ABM
ASSOCIATION OF BAYSIDE MUNICIPALITIES

Final Report | 2018

Port Phillip Bay
Managing Better Now program

REPORT 05

PORT PHILLIP BAY STORM BITE ANALYSIS

This report has been prepared by Cardno Victoria Pty Ltd for the Association of Bayside Municipalities as part of the Managing Better Now program.

ASSOCIATION OF BAYSIDE MUNICIPALITIES

The Association of Bayside Municipalities represents the ten councils with frontage to Port Phillip Bay. As coastal councils we are acutely aware of the need to protect and manage Port Phillip Bay for our local communities, and for the benefit of all Victorians, tourists and the unique ecosystems it supports.

As the appointed Committee of Management for much of the Port Phillip Bay coast, councils play a vital role in the environmental management of Port Phillip Bay, as the foreshore manager, strategic land use planning authority; asset manager; and service provider to Parks Victoria or other Committees of Management, and more.

The ABM vision is a healthy Port Phillip Bay that is valued and cared for by all Victorians.

ABM MEMBER COUNCILS:

ACKNOWLEDGEMENTS

The Association of Bayside Municipalities acknowledges funding from Member councils and state government to enable the Managing Better Now program. Thank you to the staff from ABM Member Councils and Melbourne Water for providing technical input and feedback on the reports.

The Association of Bayside Municipalities recognising the substantial support from Cardno in preparing the reports, and presenting the outputs and recommendations over many years.

Disclaimer

The Managing Better Now report series (the publication) is intended as a general reference guide, providing information on coastal processes affecting Port Phillip Bay. While due care has been taken in the compilation of the publication, the Association of Bayside Municipalities does not guarantee that the publication is without flaw (including error, omission or inaccuracy). Users of the publication need to make their own enquiries to ensure fit for purpose. The Association of Bayside Municipalities will not be liable for any loss, damage or other consequences arising from the use of this publication.

EXECUTIVE SUMMARY

The *Managing Better Now* program is an initiative of the Association of Bayside Municipalities.

Launched in 2013, the program aimed to better understand the dynamics and coastal processes of Port Phillip Bay using data modelling and analysis to:

- Improve knowledge of coastal processes in Port Phillip Bay, and their effects on vulnerable sections of the coast.
- Understand present and future risks and hazards.
- Inform the management of coastal processes impacting Port Phillip Bay 'now' and into the future.
- Contribute to a future coastal hazard assessment for Port Phillip Bay.

Outputs from the Managing Better Now program are designed to support better decision making, clearer investment, management and planning by ABM Member Councils and other bay stakeholders in:

- beach protection,
- local coastal hazard and risk assessment,
- foreshore and infrastructure management,
- maintenance planning and response to weather extremes, and
- coastal climate adaptation.

Using a 'step by step' approach, the program was undertaken in phases with work proceeding as funding and resources were secured.

Phases 1 and 2 examined the programs, strategies and approaches used to manage the coastline, beaches and immediate foreshore areas, identifying gaps in knowledge. Phases 3, 4 and 5 gathered existing information and invested in data modelling and analysis of new essential data, mapping and modelling – compiling a series of reports aimed at better understand the dynamics of Port Phillip Bay.

As coastal mangers, the ABM recognises the importance of using the best available information, and values working in partnership to improve understanding of the processes and systems affecting Port Phillip Bay

The following reports comprise the Managing Better Now series, and are available on the ABM website at www.abm.org.au.

REPORT **Snapshots**

Final Report | 2013

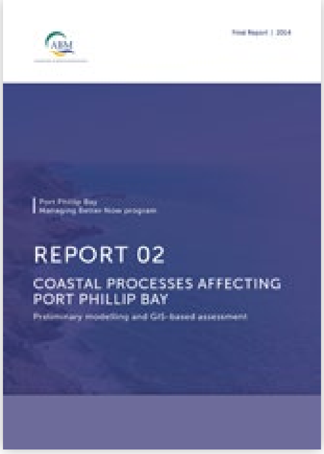
Port Phillip Bay
Managing Better Now program

REPORT 01

COASTAL PROCESSES AFFECTING PORT PHILLIP BAY – PRELIMINARY DATA COLLECTION AND GAP ANALYSIS

Report #1: Coastal Processes Affecting Port Phillip Bay - preliminary data collection and gap analysis

Identification of existing spatial and non-spatial information to inform a coastal hazard assessment. This included spatial data layers, over 200 technical reports, images and 60 strategies and plans relevant to Port Phillip Bay. More than 200 GIS data layers were identified and stored on an online GIS portal, made available to ABM councils.



Final Report | 2014

Port Phillip Bay
Managing Better Now program

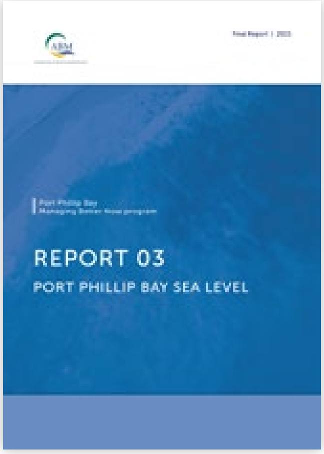
REPORT 02

COASTAL PROCESSES AFFECTING PORT PHILLIP BAY

Preliminary modelling and GIS-based assessment

Report #2: Coastal Processes Affecting Port Phillip Bay – preliminary modelling and mapping of coastal asset location and proximity to the Port Phillip Bay shoreline; and GIS-based assessment of width and volume of erodible land along Port Phillip Bay.

