

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	Storm surge and associated wave action from the South-west are already impacting the dune system and sand spit. Historical comparison of photographs depicts significant recession of the dune to the south of Field River. Video of 9th May 2016 demonstrates the action of wave runup at the base of the dune. It is likely that the dune system on both sides of Field River will be eroded should sea levels rise as projected.

Risk assessment: Field River 4:1,2

General inundation assessment

Risk identification: Inundation may in the future impact public and private assets

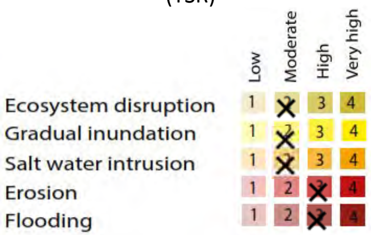
Coastal processes	The Field River is a small river set in a narrow gully with a high bank on the northern side, and roads and related infrastructure set well above the creek floor. The bank on the south side is lower, but is likely to still provide protection to the land adjacent. Coast Protection Board current sea-flood risk levels are set at 3.7m AHD (including wave set-up and wave run-up). Inundation modelling does not depict any flooding of River Parade.

Are any strategies employed to mitigate the risk? No

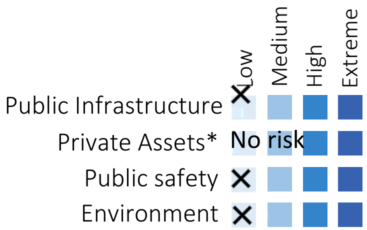
Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Inundation modelling demonstrates that River Parade is above storm surge levels. Some over topping due to wave run up is likely at 2100 SLR projections.	current	*Rare*	*Insignificant*	low
		2100	*Possible*	*Minor*	low
Private assets*	Six houses with dune frontage, six houses situated behind River Road are set above 2100 projected levels (however erosion is likely to be an issue which could lead to future inundation).	current	*Rare*	*No risk*	no risk
		2100	*Unlikely*	*Minor*	No risk
Safety of people	There is no walking trail to connect north and south of Field River. The assumption in this assessment is that people remain on designated paths.	current	*Rare*	*Minor*	low
		2100	*Rare*	*Minor*	low
Environment	Inter-tidal zone is shingle/ sand beach (underlain by clay),and backed by low dunes. Storm surge height at 2100 is unlikely to penetrate the river system higher than the bridge. Intertidal and subtidal reef habitats would be at threat. This site is a Hooded Plover nesting site – inundation would prevent nesting in this location.	current	*Rare*	*Moderate*	low
		2100	*Possible*	*Moderate*	medium

Inherent Hazard Rating

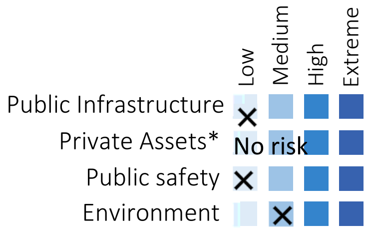
Sand spit, River mouth (TSR)



Inundation Hazard Rating
(current outlook)



Inundation Hazard Rating
(future outlook)



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

*CoM not necessarily liable for private assets

Summary	Scenario flood mapping demonstrates that River Parade, and the environs around Field River are not subject to any inundation in any scenario to 2100. It is likely that some wave run up will occur on to River Parade (see video from 9th May 2016). Houses set behind the dune are elevated at 8m AHD and higher.

Summary and recommended actions (draft)

Field River 4:1,2

Geological review: Not reviewed. The location is inter-tidal zone is shingle/ sand beach (underlain by clay), and backed by low dunes.

Historical recession: Photographic review indicates that 7-8 allotments in River Parade region have been positioned (or partially positioned) over a former dune system. Comparisons between 2002/2017 and 1949 demonstrate a substantial loss of sand volume and recession of the dune system on both sides of the river.

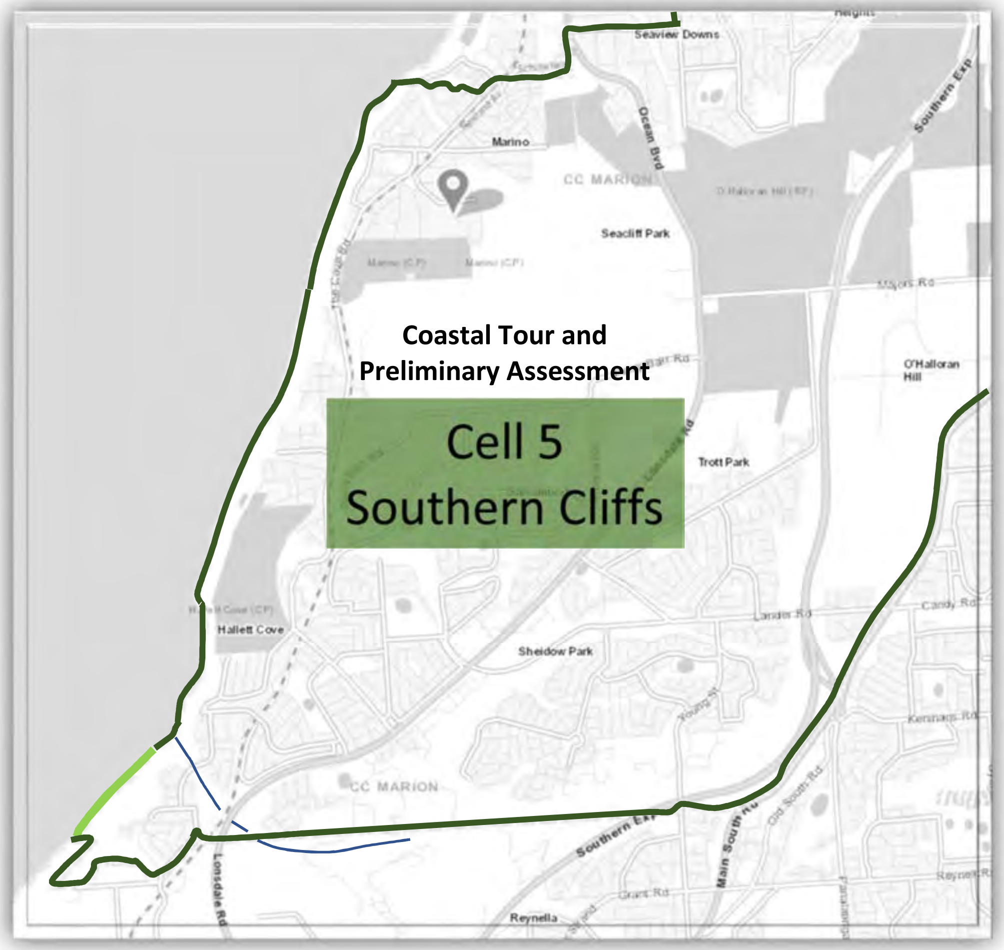
Exposure	Routine tidal impact (bi-monthly)	Storm surge impact (1 in 100 ARI)
Historical event - 2016	NA	Direct wave action impacted the dune to the south of Field River. Wave run up impacted the north side.
Current	Routine tidal action is having minimal impact on dune systems	Direct wave action impacted the dune to the south of Field River. Wave run up impacted the north side.
2050	Some routine tidal action will interelate with the dunes of the cliff (wave run up only)	Direct wave action will significantly impact the dune system (likely to erode substantially)
2100	Significant routine wave and wave run-up action will interelate with the dunes (likely to erode dunes away)	The dune systems will come under high impact direct wave attack from storm surge of 3.60m (erosion is likely to remove the dunes completely)

