Integrated Coasts

COASTAL MONITOR

MONITORING AND EVALUATION

A coastal monitoring program for:

City of Marion

2019 -2024

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Introduction

This monitoring program is the output from the third stage of a coastal adaptation study for City of Marion:

- Coastal Scope
- Coastal Study
- **Coastal Monitor**

COASTAL MONITORING

This monitoring plan is based on emerging best practice, relying primarily on CoastAdapt, UK Climate Impact Programme (UKCIP), and from numerous case studies. While most agree that ongoing monitoring is the key to coastal adaptation, there is very little uniformity about how to go about it.

'We are still at an early stage in understanding how best to adapt to future climate change, how vulnerability can be most effectively reduced, and what the characteristics of a well-adapting society might be (UKCIP, 2011).

Implementing coastal monitoring programs to support coastal adaptation decisions can be difficult for the following reasons:

- The long time frames involved in adaptation,
- High uncertainty of the timing and nature of the impacts,
- A large range of coastal contexts both in physical characteristics, but also social, cultural and economic contexts.

Everyone agrees that monitoring involves the collection and evaluation of data. However, the research shows that the emphasis on data collection is normally in relation to 'monitoring the plan' and not monitoring physical data from the coast for the purpose of creating baselines. For example, often monitoring is implemented within the social or economic realms rather than relating specifically to changes in the coastline itself.

The emphasis of this monitoring plan is on the collection of coastal data upon which to form future coastal adaptation decisions.

RATIONALE FOR THIS PLAN

The structure of this plan is framed around three main contexts:

- A contextualisation of the risk profile for City of Marion coastline,
- Providing a rationale for the proposal,
- The inclusions of case studies (where relevant).

Finally, this plan is purposefully fixed at a five-year term, at which time a full evaluation should be undertaken to assess the data, and to formulate a new or revised monitoring plan.

Key Points

There is general agreement that monitoring programs are required to underpin coastal adaptation strategies over time.

There is currently no uniformity in approaches to coastal monitoring.

It is generally agreed that coastal monitoring programs are difficult to implement and maintain because of the:

- long time frames involved in adaptation,
- high uncertainty of timing and nature of impacts,
- large range of coastal contexts.

Primary research was based on intensive evaluation of monitoring information within CoastAdapt and UK Climate Impact Programme (UKCIP).

Figure 1: Tom Doyle, 2016, Collecting physical data from coast

Conceptual Framework

A *conceptual framework* is a way to understand how the variables in a study connect with each other. It is like a 'map' for the investigation and usually presented in a way that is easy to remember and apply. Conceptual frameworks are useful for communicating with various stakeholders.

MONITORING FRAMEWORK

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

- **Coastal geology (the fabric of the coast)**

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

- **Coastal modifiers (human intervention)**

In some coastal locations human intervention has significantly altered the nature of the coast. For example, an extensive rock revetment has been installed from Brighton to Glenelg along the Adelaide coastline. This installation has modified the fabric of the coast from sand dunes to rock.

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

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

It is the combination of these three factors that determine the nature and severity of the hazard in any coastal location.

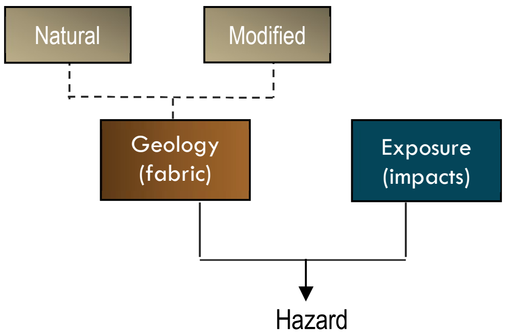
CHANGES IN THE RELATIONSHIP

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

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

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

Figure 2: Conceptual framework



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The aim of this coastal monitoring project is to collect and analyse data that enables the ongoing evaluation of the relationship between the ***fabric*** of the coastline and its current ***exposure*** to actions of the sea, and how this relationship may change over time.

Adaptation Principles

A principle is a proposition or value that is a guide for behaviour or evaluation. Three guiding principles have been adopted for coastal adaptation study. Research demonstrates that these principles remain relevant in the context of coastal monitoring.

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 geological structure and rock types, the bathymetry 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, including the underpinning risk assessment procedures, must operate in a fine-grained way that appropriately deals with the local nature of the impacts.

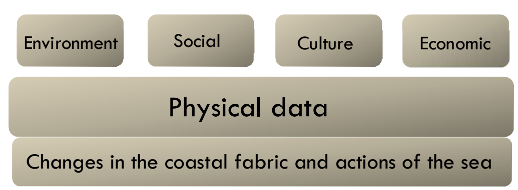
Coastal adaptation should be based on the collection and analysis of physical data

One finding of the research for this project demonstrated that monitoring data is collected across all facets of the quadruple bottom line: environmental, social, economic, and cultural. For example, data could be captured to determine beach goer's satisfaction of their local beach (social), or capital values of coastal properties could be monitored over time (economic).

Integrated Coasts views these as secondary monitoring contexts.

The primary monitoring context should be focussed on monitoring the physical changes that occur in the coastal fabric (erosion or accretion), and changes in exposure (the impact of sea level rise). This is the context that really matters, and upon which all others are ultimately dependent.

Figure 3: Primary and secondary monitoring contexts – secondary monitoring contexts will ultimately be shaped by the primary monitoring context



Funding dilemma: Monitoring projects that focus on social, economic or cultural aspects of the coast are more likely to be shorter term and have specific outcomes in mind. Monitoring of the physical nature of the coast can appear to be less focussed and the outcomes not as clear.

Coastal adaptation will take place over long time frames

Integrated Coasts recognises that coastal adaptation is a process that will take place over decades, and even centuries. And therefore, data from monitoring will form the basis for decision making. And wherever a monitoring program is envisaged, a baseline is required. Without forming a baseline, future monitoring is likely to have less meaning. In the context of coastal adaptation, the *Ecology Dictionary* provides the most appropriate definition of a baseline:

> A quantitative level or value from which other data and observations of a comparable nature are referenced… [and]
>
> Information accumulated concerning the state of a system, process, or activity before the initiation of actions that may result in changes.

Adaptation Principles

Continued…

Two basic elements reside in the definition. To illustrate:

> Comparing the position of a shoreline or cliff top using aerial photographs collected since the 1940s form a baseline rate of erosion or accretion. Once this baseline rate is established, projections can be formulated about the possible future impact of erosion along the shoreline (in the context of other data).
>
> A digital model created recently with associated imagery creates a digital baseline against which future erosion can be compared (ie monitored). Recapturing the data in five or ten years time will enable further comparisons to the historical baseline, and improvements to the projections made.

Research findings

Both CoastAdapt and UKCIP note the problem of dealing with moving baselines. Integrated Coasts diverges from both of these resources and notes that obtaining baseline data is fundamental to long term coastal adaptation. The fact that baselines will move should be anticipated, but there is no reason why a future baseline cannot be compared with a current baseline.

A case study approach is useful to make the point.

Case Study 1: Waikato Regional Council (New Zealand)

Waikato Regional Council has been collecting beach profile data for forty years from up to 60 sites along its coastline. The Council also conducts beach video monitoring at selected locations.

The key purpose of the project is to understand shoreline changes over both short and long-time frames. The monitoring **indicators** were 'beach volume' and 'shoreline position'.

Many beaches suffered erosion in the 1970s but these beaches were rebuilt in the 1980s.

The results show that sandy beaches can fluctuate by up to 30m with changes to erosion and accretion occurring over decades.

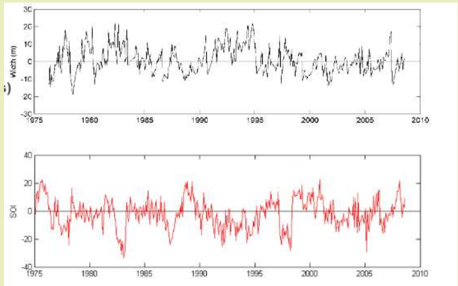
'Despite sometimes dramatic changes, our records don't show that any of our Coromandel beaches are experiencing a long-term trend for erosion. This may change in the future with projected sea level rise'.

Case Study 2: Narrabeen Beach, NSW

The Water Research Laboratory of NSW (and its predecessors) have been conducting monthly profile monitoring of Narrabeen Beach since 1976. Equipment in the early days was very basic but in latter times WRL has utilised video monitoring, RTK surveying, fixed LiDAR, and airborne LiDAR.

The conclusion after forty years is that the net trend movement of the beach is ZERO, but the beach can vary by up to 80m. The erosion trend was observed to operate in opposite correlation with the Southern Oscillation Index.

Conclusion: '…the reality is that in Australia, we presently know very little about the present day variability and trends that are occurring around our coastlines' (Ian Turner. 2018).



Beach width in opposite correlation with Southern Oscillation Index.

Source: WRL 2018, PPT presentation.

Adaptation Principles

Continued…

These case studies were chosen specifically to illustrate the importance of understanding the normal parameters of a coastline. There are places around the world where sea level rise is already having a large impact on coastlines. The chalk cliffs in England appear to be suffering ongoing erosion. In our own State, trees that have stood for 40 years or more in the Foul Bay area are falling into the sea which suggests that the beach is now operating outside of its normal range. The point here is that an understanding of how our coastlines behave now is imperative to be able to determine when sea level rise is changing the baseline. This understanding will allow Council to know when hard decisions are necessary, and when the coastline is operating within its usual parameters.

'Pathways' adaptation -a review

What is known as 'pathways' adaptation methodology is the preferred way to undertake coastal adaptation. A pathways approach attempts to deal with uncertainty using three main ingredients: scenario planning, time, and triggers or thresholds. A 'pathways' approach outlines plausible futures from which to identify key thresholds and triggers, and then to consider alternative pathways when these are breached. However, Integrated Coasts is of the view that in most cases less time should be placed upon considering triggers and alternative pathways, and more time in collecting the data which will inform decision making for decades to come[1].

Case Study 3: Australian Baseline Sea level rise monitoring project

In 1992, thirteen gauges were installed around Australia to measure the rate of sea level rise using 'mean sea level'. This project also known as the SEAFRAME project (find acronym).

In the earlier years, Bureau of Meteorology produced annual reports. However, it was soon noted that there was variability in the rate of rise from year to year, and that climate trends such as El Nino and La Nina played a part in determining shorter term rates.

It is now accepted that a minimum of 20 years data is required to identify the current baseline rate of sea level rise, which is presentaly averaged at 4-5mm within the South Australian region.

Case Study 4: Findings in South Australian context

Alexandrina coastline

A study of the Alexandrina coastline demonstrated that while some erosion has been experienced since 1949, the coastline is currently going through an accretion stage. A comparison of historical photographs between 1949 and 2006 showed that net erosion was 12-15m. However, between 2006 and 2018 the shoreline in these locations accreted back to the 1949 position. There are some smaller sections where erosion has continued to accelerate. When making coastal adaptation decisions it is imperative to understand the normal cycle of the beach. If the normal cycle of the beach is not understood, then very costly decisions could be made within what is the normal erosion cycle of the beach.

Changes on a beach usually relate to a larger macro driver. The archives from 1970s and 1980s relating to Sugars Beach (opposite the Murray Mouth) noted a high rate of erosion upon the beach. Even in this era Coastal Management Branch suggested that sea level rise may be the underlying cause. However, a recent study demonstrated that subsequent to the installation of the Goolwa Barrages in 1938, the Murray Mouth migrated westwards by ~1km and the position of the main channel moved north towards Sugars Beach. This was the main cause of the erosion resulting in an erosion rate of 1m p.a.

[1] The exception is where new or upgrades to infrastructure is envisioned. In this case a study of thresholds and trigger points is essential.

Adaptation Principles

Summary

Coastal Adaptation Principles

1. Coastal adaptation takes place within localities and therefore a fine-grained approach is required.

2. Coastal adaptation should be based on the collection and analysis of physical data

3. Coastal adaptation will take place over long time frames – decades, and even centuries

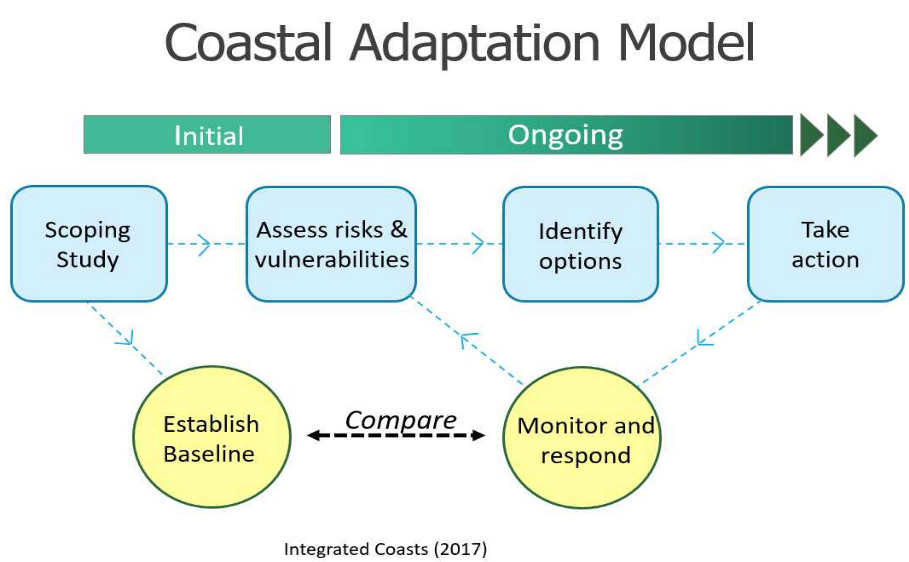
These three adaptation principles and the central role of coastal monitoring is depicted in Figure 4.

Case study: dialogue and conclusion

If Waikato Regional Council had not been monitoring coastal change and a rapid increase in erosion occurred as it did in the 1970s, but this time in the context of high awareness of climate change and sensational media reporting, how would it have interpreted the erosion? What actions might the Council have taken that could be very high cost thinking that the rate of erosion was outside the norm, and expected to continue and accelerate? A similar question could be asked for the Narrabeen coastline.

These questions do not undermine the prevailing view that sea level rise will have an impact upon our coastlines, but rather show that maladaptation, along with high costs, are more likely in the absence of an understanding of how local beaches behave over time. And the only way to understand how they behave is to conduct monitoring of the coastline.