Storm water: Small catchment area empties into Field River in River Parade area (however, Field River is catchment for significant run off from urban environs)

Risk Assessment: The area is not likely to be subject to inundation (apart from overtopping due to wave-runup). The dune systems and banks protecting River Parade private and public infrastructure will come under increasing attack threatening both.

Recommended actions (draft):

Number	Action	Comments	Time frame
4:1 (1)	Review nature of storm water outflows and monitor impacts	Routine inspections are taken of the outfall areas. Recommend that staff incorporate review of scouring impacts (use photography)	1-2 years
4:1 (2)	Quantify more accurately the nature of routine and storm surge interaction with dune systems	Monitor tidal regime for period of three months (winter). Monitor the impact of storm surge events (if, and when they occur)	1-2 years
4:1 (3)	Recapture digital model as basis for comparison	Use appropriate software to quantify changes in the coastal environment.	3-5 years
4.1 (4)	Investigate options for protection for River Pde area and dune system to south.	There is unlikely to be a requirement to protect private property. The Council will have interest in protecting River Parade. Shared costs should be canvassed where private and public interests coincide	1-2 years


Coastal Tour and
Preliminary Assessment
Cell 5
Southern Cliffs
Seaview Downs
Marino
Ocean Bvd
CC MARION
Seacliff Park
Southern Exp
O'Halloran Hill
Trott Park
Hallett Cove
Sheidow Park
CC MARION
Lonsdale Rd
Southern Exp
Main South Rd
Reynella

Cell 5: Southern Cliffs (5:1)

One house is close to the top of the escarpment, but the slope of the embankment is quite low. By 2100, it is likely the base of the cliff will be inundated more frequently, allowing direct wave action against the base of the cliffs. Routine monitoring of the cliff condition and stability should be undertaken (particularly the discharge of stormwater) HCCMS, P. 45

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Notes

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Map

Southern Cliffs 5:1

Sea-flood 2.43m AHD

Event: 9 May 2016
Risk: Historical benchmark
Date: 12 May 2018

Typical wave-run up for this region

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Notes

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Map

Southern Cliffs 5:1

Sea-flood 2.60m AHD

Event:	Scenario: current
Risk:	1 in 100 ARI
Date:	12 May 2018

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Map

Southern Cliffs 5:1

Sea-flood 2.90m AHD

Event: Scenario: 2050
Risk: 1 in 100 ARI
Date: 12 May 2018

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Notes

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Map

Southern Cliffs 5:1

Sea-flood 3.60m AHD

Event: Scenario: 2100
Risk: 1 in 100 ARI
Date: 12 May 2018

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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been included at 0.7m with approximate location indicated by dotted line. Sea level rise of 0.0 has been added.

Map

Southern Cliffs 5:1

High tide 1.6m AHD

Event: Scenario: current
Risk: Escarpment erosion
Date: 12 May 2018

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1300 767 333 (free call)

Notes

While This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. . Wave run up has been included at 0.7m with approximate location indicated by dotted line. Sea level rise of 0.3 has been added.

Map

Southern Cliffs 5:1

High tide 1.90m AHD

Event: Scenario: 2050
Risk: Escarpment erosion
Date: 12 May 2018

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

Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. . Wave run up has been included at 0.7m with approximate location indicated by dotted line. Sea level rise of 1.0 has been added.

Map

Southern Cliffs 5:1

High tide 2.6m AHD

Event: Scenario: 2100
Risk: Escarpment erosion
Date: 12 May 2018

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

Notes

To analyse the rate of shoreline recession over the last seventy years, comparative analysis was conducted using georeferenced aerial photographs from 1949, 2002, and 2017. This analysis provides a long-term review (70 years), and a shorter-term review (15 years). The longer-term review is dependent on black and white photographs that are often difficult to decipher.

Map

Southern Cliffs 5:1

Erosion assessment

Event: Oct 2017
Risk: Shoreline recession
Date: 12 May 2018

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

Notes

No discernible recession or erosion from 2002 to 2017.