A valid conclusion from the case studies is that cost-effective monitoring is likely to save the Council money over time, and give Council the necessary data to both make hard decisions when these are required, but also resist the political and media pressures that are increasingly prevalent in dealing with climate change.



THE MONITORING CONTEXT

City of Marion

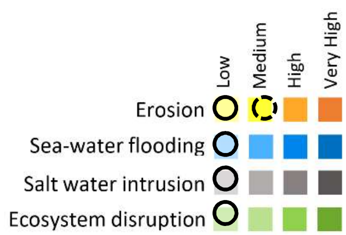
It is important to understand the overall monitoring context for the City of Marion coastline. The coastline has a unique geological layout and is situated in a particular coastal setting within Gulf St Vincent, and as such has a unique set of risks in the context of sea level rise. The nature of these risks will determine the type of monitoring that is required. The answers to the following questions set the parameters for this monitoring project:

- What is the risk context?
- What is the purpose of the monitoring?
- What is the type of monitoring? (Summative or Formative)
- What is the preferred length of monitoring project?
- What indicators are to be assessed?

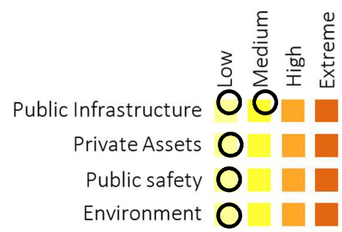
The monitoring context

What is the risk context?

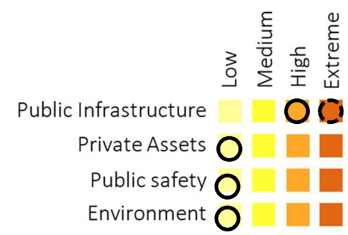
Inherent Hazard Rating



Erosion Hazard Rating
(Current outlook)



Erosion Hazard Rating
(Future outlook)



Risk overview:

The geological layout of Cell 1 is such that the majority of this coastline is not subject to inundation.

Cliff vulnerability has been classed in the range of 2-3:

(1) Highly vulnerable
(2) Likely vulnerable
(3) Likely resistant
(4) Highly resistant

Hotspots or exceptions:

- The Esplanade at Marino had mild inundation in 2016
- The base of the embankment at the Marion Rocks carpark incurred minor erosion in 2016

Monitoring purpose

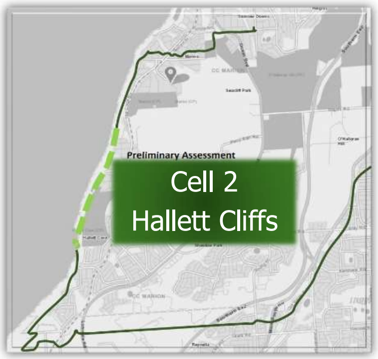
Generally, monitor changes in backshore to ascertain when public infrastructure may be impacted in the future

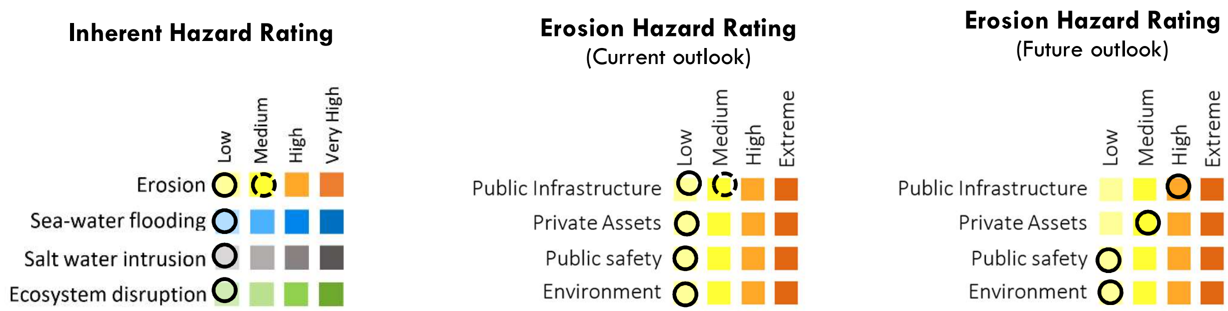
Specifically monitor inundation at The Esplanade, Marino, and erosion to the escarpment at Marino Rocks carpark.

Monitor impact of storm water on cliff stability.

The monitoring context

What is the risk context?





Risk overview:

The geological layout of Cell 2 is such that this coastline is not subject to inundation.

Cliff vulnerability has been classed in the range of 2-3:

(1) Highly vulnerable
(2) Likely vulnerable
(3) Likely resistant
(4) Highly resistant

Hotspots or exceptions:

- The Esplanade, and northern end of Clifftop Crescent. Public infrastructure is set within 2m- 5m of the cliff escarpment. The cliff vulnerability is classed as (2) likely vulnerable.

Monitoring purpose

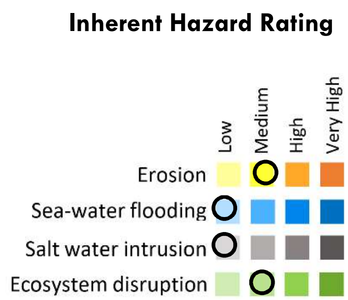
Generally, monitor changes in cliffs to ascertain when public or public infrastructure may be impacted in the future

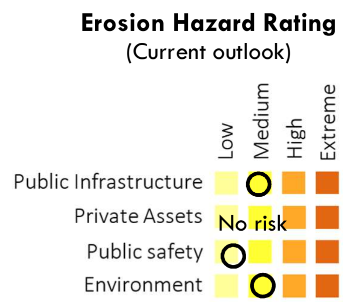
Specifically, monitor the cliff escarpment more closely at The Esplanade and Clifftop Crescent.

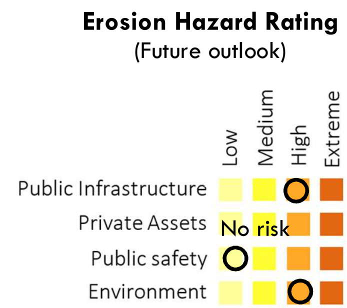
Monitor impact of storm water on cliff stability.

The monitoring context

What is the risk context?







Risk overview:

The geological layout of Cell 3 is such that this coastline is not subject to inundation.

Backshores include sand dunes and earthen embankment and are classed as:

(1) Highly vulnerable
(2) Likely vulnerable
(3) Likely resistant
(4) Highly resistant

Hotspots or exceptions:

- Dunes are experience minimal actions from the sea, but storm water from the amphitheatre has eroded gullies through the dunes.
- If dunes were eroded, the ecology of this portion of coast would change
- Previous storm events have eroded the embankment to Heron Way Reserve.

Monitoring purpose

Monitor changes to the volume of sand on beach and dunes.

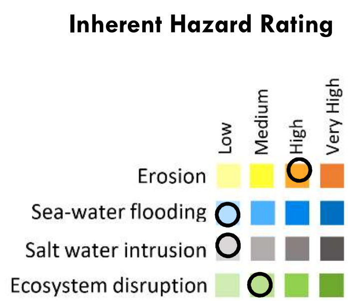
Monitor the position of the shoreline (vegetation line)

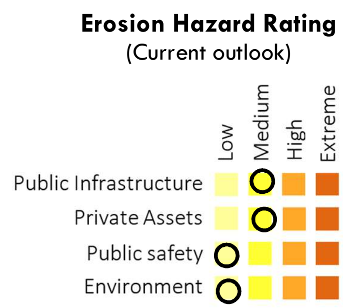
Monitor the base of the embankment at Heron Way Reserve.

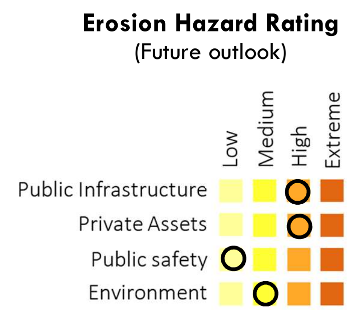
Monitor impact of storm water on dunes.

The monitoring context

What is the risk context?







Risk overview:

The geological layout of Cell 4 is such that this coastline is not subject to inundation. Sea level rise will increase salt water intrusion into Field River, but the slope of the river bed is such that this intrusion is unlikely to proceed further than the road bridge over Cormorant Drive.

Backshores include sand dunes and earthen embankment and are classed as:

(1) Highly vulnerable
(2) Likely vulnerable
(3) Likely resistant
(4) Highly resistant

Hotspots or exceptions:

- Sand dune on the south side of Field River
- Sand dunes in front of private properties
- The embankment protection River Parade.

Monitoring purpose

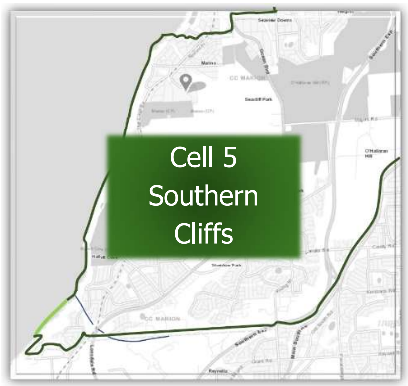
Monitor changes to the volume of sand on beach and dunes.

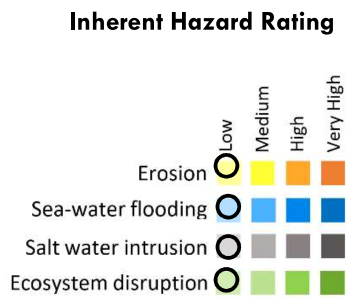
Monitor the position of the shoreline (vegetation line)

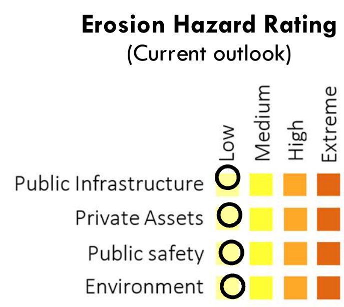
Monitor the base of the embankment on River Parade.

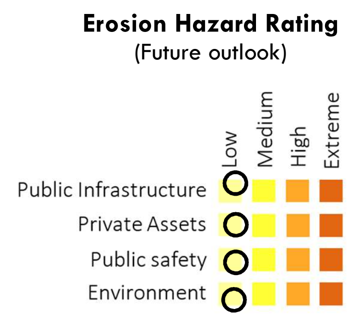
The monitoring context

What is the risk context?









Risk overview:

The geological layout of Cell 4 is such that this coastline is not subject to inundation. Sea level rise will increase salt water intrusion into Field River, but the slope of the river bed is such that this intrusion is unlikely to proceed further than the road bridge over Cormorant Drive.

Backshores include sand dunes and earthen embankment and are classed as:

(1) Highly vulnerable
(2) Likely vulnerable
(3) Likely resistant
(4) Highly resistant

Hotspots or exceptions:

- Nil

Monitoring purpose

Monitor changes to the cliffs over time.

The monitoring context

What is the risk context?

On the basis of the previous pages (pp 10-14), and when considering all coastal environments within South Australia, City of Marion Council should be currently deemed as 'low risk' to impacts from coastal processes. Overall, the coastline is elevated well-above any future sea level rises, and generally infrastructure is set well-back from the shoreline. Most of the geology of the coastline of City of Marion is rated in the mid-range of the vulnerability / resistant classification, neither highly resistant but nor highly vulnerable. This general assessment does not suggest that City of Marion is risk free, nor does it infer that the coastline will not come under increasing threat in the second half of this century.

What is the purpose of the monitoring?

Because impacts are not expected to be felt along much of the coastline until later in this century the **main purpose** of monitoring is to establish a baseline understanding of how the coast operates in this current era. The case study history indicates that this understanding is necessary so that it forms the basis for appropriate decision making in the future.

In the context of coastal adaptation, the Ecology Dictionary provides the most appropriate definition of a baseline:

> A quantitative level or value from which other data and observations of a comparable nature are referenced… [and]
>
> Information accumulated concerning the state of a system, process, or activity before the initiation of actions that may result in changes.

In regard to the first part of the definition, this current coastal adaptation study has obtained a high-resolution 3D model which forms the basis for comparison of changes within the fabric of the coast over time. In regard to the second part of the definition, the main purpose of the monitoring is to accumulate information about the current state of coastal processes and associated impacts so that in the future it can be determined when the coast is operating within normal parameters, and when it is moving outside of its normal range due to increases of sea level rise.

A **secondary purpose** is to monitor specific hotspot locations where assets may be currently at risk. For example, the base of the escarpment at Marino Rocks carpark shows evidence of minor erosion. However, remedial action is not likely to be warranted at this point in time. Monitoring the escarpment more closely will provide the decision making context as to when to intervene. If the escarpment is not monitored, then the erosion escarpment could become much more significant and remediation costs spiral upwards.

THE MAIN PURPOSE

Generally, City of Marion coastline should be currently be regarded as at 'low risk' from coastal processes that might impact urban infrastructure. This assessment does not infer that City of Marion is risk free, nor that the coastline will not come under increasing threat in the latter part of the century.

However, this more general assessment does provide a risk context from which to determine the purpose of monitoring. The main purpose of coastal monitoring should be to establish a baseline understanding as to how coastal process currently operate. This understanding will provide the basis for decision making in the context of ongoing sea level rise.

The monitoring context

What is the type of monitoring?

There are two basic types of monitoring and evaluation plans:

- Formative
- Summative

A **formative monitoring** program collects and evaluates data for the purpose of informing ongoing decision making. For example, monitoring a dune system that was actively eroding outside of its normal range would form the basis on how to implement an adaptation option for this threat. A **summative monitoring** program seeks to collect data over a designated period of time, and then evaluate the outcomes at the end of the project.

In the case of City of Marion, the overriding purpose is to collect and analyse data to provide an understanding of the ways in which the coastline currently operates. Therefore, a **summative** approach is required at the conclusion of the monitoring period a comprehensive evaluation will be undertaken.

However, while monitoring for the bigger baseline picture, hotspots will also be monitored, and the data evaluated to **form** the basis for decision making.

What is the preferred length of time of the monitoring project?

The optimal length of the monitoring and evaluation project is five years for the following reasons:

- The core evaluation mechanism will be the recapture of the 3D digital model. Five years is an appropriate length of time both from a budgetary sense, but also to make comparisons between the original baseline capture in 2018.