Map

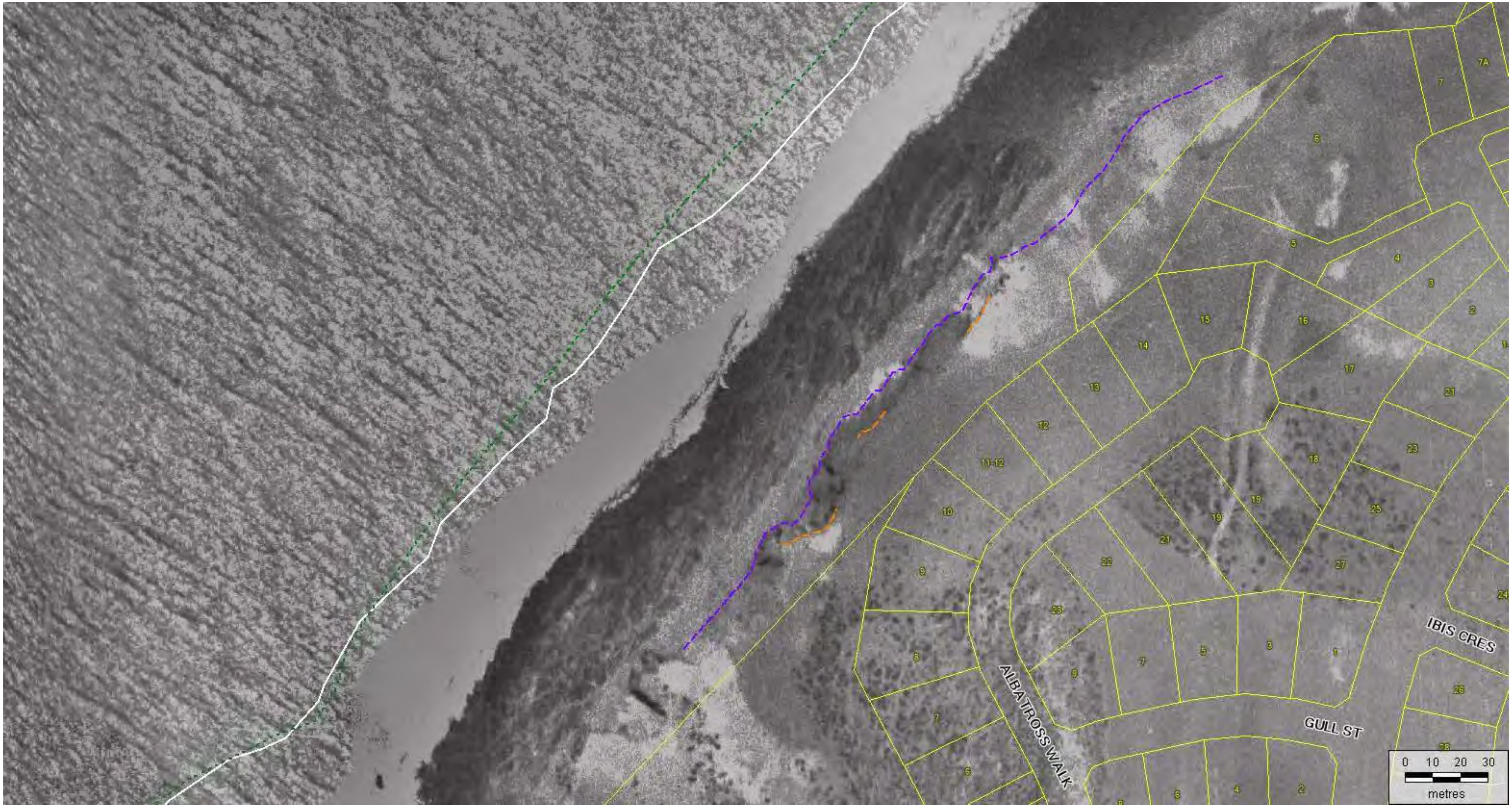
Southern Cliffs 5:1

Erosion assessment

Event: 2002

Risk: Shoreline recession

Date: 12 May 2018



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

Notes

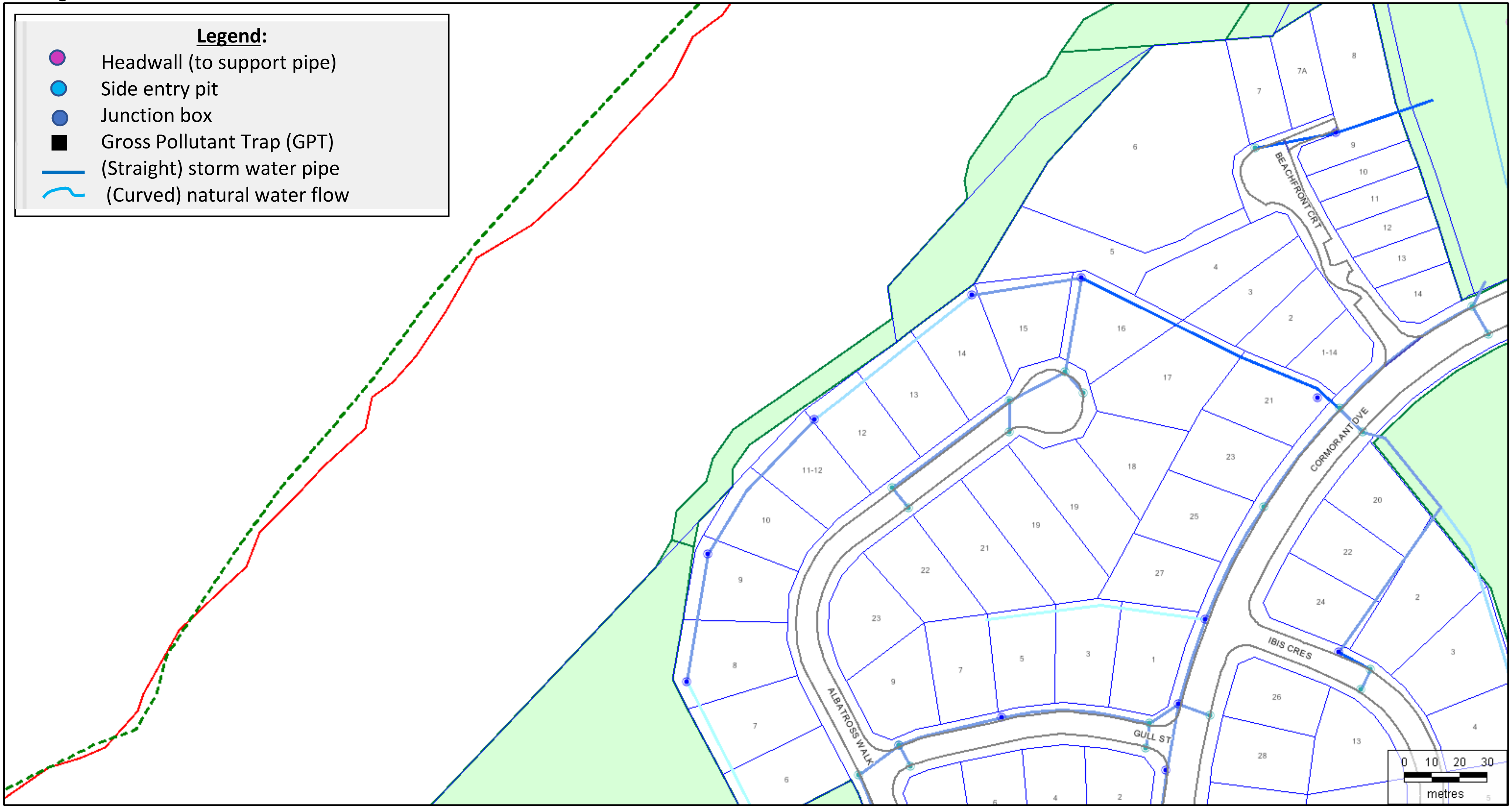
Difficult to assess, but top of escarpment appears to be in the same position. More scouring and cracking is observed in later photographs.

Map

Southern Cliffs 5:1

Erosion assessment

Event: 1949
Risk: Shoreline recession
Date: 12 May 2018



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

Notes

Stormwater drains to Field River (no storm water into coastal environs)

Map

Southern Cliffs 5:1

Stormwater assessment

Event: Ongoing
Risk: Cliff erosion
Date: 12 May 2018

Cell 5: Southern Cliffs (5:2)

All private and public infrastructure is set well-back from cliffs. By 2100, it is likely the base of the cliff will be inundated more frequently, allowing direct wave action against the base of the cliffs. Routine monitoring of the cliff condition and stability should be undertaken (particularly the discharge of stormwater) HCCMS, P. 45

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

Notes

On 9th May 2016 the highest level of water was recorded at Outer Harbor in 80 years at 3.80 CD (2.36 AHD). To calculate the storm surge height at Hallett Cove: secondary port relationship methodology was used with Port Stanvac (calculated at 90%) and wave height of 0.30m added in accordance with storm surge allowance allocated by Coast Protection Board for the Kingston Park Region. The height of this flood map is depicted at 2.43 (AHD). Wave run up is depicted with a dotted line at approximately 1m higher.

Map

Southern Cliffs 5:2

Sea-flood 2.43m AHD

Event: 9 May 2016
Risk: Historical benchmark
Date: 12 May 2018

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

Notes

DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has been mapped at approximately 1m higher by way of dotted blue line. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Southern Cliffs 5:2

Sea-flood 2.70m AHD

Event: Scenario: current
Risk: 1 in 100 ARI
Date: 12 May 2018

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

Notes

DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has been mapped at approximately 1m higher by way of dotted blue line. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Southern Cliffs 5:2

Sea-flood 3.00m AHD

Event: Scenario: 2050
Risk: 1 in 100 ARI
Date: 12 May 2018

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

Notes

DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has been mapped at approximately 1m higher by way of dotted blue line. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Southern Cliffs 5:2

Sea-flood 3.70m AHD

Event: Scenario: 2100
Risk: 1 in 100 ARI
Date: 12 May 2018

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

Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been included at 0.7m with approximate location indicated by dotted line. Sea level rise of 0.0 has been added.

Map

Southern Cliffs 5:2

High tide 1.6m AHD

Event: Scenario: current
Risk: Escarpment erosion
Date: 12 May 2018

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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been included at 0.7m with approximate location indicated by dotted line. Sea level rise of 0.3 has been added.

Map

Southern Cliffs 5:2

High tide 1.9m AHD

Event: Scenario: 2050
Risk: Escarpment erosion
Date: 12 May 2018

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Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been included at 0.7m with approximate location indicated by dotted line. Sea level rise of 1.0 has been added.

Map

Southern Cliffs 5:2

High tide 2.6m AHD

Event: Scenario: 2100
Risk: Escarpment erosion
Date: 12 May 2018

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1300 767 333 (free call)

Notes

To analyse the rate of shoreline recession over the last seventy years, comparative analysis was conducted using georeferenced aerial photographs from 1949, 2002, and 2017. This analysis provides a long-term review (70 years), and a shorter-term review (15 years). The longer-term review is dependent on black and white photographs that are often difficult to decipher.

Map

Southern Cliffs 5:2

Erosion assessment

Event: 2017
Risk: Shoreline recession
Date: 12 May 2018

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

Notes

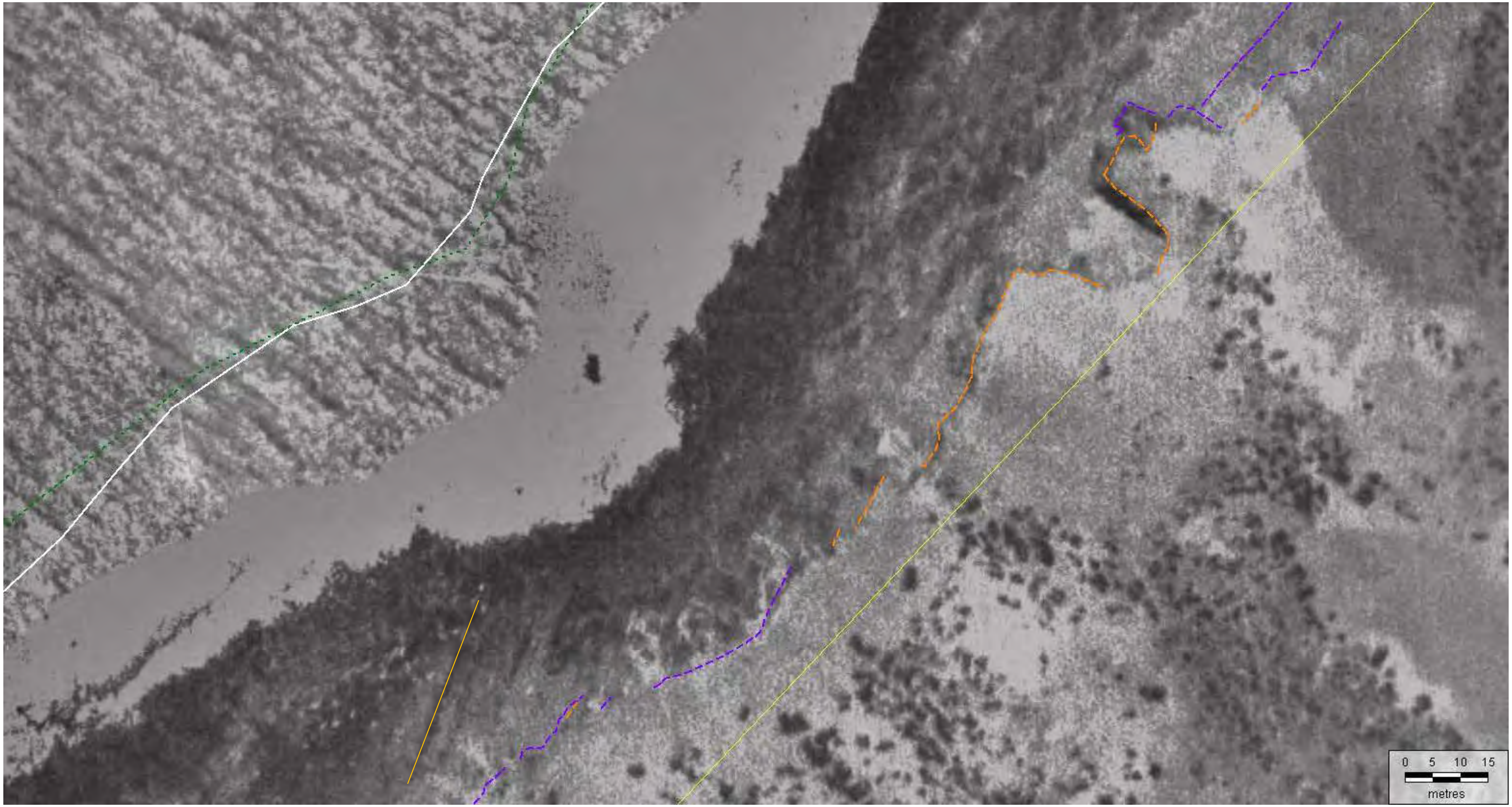
No observable recession in 15 years. The crevice on the rock platform appears to be in same place on next photograph (1949)