- Also, in the context of the allocation of budget, a comprehensive review in 5 years will provide an end-point for costing, but also the opportunity to put a rationale for monitoring over future time frames. For example, the recapture of the 3D model may show very limited change in the cliffs, and therefore a revised project may extend the recapture period.

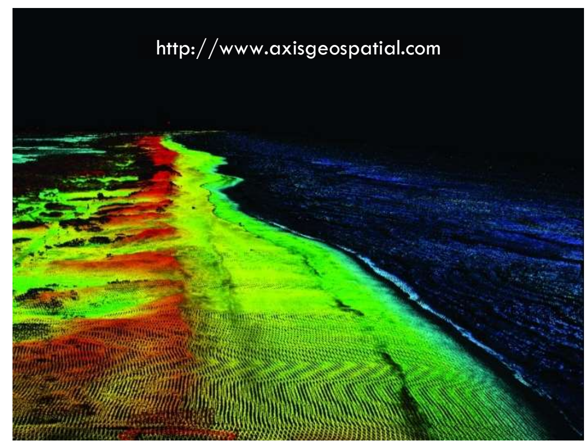
MONITORING TYPE

A summative approach – the main aim is to collect data over five years and evaluate the data to arrive at conclusions as to the normal parameters of coastal operation. The conclusions will form the basis for ongoing decision making.

A formative approach will be taken in hotspot locations to inform current decision making.

PROGRAM LENGTH

5 years.



The monitoring context

What indicators are to be assessed?

Indicators are things that we can measure. They help to determine whether objectives have been achieved for a specific program or project. Therefore, the adaptation plan should contain measurable objectives together with indicators for each of the objectives. Monitoring programs need to be in place so that they can collect appropriate data on each indicator and assess these against a baseline or reference conditions. Depending on the types of indicators, a variety of data will need to be collected[1].

The key indicator: the shoreline[2]

Generally, we are most interested in the position of the shoreline over time. Both coastal management and engineering design require information about where the shoreline is, where it has been in the past, and where it is predicted to be in the future.

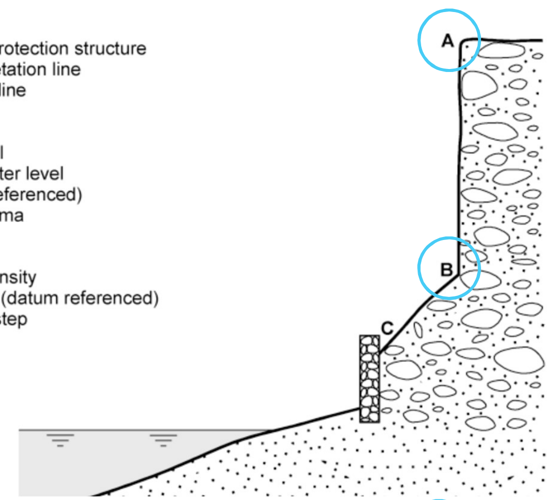
The shoreline is the position of the land-water interface at one instant in time. But in reality, the shoreline position changes continually through time because of the dynamic nature of water levels at the coastal boundary (waves, tides, storm surge, wave setup, wave runup), and because of cross-shore and alongshore sediment movement in the littoral zone. Over a longer period, such as 100 years, the position of the shoreline had the potential to vary by hundreds of metres or more. The shoreline is a time-dependent phenomenon that my have substantial short-term variability, and this needs to be carefully considered when determining the shoreline position.

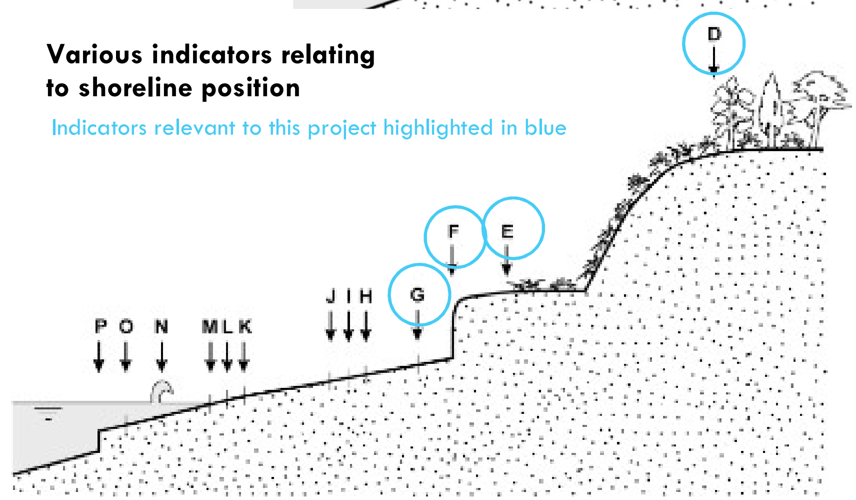
Examples where analysis of the shoreline is useful are:

- Design of coastal protection
- Assessment of sea level rise
- To identify hazard zones
- For planning policies to regulate coastal development
- To assist with legal boundary definition
- Shoreline reorientation adjacent man-made structures
- Beach width and volume
- To quantify historical rates of change.

KEY

A Bluff top/cliff top
B Base of bluff/cliff
C Landward edge of shore protection structure
D Seaward stable dune vegetation line
E Seaward dune vegetation line
F Erosion scarp
G Storm/debris line
H An old high tide water level
I Previous high tide high water level
J Mean high water (datum referenced)
K Wet/dry line or runup maxima
L Groundwater exit point
M Instantaneous water line
N Shorebreak maximum intensity
O Mean lower low water line (datum referenced)
P Beach toe/crest of beach step





Various indicators relating to shoreline position

Indicators relevant to this project highlighted in blue

[1] CoastAdapt

[2] This section relies on Boak and Turner (2005) Shoreline definition and detection: Journal of Coastal Research.

The monitoring context

The indicators to be assessed (continued)

Council wide

General monitoring issue	Indicator	Indicator reference (p.17)	Metric	Methodology
Changes in the coastal fabric	Physical changes that can be measured in distance or volume.	A, B, D, E, F	m or m^3	Recapture 3D model and compare to baseline capture of 2018.
The nature of impact of storms on the coastal fabric	Physical changes that can be measured in distance or volume and height of flood measured within Field River in AHD.	B, F, G (and height of water in Field River)	m or m^3 or height AHD	Photograph/ video storms in strategic locations, inspect coastline post-storm and photograph. Measure height of storm surge within Field River
Changes to bathymetry	Sand volumes	NA	m^3	Use jetski and bathymetric equipment (to be confirmed).

Comparison of coastal fabric

Remote sensing technology, usually captured using a drone or aircraft, has revolutionised the ability to capture high resolution accurate data. Recapturing data at strategic intervals then provides the ability to compare how a cliff or beach may have changed over time. In the example pictured on this page, software has compared the position of pixels from two data sets. This methodology allows comparisons to quantify very accurately where cliffs may have receded, or beaches and dunes accreted or eroded.

Hallett Cove Beach Coastal Management Study

This study noted the lack of bathymetric data for the region of the coastline from the southern City of Marion boundary through to Kingston Park and stated that this 'data is essential for any future refinement of the coastal process understanding and beach management.It is recommended that the City of Marion discuss with CPB opportunities for this baseline survey data to be collected from the back of the beachfront dunes to a depth that overlaps the available survey data in deeper water (>10m) (p. 78)

The monitoring context

The indicators to be assessed (continued)

Within these predominantly cliff environments the key assessment relates to movements of the cliffs over time, in this case, five years.