Map

Southern Cliffs 5:2

Erosion assessment

Event: 2002
Risk: Shoreline recession
Date: 12 May 2018



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Notes

Top and bottom of the escarpment appears in the same position. The crevices on the rock appear to be in the same position. However it appears that there is a greater amount of sediment and sand in this area in 1949 than in 2002/ 2017. (and rock platform less weathered)

Map

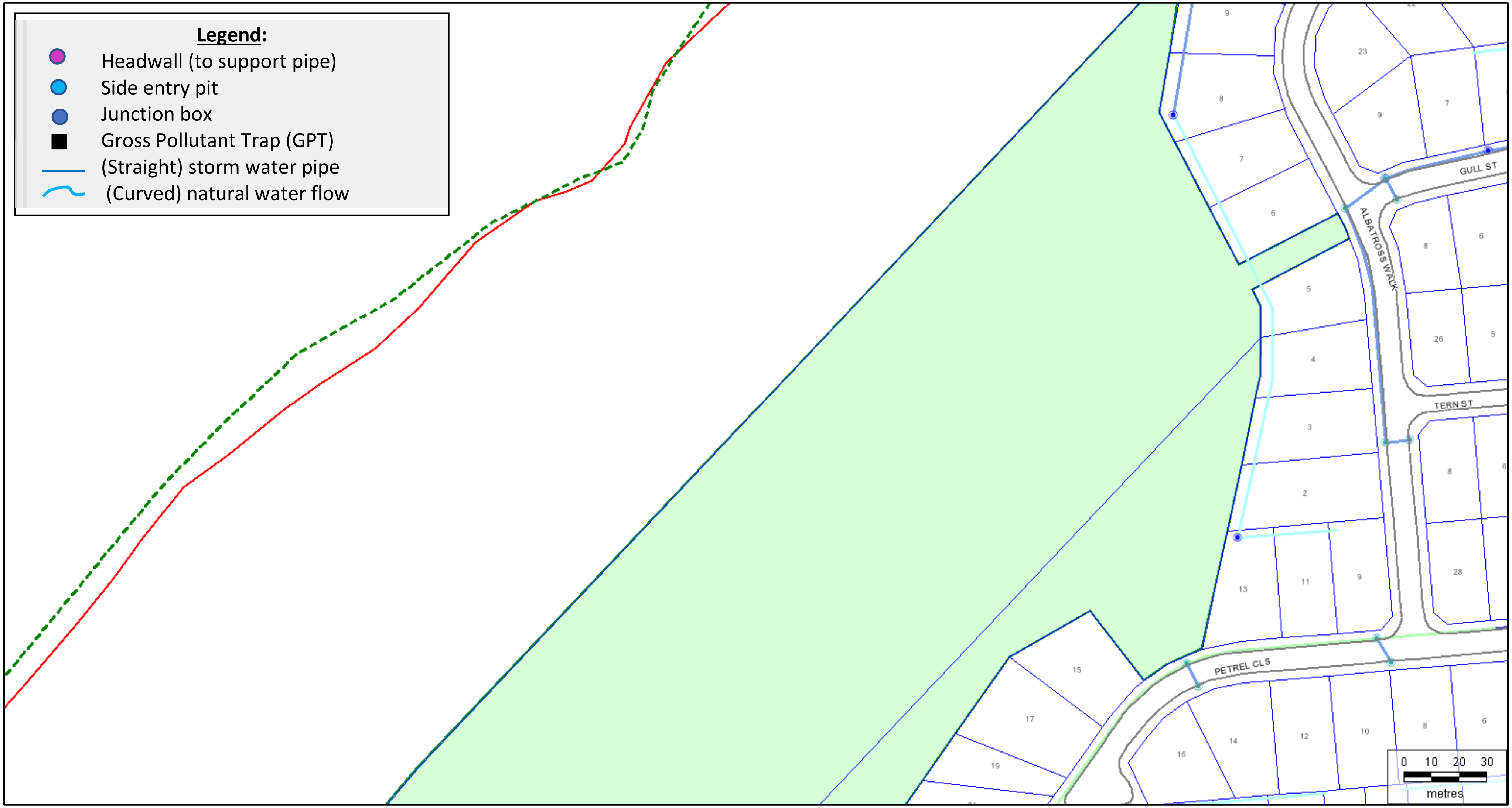
Southern Cliffs 5:2

Erosion assessment

Event: 1949

Risk: Shoreline recession

Date: 12 May 2018



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

Notes

All storm water drains into the Field River catchment (no storm water into coastal environs).

Map

Southern Cliffs 5:2

Stormwater assessment

Event: Ongoing
Risk: Cliff erosion
Date: 12 May 2018

Cell 5: Southern Cliffs (5:3)

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1300 767 333 (free call)

Notes

On 9th May 2016 the highest level of water was recorded at Outer Harbor in 80 years at 3.80 CD (2.36 AHD). To calculate the storm surge height at Hallett Cove: secondary port relationship methodology was used with Port Stanvac (calculated at 90%) and wave height of 0.30m added in accordance with storm surge allowance allocated by Coast Protection Board for the Kingston Park Region. The height of this flood map is depicted at 2.43 (AHD). Wave run up is depicted with a dotted line at approximately 1m higher.

Map

Southern Cliffs 5:3

Sea-flood 2.43m AHD

Event: 9 May 2016
Risk: Historical benchmark
Date: 12 May 2018

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

Notes

DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has been mapped at approximately 1m higher by way of dotted blue line. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Southern Cliffs 5:3

Sea-flood 2.60m AHD

Event: Scenario: current
Risk: 1 in 100 ARI
Date: 12 May 2018

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

Notes

DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has been mapped at approximately 1m higher by way of dotted blue line. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Southern Cliffs 5:3

Sea-flood 2.90m AHD

Event: Scenario: 2050
Risk: 1 in 100 ARI
Date: 12 May 2018

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

Notes

DEWNR advises that current storm surge risk for Kingston Park to the north of the depicted location is 2.4m AHD storm surge, and 0.3m wave set-up, and at Port Noarlunga to the south is 2.3m storm surge and 0.4m wave set-up. In all Hallett Cove regions storm surge has been set at 2.3m and wave set-up at 0.3m. Wave run-up has not been mapped but the need to consider this factor is indicated <u>schematically</u> by way of dotted blue line. Coast Protection Board sea level rise policy levels are 0.3m indicatively by 2050, and a further 0.7m indicatively by 2100.

Map

Southern Cliffs 5:3

Sea-flood 3.60 AHD

Event: Scenario: 2100
Risk: 1 in 100 ARI
Date: 12 May 2018

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

Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been included at 0.7m higher and depicted by way of a dotted blue line. Sea level rise of 1.0 has been added.

Map

Southern Cliffs 5:3

High tide 1.6m AHD

Event: Scenario: current
Risk: Escarpment erosion
Date: 12 May 2018

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

Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been included at 0.7m higher and depicted by way of a dotted blue line. Sea level rise of 1.0 has been added.

Map

Southern Cliffs 5:3

High tide 1.9m AHD

Event: Scenario: 2050
Risk: Escarpment erosion
Date: 12 May 2018

June 2018

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

Notes

This map depicts the more routine impact of tidal action on the base of the cliffs. To calculate the height of this tide, an average of all monthly high tides from 1992 to 2000 was calculated for the tidal record at Outer Harbor and Port Stanvac, and extrapolations made between the two gauges for this region and a wave height added of 0.3m. It is likely that this tidal regime would occur on average once per month. Wave run up has been included at 0.7m higher and depicted by way of a dotted blue line. Sea level rise of 1.0 has been added.

Map

Southern Cliffs 5:3

High tide 2.6m AHD

Event: Scenario: 2100
Risk: Escarpment erosion
Date: 12 May 2018

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

Notes

To analyse the rate of shoreline recession over the last seventy years, comparative analysis was conducted using georeferenced aerial photographs from 1949, 2002, and 2017. This analysis provides a long-term review (70 years), and a shorter-term review (15 years). The longer-term review is dependent on black and white photographs that are often difficult to decipher.

Map

Southern Cliffs 5:3

Erosion assessment

Event: 2017

Risk: Shoreline recession

Date: 12 May 2018

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

Notes

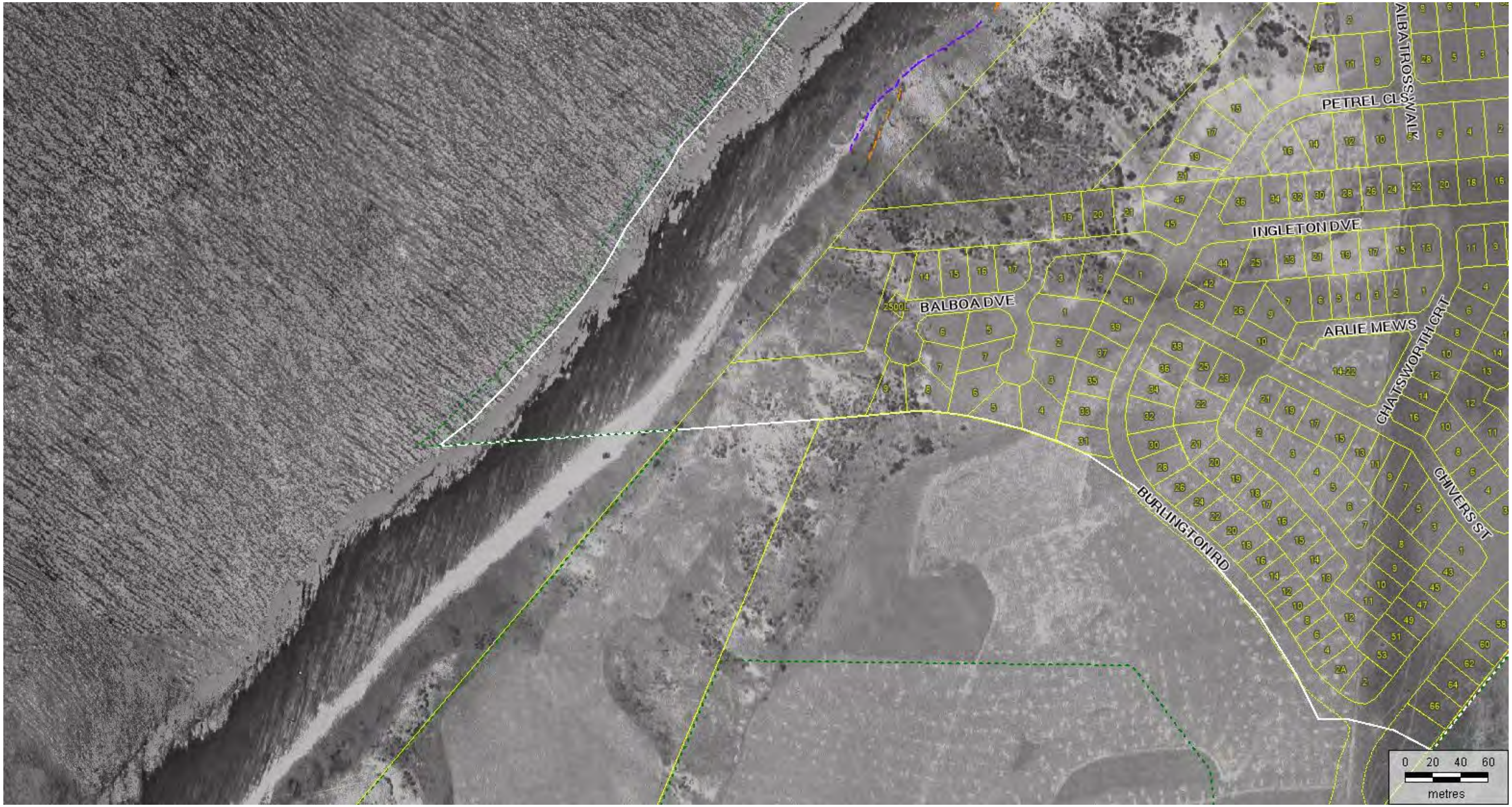
The top and bottom of this cliff escarpment appear in the same location and condition as photograph in 2017.

Map

Southern Cliffs 5:3

Erosion assessment

Event: 2002
Risk: Shoreline recession
Date: 12 May 2018



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

Notes

Rock platform at base of cliff appears as same nature as current form and in the same location. The top of the cliff escarpment appears in the same location. More sand is evident on either side of the rock platform than in the later photographs (2002, 2017).

Map

Southern Cliffs 5:3

Erosion assessment

Event: 1949

Risk: Shoreline recession

Date: 12 May 2018

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

Notes

One storm water outlet into gully at southern border of CoM. Very difficult location to access. Some remedial work trialled (under review by CoM).