However, hotspots need constant monitoring to ensure that they are not adversely impacted by storm action. For example, repeated storm action at the Marino Rocks Carpark may cause the base of the escarpment to erode quickly. Monitoring ensures that remedial action can be taken at the appropriate time and with limited cost.

Cell 1: Marino Cliffs

General monitoring issue	Indicator	Indicator reference (p.17)	Metric	Methodology
Cliff recession	Physical movement landwards of cliffs	A, B	m or m^3	Recapture 3D model and compare to baseline capture of 2018.
	Impacts to the base of the cliffs/ embankments	B	Nil	Annual visual inspection and post storm inspection (using drone photography)
Hotspot monitoring				
Inundation of The Esplanade	Overtopping of The Esplanade in storm events	M	Frequency and height AHD	Photograph/ inspection after storm events
Erosion of base of embankment at Marino Rocks carpark	Erosion of the base of the escarpment	B	m or m^3	Annual visual inspection and post storm inspection (using drone photography)

Cell 2: Hallett Cove Cliffs

General monitoring issue	Indicator	Indicator reference (p.17)	Metric	Methodology
Cliff recession	Physical movement landwards of cliffs	A, B	m or m^3	Recapture 3D model and compare to baseline capture of 2018.
	Impacts to the base of the cliffs/ embankments	B	Nil	Annual visual inspection and post storm inspection (using drone photography)
Hotspot monitoring				
The Esplanade and Clifftop Ave	Erosion of the base and top of the escarpment	A ,B	m or m^3	Annual visual inspection and post storm inspection (using drone photography)

The monitoring context

The indicators to be assessed (continued)

Cell 3 and 4 : Hallett Cove Beach and Field River

General monitoring issue	Indicator	Indicator reference (p.17)	Metric	Methodology
Dune recession (National Park, Field River area)	Vegetation line, escarpment position, sand volumes.	D, E, F	m^3	Recapture 3D model and compare to baseline capture of 2018. Capture 4x annually for 2 years by drone.
Embankment erosion (Heron Way, River Parade)	Recession of the base, or increase to the slope	A, B	m or m^3	Recapture 3D model. Capture 4x annually for 2 years by drone. Assess impact after storms.
Sand volumes on beach	Volume	Not listed (not possible in 2005)	m^3	Recapture 3D model. Capture 4x annually for 2 years by drone. Assess impact after storms.

The Hallett Cove Beach Coastal Management Study by Coastal Environment Pty Ltd

This study completed in 2012 by Dr Doug Lord recommended the following as a high priority:

A high priority is the establishment of a programme and methodology for monitoring changes to the beach along the Hallett Cove foreshore, to determine changes over time. This is 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 overall 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 on the beach changes. A likely strategy could include approximately two beach cross-sections (surveyed) within each identified beach section (see section 4.2) to be surveyed at six-month intervals. These could be augmented with more regular annotated photographs of the beach state or specific areas of interest, building a longer-term database of the area (p. 78)

Application

To basic methodologies are mentioned in the HCBCMS:

- **Utilise the community to collect data**
- **Create two beach cross sections to be surveyed at six-month intervals**

In relation to the latter, developments in drone technology mean that the whole beach can be captured and analysed at much less cost than conducting cross sections using traditional survey methods.
HCBCMS also recommends working with CPB in the design of the project.

The monitoring context

Cell 5: Southern Cliffs

The Southern Cliffs appear to be the least impacted by coastal processes and urban infrastructure is set well back from the cliff escarpment. Therefore, this cell is of the lowest monitoring priority.

General monitoring issue	Indicator	Indicator reference p. 17	Metric	Methodology
Cliff recession	Movement landwards of cliffs, evidence of instability.		m or m^3	Recapture 3D model and compare to baseline capture of 2018.
	Impact of storm events		na	After significant storm event, recapture by drone and compare.

EVALUATION AND REPORTING

City of Marion

EVALUATION AND REPORTING

Evaluation 1 (formative):

Throughout the project the following evaluation questions will apply in relation to hotspots:

1. What changes have occurred in hotspot locations?
2. What is the impact of storm events on hotspot locations?
3. What decisions should be made in regard to hotspots (ongoing)

Reporting: annually, and final report at culmination.

Evaluation 2 (summative)

At the conclusion of the project the following evaluation questions will be applied:

1. What is the range of beach volume (any trends)
2. What is range of movement of dune escarpments?
3. What movement has occurred in top or bottom of cliffs
4. What was nature and impact of storms (especially height at Marino and within Field River)

Reporting: at culmination of project

Evaluation 3

1. Were tasks that arose out of the coastal adaptation study completed?

Reporting: annually, and final report at culmination.

Evaluation 4

Annually, and at the conclusion of the project the following evaluation questions will be applied:

1. Has the project collected and analysed sufficient data to from an opinion about baseline behaviour
2. What changes should be made to the monitoring project post 5 years.

Reporting: annually, and final report at culmination.

CITIZEN SCIENCE

City of Marion

The term 'citizen science' within this project means the input from volunteers from the community in the data collection process. The normal way citizen science has been conducted in the context of coastal study is using the modern mobile for recording photography and/or videos.

CITIZEN SCIENCE

Citizen science is a relatively new concept first defined in the Oxford Dictionary in 2014 as, *Scientific work undertaken by members of the general public, typically in collaboration with professional scientists.*

Put simply, citizen science occurs when ordinary people help to conduct real scientific research[3].

Current examples:

In the context of coastal adaptation and monitoring, citizen science has mainly been focussed around the collection of photography. The purpose here is not to provide a comprehensive review of citizen science projects but rather to provide a context for understanding the type of citizen science that should be considered for City of Marion. Four current examples exist, and hyperlinks are included for easy review:

- Witness King Tides Project
- Coast Snap
- Fluker Posts
- Photomon

(See also Photomon case study on this page)

All of these projects involve the taking of photographs and uploading to websites. The final three on the list now have specialised phone apps that manage the uploading of the data more effectively.

Coast Snap and Fluker Posts control the point of view with simple structures so that appropriate comparisons can be made over time. Photomon controls the point of view using a baseline image within the app so that no infrastructure is required at the site.

Advantages of citizen science

It is imperative that Council engage the community in relation to coastal hazards and adaptation issues. There are two ways to achieve community engagement. The first is predominantly one-way communication from Council to the community utilising websites, presentations, workshops, and similar.

The second way is to involve the community in the collection of meaningful data and then to report back to the community about the findings. This type of engagement tends to be more two-way, and people become actively engaged, rather than passively interested (at best).

Another advantage of citizen science is the reduction in the cost of obtaining data. For example, to pay numerous personnel to monitor a storm event out of normal business hours would be almost impossible to manage, and cost-prohibitive. Well-organised and motivated volunteers could gather this data much more efficiently.

Challenges of citizen science

In conferring with experts with experience in this field the following challenges were noted[4]:

- Projects that have little focus usually collect relatively meaningless data
- The volume of data can be difficult to manage
- Projects require constant oversight.
- Councils are advised to outsource the management to a specialist that is collecting data within much larger regions.