Map

Southern Cliffs 5:3

Stormwater assessment

Event: Ongoing
Risk: Cliff erosion
Date: 12 May 2018

Risk assessment: Southern Cliffs (5:1-3)

Risk identification: Erosion is currently, or may in the future, threaten the toe of the cliff escarpment causing instability and/or recession

Coastal processes	Preliminary assessment indicates that the geology at the base of the cliff is similar to that as Black Rock (resistant). Modelling suggests that the base of the cliff is not subject to ongoing tidal action, but storm surges are likely to be impacting the rock sections of the cliff with wave run-up. There is no apparent evidence of erosion in non-rock locations along the base of the cliff.

Are any strategies employed to mitigate the risk? No

Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Walking trail set well back from cliff escarpment.	current	*Rare*	*Insignificant*	low
		2100	*Rare*	*Insignificant*	low
Private assets	Three houses set back 20m from top of cliff in northern section (Southern Cliffs -1). Closest house to top of cliff is in Southern Cliffs 3 (46m)	current	*Rare*	*Insignificant*	low
		2100	*Rare*	*Insignificant*	low
Safety of people	The walking trail has some pedestrian traffic. Unlikely that there is significant traffic at base of the cliff (on beach). Risk assessment assumes that people stay on designated pathways.	current	*Rare*	*Insignificant*	low
		2100	*Rare*	*Insignificant*	low
Environment	Inter-tidal zone is rock shelf. Intertidal and sub-tidal habitats are at threat. Clifftop vegetation is highly significant however unlikely to be threatened by erosion from sea level rise.	current	*Rare*	*Minor*	low
		2100	*Possible*	*Moderate*	medium

Inherent Hazard Rating

Hard rock sloping shore

(R-1)

	Low	Moderate	High	Very high
Ecosystem disruption	X	2	3	4
Gradual inundation	X	2	3	4
Salt water intrusion	X	2	3	4
Erosion	X	2	3	4
Flooding	X	2	3	4

Erosion Hazard Rating

(current outlook)

	Low	Medium	High	Extreme
Public Infrastructure	X			
Private Assets	X			
Public safety	X			
Environment	X			

Erosion Hazard Rating

(future outlook)

	Low	Medium	High	Extreme
Public Infrastructure	X			
Private Assets	X			
Public safety	X			
Environment		X		

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

*CoM is not necessarily liable for private assets

Summary	Generally assets and infrastructure are set well-back from cliff escarpment. Three houses in 5.1 are set back approximately 20m from the top of the cliff escarpment which appears to be of resistant composition. Storm water run off will scour the gullies of the cliffs.

Southern Cliffs (5:1-3)
Erosion outlook and recommended actions (draft)

Geological review: The base of the cliff is similar geological fabric as Black Rock and therefore resistant. The upper portions of the cliff (especially in southern sections of Southern Cliffs) is of more friable material.

Historical recession: Based on photographic analysis, there appears to be no significant recession of the cliff since 1949. It appears as if there is sediment loss and perhaps more erosion to the rock platform at the base of the cliff.

Exposure:	**Routine tidal impact (bi-monthly)**	**Storm surge impact (1 in 100 ARI)**
Historical event - 2016	NA	This event had some impact upon the rock sections of the cliff, but minimal elsewhere.
Current	Routine tidal action does not impact the base of the cliff (apart from some rock sections)	The wave run up of storm surge 2.60m will interact with minimal impact with the base of the cliff.
2050	Routine tidal action is likely to interact with rock sections of the cliff (but not significant impact into the sediment sections)	The wave run up of storm surge 2.90m will interact with some impact with the base of the cliff.
2100	Some routine tidal action is likely (wave run up)	The base of the cliff will come under high impact direct wave attack from storm surge of 3.60m

Storm water: Storm water from urban settlements is pipe to Field River and therefore has limited impact in the cliff environs. One location is piped to the base of the cliff (but requires upgrading).

Risk Assessment: This area is subjected to less action from the sea, but is vulnerable for erosion at the top of the cliff (storm water).

Recommended actions (draft):

Number	Action	Comments	Time frame
5:1 (1)	Review nature of storm water outflows in 5:3 and assess impacts.	Routine inspections are taken of the outfall areas. Recommend that staff incorporate review of scouring impacts (use photography)	1-2 years
5:1 (2)	Quantify more accurately the nature of routine and storm surge interaction with cliff base.	Monitor tidal regime for period of three months (winter). Monitor the impact of storm surge events (if, and when they occur)	1-2 years
5:1 (3)	Recapture digital model as basis for comparison	Use appropriate software to quantify changes in the coastal environment.	3-5 years

5. Recommendations

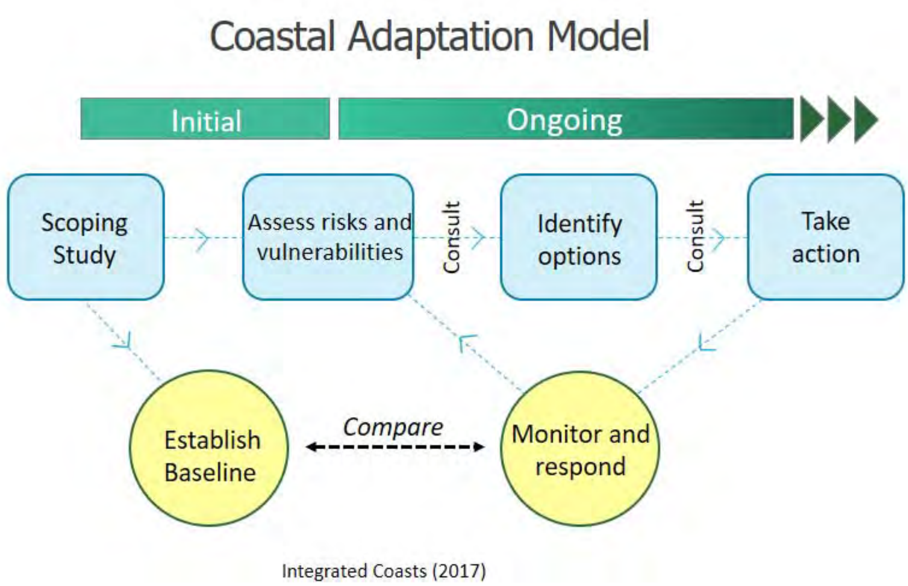
This project has established the necessary baseline from which to build a coastal management and adaptation program (Figure 26). First, a high resolution digital model has been obtained that replicates the current terrain with accuracy better than 50mms. Second, the analysis of historical aerial photographs has demonstrated that apart from the Field River region (Cell 4) that the coastline has been largely stable over the last eighty years. Third, scenario modelling of tidal and storm surge action has established a baseline understanding of the current interrelationship of the coastline with actions of the sea.

The scoping study has now been completed and risks and vulnerabilities assessed.

Monitoring strategy

The core of a coastal adaptation and management strategy should be ongoing monitoring. While the science that underpins projections of sea level rise should be regarded as sound, precise predictions around timing and localise impacts are difficult to project. Effective monitoring will give the impetus for necessary responses over time, and these responses will be built around accurate historical data, not just based on projected data.

Figure 26: Coastal adaptation model (Integrated Coasts)



The key ingredients of an effective monitoring program include:

The routine recapture of the 3D high resolution model. The first recapture should occur in approximately three years time. Software such as *Cloud Compare* can be utilised to make accurate assessments of the change between the two models. The level of change identified in the first comparative study will determine the periodicity of the recapture thereafter. A suitable budget for recapture of the coastline would be approximately 20k for the recapture (including ground control work), and 5-8k for a comparative study using soft ware tools. Note: The 3D model may become a cost neutral project. For example, other procedures such as routine maintenance checks of storm water infrastructure, walking trails, and vegetation monitoring may be effectively managed from the desk-top.

Figure 27: Changes to coastal enviroments can be accurately assessed and graphically portrayed with 3D digital models

Source: Example provided by Aerometrix

- The reinstatement of the SEAFRAME gauge is outside the jurisdiction control of City of Marion, but the State Government should be vigorously lobbied to ensure that this is reinstated to Port Stanvac region. Eighteen years of sea level rise data was obtained prior to 2010, but eight years of data has now been lost. Twenty years of data are required to establish a trend from which action could be predicated. An escalation in the rate of rise will be an early warning in the region that the projections of rapid sea level rise are underway.

- An annual visual check should be made of the coastline with a particular focus on areas that are identified as potentially at risk or under attack from wave action. Observations and comparisons of minor erosion escarpments will ensure that early warning of the need for remediation at low cost is provided. Two days in the field and one day reporting should suffice, and a budget of approximately 3k.

- Bi-annual check of protection structures should be undertaken by a suitably qualified engineer. The initial data (3D model, photographs and report from the annual inspection mentioned above) would enable some of this review to be conducted from the desktop.

- Implement a simple citizen science program. A citizen’s science program is a way to move the community from considering and worrying about projections, to become active participants in a monitoring program. The most effective way to start a citizen science program is to start simply. First, install a tidal staff within Field River and identify volunteers who, upon receiving a SMS, be willing to take pictures at ten minute intervals of the staff throughout a storm surge[1]. This data can then be compared back to records of Outer Harbor, and to other monitoring locations along the Adelaide coastline. Over time, a picture would emerge of how storm surges are interrelating with the coastline.

[1] Note, installing the staff within the river ensures that wave effects are removed from the storm height and that the storm surge height is being measured. This measurement would tend to correlate more accurately with how the storm surge is being measured at Outer Harbor within a stilling well. If the storm event was combined with extensive rainfall confluence impacts could also be measured (but storm surge height negated)

Second, install one or two camera points. These camera holders ensure that photographs are taken in exactly the same position and therefore useful comparisons can be obtained over time. Details of where to post the pictures are included on a sign board, usually to a Facebook page[2].

- An inspection of the coastline after storm events of a certain magnitude (for example a pre-determined tide height at Outer Harbor). This strategy will ensure that immediate and structured action is taken after each storm event to identify any damage, but also capture key data about impacts, storm heights, photographs (from citizen science program). It is likely that an effective partnership would be formed with the community in gathering data and evidence for post storm assessment (see footnote 2 also).

Other tasks and strategies

1. Geotechnical review at specific locations

Further geological/ geotechnical analysis is warranted at three locations along the coastline:

- Marino carpark
- Westcliff which is situated on Pleistocene material
- The Esplanade, Hallett Cove

In relation the latter, the work by Golder Associates who completed geo-technical studies of an area to the south of The Esplanade may provide the basis for the future work.

2. Review and rectify impact of stormwater on coastal environs

A repeated theme in the geology work and in advice received from Coast Protection Board over the years is the requirement to effectively control the discharge of storm water through cliff environments. The first reason to ensure that storm water is adequately managed is to ensure that cliffs do not undergo unnecessary erosion. The second reason relates to liability. Storm water is likely to be viewed as the responsibility of Council. If an event occurs where storm water discharge is part of the cause of the incident, then Council may be held increasingly liable for the event.

[2] Integrated Coasts would be interested in partnering with City of Marion in a pilot program to install camera point over looking the cliff escarpment at Marino Carpark (from somewhere on the walking trail), and one point over looking Hallett Cove beach (to monitor action at base of escarpment, and the Hallett Cove Beach beyond.

A way to conduct this review would be to start with the locations in the geology report where cliff tops are deemed as 'friable' (likely vulnerable), and assess the impact of storm water in those locations, taking remedial action where necessary.

As part of an ongoing monitoring program, Council personnel that inspect storm water outlets on a routine basis to ensure that they are clear of rubbish and debris, could also take pictures of any scouring or gullying around storm water outlets and these pictures fed into the monitoring program.

Also in this section of work should be a consideration of the storm water gullying within the dunes on Hallett Cove Beach (recognising that this area is likely under the control of DEW).

3. Design and install protection items:

It is likely that protection options will be required in the Field River area to slow the progress of erosion of the sand spit and the sand dunes. The embankment to the west of River Parade may need erosion control measures.

Find a solution to the increasing slope of the escarpment at Heron Way Reserve. It is understood that a major redevelopment is being considered, including the possible implementation of a tidal pool. This study recommends that whatever is being considered that one of the primary considerations in the design should be the mitigating of coastal impacts into this region as has been recommended by Lord (2012). Effective design may set this region up to be resilient over the coming century. Ineffective design may set this region up for failure over the coming century.

The Esplanade at Marino in extreme events is being over-topped by wave run up. A simple and cost-effective solution is likely to be found to prevent this from occurring. However, the rock revetment in this region has degraded (see 3D model in comparison to Holdfast Shores rock revetment).

4. Plan for climate change in urban planning policy

It is difficult to accurately quantify what the impact of increasing sea levels upon cliff and dune environments will be over the coming century. Council has responsibility for urban planning and for stormwater management both of which have the potential to significantly influence the likelihood of coastal erosion and the consequences of cliff collapse or recession. With the current levels of understanding around the likely impacts of climate change, Council must take care not to make decisions that compromise the future otherwise liability for future climate change related damages are likely to fall on the Council.

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