Case Study: Photomon (WA)

In response to concerns about erosion the WA funded the development of an app which enables community volunteers to take photos of coastal erosion. The app works by using a reference photo that appears to subsequent photographers as a transparent image, thereby allowing the photograph to be taken in exactly the same position.

Since 2013, an army of community volunteers have recorded more than 10,000 photos at about 100 sites from Guilderton to Kalbarri. The app is now also being used to monitor weeds and revegetation sites.

[3] www.citizensciencecenter.com

[4] J. Carley, D. Lord, P Hesp and others.

CITIZEN SCIENCE

The main focus of this citizen science project is to collect data relating to the nature and impact of storm events.

Preliminary Concept:

Implement a number of monitoring points using a suitable photographic capture method where the aspect of images is captured in the same way.

Goals:

- Record the nature of the impact of storms upon selected dunes and escarpments
- Record the height of the water AHD at Marino and a tide pole positioned within Field River.

Methodology

- Recruit at two or three volunteers for each monitoring post.
- When a prescribed storm is developing volunteers are messaged the time at which they are required at their posts (this would normally be a 20 minute window of data capture).
- Data is uploaded to designated site where external consultant manages and analyses the data.

Locations

A preliminary set of locations are depicted on this page (further research required for final confirmation).

Tidal pole – Field River

Photo capture – Field River

Photo capture – Hallett Cove Beach

Photo capture – Heron Way Escarpment

Photo capture – Marino overtopping

Photo capture – Marino Rocks escarpment

THE MONITORING PLAN

City of Marion

This section includes the summary tasks of the monitoring plan, the proposed schedule, and indicative costs.

Matters remaining outstanding from Stage 2 of the Coastal Adaptation project have also been brought into this plan to ensure that these matters receive appropriate attention.

THE MONITORING PLAN

Summary

The purpose (p. 15)

- To obtain a baseline understanding of how the City of Marion coastline operates within this current era so as to inform future decision making
- A secondary purpose is to monitor current hotspots so as to inform current decision making.

The Type (p. 16)

- Predominantly summative – the data will be collected and analysed to produce a final report that details the normal parameters of the beach
- Secondarily, informative – specific data will be collected and analysed from hotspots locations to inform current decision making.

Project length (p. 16)

- Five years

Indicators to be assessed

- See pages 17-20

Evaluation

- Annually, and main report at culmination of the project

Project management

- Recommendation: external consultant specialising in monitoring services, and who will also manage the citizen science aspects of the project.

Project outcomes

- Baseline understanding of the parameters in which the coastline of City of Marion operates. Analysis of data upon which to make decisions in regard to hotspots. These outcomes compiled into annual reports, end of project reporting, and presentations to community and Council.

THE MONITORING PLAN

No.	Item	Rationale	2019/2020	2020/2021	2021/2022	2022/2023	2023/2024	Total over five years
1	Recapture 3D model, including ground-truthing, and comparative analysis.	A key plank in the monitoring plan that enables detailed comparison between two data sets five years apart					$25,000	$25,000
2	Biannual capture sand volumes for Hallett Cove Beach and Field River (drone capture)	Noted as high priority in Hallett Cove Beach Management Study from which to base future management decisions	$5,000	$5,000	$5,000	$5,000	$5,000	$25,000*
3	Capture bathymetry for Hallett Cove Beach as a baseline for future comparisons.	Noted as a priority in Hallett Cove Beach Management Study from which to ascertain longer-term outlook.	0	0	0	0	0	$0
4	Analyse wave buoy data from Port Stanvac (new installation by Flinders University)	Analysing wave buoy data will provide a context from which to understand the trends that drive the coastal processes.	$2,000	$2,000	$2,000	$2,000	$2,000	$10,000
5	Initiate and operate a citizen science project at key locations.	Citizen science projects are a cost-effective way to collect data and also a way to involve the community in coastal management.	$5,000	$5,000	$5,000	$5,000	$5,000	$25,000
6	Install tidal pole within Field River	As part of the citizen science project useful tidal data can be obtained and recorded.	$7,500	0	0	0	0	$7500
7	Implement photo monitoring points and recording methods	As part of the citizen science project useful tidal data can be obtained and recorded.	$7,500	0	0	0	0	$7500
8	Monitor storms (x2 per annum). Recapture coastline using drone to identify damage. Analyse wave buoy data.	Two reasons: Assess impacts at hotspot locations and identify the nature and impact of the storm to improve baseline understanding of storm action in the context of sea level rise.	$4,000	$4,000	$4,000	$4,000	$4,000	$20,000
9	Annual report, evaluation and communication to key partners and the community		$5,000	$5,000	$5,000	$5,000	$10,000	$30,000
	Totals		**$36,000**	**$21,000**	**$21,000**	**$21,000**	**$51,000**	**$150,000**

*Based on preliminary quote received from Airborne Data Acquisition at 2.5k per day (including supply of data). **Project to be negotiated with Coast Protection Board.

OTHER ACTIONS

Stage two of Coastal Climate Change Adaptation Plan identified four other areas of study or work:

1. Further geological/ geotechnical analysis at three locations along the coastline:
   Marino Carpark
   Westcliff which is situated on Pleistocene material
   The Esplanade, Hallett Cove

   See p. 368 of Coastal Climate Change Adaptation Plan.

2. Review and rectify impact of stormwater on coastal environs

   A repeated theme in the geological study and in advice received from Coast Protection Board is the requirement to effectively control the discharge of storm water through cliff environs. The first reason is to ensure that storm water is adequately managed to limit the erosion of cliffs and dunes. 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 deemed as part of the cause of the incident, then Council may be held liable for the event. (See pg 368,369 of Coastal Climate Change Adaptation Plan). Storm water is currently gullying the dunes of Hallett Cove Beach.

3. Design and install protection items

   Field River area: It is likely that protection options will be required in the Field River area to slow progress of erosion of the sand spit and sand dunes. The embankment to the west of River Parade may also need erosion control measures.

   Heron Way Reserve: A solution is required for the increasing slope of the escarpment at Heron Way Reserve, but this should be considered in the context of the proposed tidal pool (see also HCBCMS, p.79)

   The Esplanade at Marion in extreme events is being over-topped by wave run-up and a way to prevent this occurring should be investigated. The rock revetment in this location is also degraded.

4. Review urban planning policy

   It is difficult to quantify what the impact of increasing sea levels upon cliffs and dunes will be over the coming century. There are two main areas of concern. The first is in the context of new subdivisions (ie the expansion of the urban settlement), although this is an unlikely issue within the coastal environs of Marion Council as most areas are already developed. The second relates to any increases to density. This matter is especially important within areas close to cliff escarpments, dunes or embankments.

See also pps 78, 79 of Hallett Cove Beach Coastal Management Study, Coastal Environmental, 2012.

BIBLIOGRAPHY

Assenbaum M (2018) Monitoring coastal erosion with UAV Lidar, https://www.gim-international.com/content/article/monitoring-coastal-erosion-with-uav-lidar . Accessed May 2019

Baker T, Woodworth P, Blewitt G, Boucher C & Woppelmann G (1997) A European network for sea level and coastal land level monitoring, Journal of Marine Systems 13 pp163-171.

Baptista P, Bastos L, Bernades C, Cunha T & Dias J (2008) Monitoring Sandy Shores Morphologies by DGPS_ A practical tool to generate digital elevation models, Journal of Coastal Research, 246, pp1516-1528.

Blacka, M., 2017: Coastal Imaging: using coastline monitoring to observe and analyse coastal processes. Snapshot for CoastAdapt, National Climate Change Adaptation Research Facility, Gold Coast.

Blasco F, Saenger P & Janodet E (1996) Mangroves as indicators of coastal change, Catena, 27 pp167-178.

Boak E & Turner I (2005) Shoreline definition and Detection: A Review, Journal of Coastal Research, 21 (4), pp688-703.

Bruun P (1962) Sea level rise as a cause of shore erosion, Journal of Waterways Harbors Division, 88, pp 117-130.

Chabaan F, Darwishe H, Battiau-Queney Y, Louche B, El Khattabi J & Carlier E (2012) Using ArcGIS Modelbuilder and Aerial Photographs to Measure Coastline Retreat and Advance: North of France, Journal of Coastal Research, 28 (6), pp1567-1579.

Cigliano J, Meyer R, Ballard H, Freitag A Phillips T & Wasser A (2015) Making marine and coastal citizen science matter, Ocean and Coastal Management, 115 pp77-87.

City of Wannaroo (2019) Coastal Monitoring, http://www.wanneroo.wa.gov.au/info/20041/environment/236/coastal_management/13 Accessed May 2019.

Esteves L, Williams J, Nock A & Lymbery G (2009) Quantifying shoreline changes along the Sefton coast (UK) and the implications for research informed coastal management, Journal of Coastal Research, 56(1), pp602-606.

Florida Department of Environmental Protection (2019) https://floridadep.gov/water/beach-field-services/content/regional-coastal-monitoring-data . Accessed May 2019

Fluker Posts (ND) http://www.flukerpost.com/ Accessed May 2019.

Geomatics World (2017) UAV monitoring of coastal erosion, https://www.geomatics-world.co.uk/content/article/uav-monitoring-of-coastal-erosion

Goncalves R, Awange J & Krueger C (2012) GNSS-Based monitoring and mapping of shoreline position in support of planning and management of Matinhos/PR Brazil, Journal of Global Positioning Systems, 11 (1), pp156-168.

Gold Coast City Council (ND) Coastal Monitoring, http://www.goldcoast.qld.gov.au/thegoldcoast/coastal-management-3246.html .Accessed May 2019.

Gold Coast City Council (ND) Coastal Monitoring: Shoreline Position, http://www.goldcoast.qld.gov.au/thegoldcoast/coastal-management-3246.html . Accessed May 2019

Gorman L, Morang A & Larson A (1998) Monitoring the Coastal Environment; Part IV: Mapping Shoreline changes and bathymetric analysis, Journal of Coastal Research, 14(1), pp61-92.

Leatherman S (2003) Shoreline mapping and management along the US east Coast, Journal of Coastal Research, 38 pp5-13.

Leatherman S & Douglas B & La Brecque J (2003) Sea level Rise and Coastal Erosion Require Large Scale Monitoring, Eos, 8(2), pp13-20.

Lewis A, Oliver S, Lymburner L, evans B, Wybourn L, Mueller N,Raevski G, Hooke j, Woodcock R, Sixsmith s, Wu, W, Tan P, Li F, Killough B, Minchin S, Roberts D, Ayers D, Biswajit B, Dwyer J, Dekker A, Dhu T, Hicks A, Ip A, Purrs M, Richards C, Sagar S, Trenham C, Wang P & Wang L-W, (2017) The Australian Geoscience Data Cube, Remote Sensing of Environment, 201 pp276-292.

Lim M, Rosser N, Allison R & Petley D (2010) Erosional processes in the hard rock coastal cliffs at Staithes, North Yorkshire, Geomorphology, 114, pp12-21.

Mathew, S., S. Trueck, and C. Truong, 2016: Monitoring the effectiveness of beach nourishment in the City of Mandurah. Snapshot for CoastAdapt, National Climate Change Adaptation Research Facility, Gold Coast.

Mathew, S., S. Trueck, and C. Truong, 2016: Monitoring and evaluation in the City of Shoalhaven. Snapshot for CoastAdapt, National Climate Change Adaptation Research Facility, Gold Coast.

McCormick S, (2012) After the Cap: Risk Assessment, Citizen Science and Disaster Recovery, Ecology and Society, 17(4), pp31.

McGuiness, V., 2017: Community Photo-Monitoring in Western Australia. Snapshot for CoastAdapt, National Climate Change Adaptation Research Facility, Gold Coast.

Mills J, Buckley S, Mitchell H, Clarke P& Edwards S (2005) A geomatics data integration technique for coastal change monitoring, Earth Surface Processes and Landforms, 30 pp651-664.

Murphy, D., 2016: Bega Valley Shire Integrated Coastal Management Program. Snapshot for CoastAdapt, National Climate Change Adaptation Research Facility, Gold Coast.

NSW Government (2019) Coastsnap Beach Monitoring, https://www.environment.nsw.gov.au/research-and-publications/your-research/citizen-science/digital-projects/coastsnap

Office of Environment and Heritage (2017) CoastSnap, https://www.environment.nsw.gov.au/research-and-publications/your-research/citizen-science/digital-projects/coastsnap NSW Government. Accessed 12/03/2019

Plymouth Coastal Observatory (2019) Bathymetry, https://southwest.coastalmonitoring.org Accessed April 2019.

Ranasinghe R, Callaghan D & Stive M (2012) Estimating coastal recession due to sea level rise: beyond the Bruun rule, Climatic Change, 110, pp561-574.

Ruggiero P, Kaminsky G, Gelfenbaum G & Voight B (2005) Seasonal to Interannual Morphodynamics along a High-Energy Dissipative Littoral Cell, Journal of Coastal Research, 213, pp553-578.

Sutherland J (2007) Inventory of coastal monitoring methods and overview of predictive models for coastal erosion, Commission of the European Communities.

Sutherland J (2010) Guidelines on Beach Monitoring for Coastal Erosion, Commission of the European Communities.

Tuominen M (2016) Coastal Mapping & Foreshore Monitoring for the Gold Coast, http://bennettandbennett.com.au/photogrammetry-blog/coastal-erosion-mapping-foreshore-monitoring-for-the-gold-coast/ Viewed May 2019.

Waikato Regional Council (2019) Shoreline Change Monitoring, https://waikatoregion.govt.nz/environment/natural-resources/coast/coastal-monitoring/cam-era-video-beach-monitoring/ . Accessed May 2019

Water Research Laboratory (ND) Narrabeen – Collaroy Coastal Monitoring, http://ci.wrl.unsw.edu.au/current-projects/narrabeen-collaroy-beach/ . Accessed May 2019.

Watson P (2011) Is there evidence yet of acceleration in mean sea level rise around mainland Australia? Journal of Coastal Research, 27(2) pp368-377.

WA Government, New industries (2019), Photomon, https://www.innovation.wa.gov.au/showcase/photomon . Accessed May 2019

Williams K, Ewel K, Stumpf R, Putz F& Workman T (1999) Sea Level Rise and Coastal Forest Retreat on the West Coast of Florida, USA, Ecology 80(6), pp2045-2063.

Witness King Tides Project (ND) http://photos.witnesskingtides.org/ . https://www.ecocitizenaustralia.com.au/king-tides-project/ Accessed May 2019.