- **Part 1:** Preliminary modelling and mapping of coastal asset location and proximity to the Port Phillip shoreline. Purpose of this study was to use readily available spatial information layers identified in Report 1 to locate and map coastal assets at a bay-wide scale, and improve understanding of the proximity of assets to the Port Phillip Bay shoreline. This work was not intended to be a comprehensive study or replace a local hazard study. It provided a demonstration of the type of analysis that can be undertaken using readily available spatial data layers, informing local studies by individual coastal land managers such as the effects of coastal storms on sections of shoreline, the effects of coastal inundation on parts of the coast, the quality of drainage networks and associated infrastructure to model water flow, availability of information for assets of significance, their values, etc.
- **Part 2:** Spatial Analysis of area (width) and volume of erodible land along Port Phillip Bay. Three methodologies were used to demonstrate the calculation of area and volume of sand between the mean sea level (taken as the shoreline) and three different landward extents. The landward extents are based on existing infrastructure such as roads or houses; horizontal distances (eg, within 5 metres, 10 metres, etc.); or vertical elevation (eg, 0.5 metres, 1.0 metres, etc.) from the shoreline. Information about physical processes or hazards, including sediment transport rates, wave impacts, shoreline erosion rates or other such information was not available. The approach used is of generic and demonstrative nature and can be applied around Port Phillip Bay; and substantially enhanced if coupled with information about coastal processes and coastal hazard information.



Report #3: Port Phillip Bay Sea Level

Analysis of existing historical sea level data for Port Phillip Bay measuring sea levels over an extended period at multiple locations. Data was collected from Port of Melbourne Corporation, National Tidal Centre, Victorian Regional Channel Authority and Melbourne Water. Data was subjected to extreme value analysis to develop values for sea level with Annual Exceedance Probabilities at 1%, 2%, 5% and 10% (corresponding to Annual Recurrence Intervals of 100, 50, 20 and 10 years).

The results are intended to support the setting of values for planning and design, not replace decisions made by the appropriate responsible authorities. Results may be useful in establishing regional variations; undertaking assessments of the appropriate values in setting planning benchmarks and design criteria; investigating potential risks; supporting planning, design and assessment of future coastal vulnerability considering climate change.

Report #4: Port Phillip Bay Wave Climate

Wave modelling for the whole of Port Phillip Bay using a tested and consistent approach. The modelling incorporated annual and seasonal occurrence of wave conditions, highlighting the marked seasonal variability in wave conditions over Port Phillip Bay resulting from seasonal wind changes. The longshore component of wave power was also computed for the entire shoreline providing insights into the annual and seasonal variability of potential sediment transport around Port Phillip Bay.

Modelling results can be used to understand phenomena observed on a specific beach, or to review broad bay-wide scale processes.

In addition to the data presented in the report, detailed frequency of occurrence matrices for each of the 248 data extraction points have been provided as tables which can be accessed via a Geographic Information System. Contact the ABM for further information.

Report #5: Port Phillip Bay Storm Bite Analysis

Building on the previous studies of waves and sea levels in Port Phillip Bay, this project modelled likely volumes and extent of storm bite erosion on 20 beach profiles in Port Phillip Bay between Little River and Sorrento, under varying storm conditions. Results inform changes in beach profile following an individual storm event, and the magnitude of the storm event.

This report provides a first-pass risk assessment of coastal erosion that can be used to identify and prioritise areas of concern; focus more detailed studies on areas of intolerable risk level; and to understand what level of coastal erosion might be expected in a 'typical' or an 'extreme' storm event.

Contents

Figures

Tables

01. Introduction

The increasing physical, economic and liability risks associated with climate change, including those resulting from erosion hazards, is a growing challenge faced in the management our coastlines. A coastal erosion risk analysis typically requires both numerical modelling and detailed measurements to calibrate and validate the model, in order to provide quantitative estimates of risk and minimise the uncertainty.

However, there is insufficient data and understanding of the relevant processes for Port Phillip Bay to support this detailed level of risk analysis. Despite the uncertainty, coastal managers are still required to manage coastal erosion risk, including assessing the risk level and evaluating it against risk criteria. The Association of Bayside Municipalities (ABM) commissioned a first-pass risk assessment that can be applied throughout Port Phillip Bay, to identify and prioritise areas of concern.

Cardno have built on its previous investigations of waves and water levels in the Bay to undertake this first-pass risk assessment of coastal erosion. This study aims to:

- Identify areas that require subsequent detailed studies due to an intolerable risk level.
- Provide managers with information on what level of coastal erosion might be expected in a 'typical' or an 'extreme' storm event.

02. Background

2.1. Coastal Processes

- **Astronomical tides** are changes in level due to gravitational effects, with ebb (falling) and flood (rising) tides.
- **Wind** blowing over the water surface causes a change in level (water 'piling up' against the coast towards which the wind is blowing).
- **Atmospheric pressure** leads to changes in sea level (high pressure lowers sea level, low pressure increases sea level).
- **Storm surge** is the combined effect of wind and atmospheric pressure on sea levels
- **Storm tide** is the combination of astronomical tides and storm surge

The coast is the interface between the ocean and the land. Interactions occurring in this environment are complex.

Energy from the ocean is transferred onto the coastline, moving sediment, creating flow paths and reshaping the coast. Storms see wave energy and water levels acting together.

The astronomical tides, winds and atmospheric pressure all impact on water levels.

Waves are generated by wind blowing over the surface of the ocean. The height of waves depends on the strength of the wind, the length of time it blows, and the distance over water that the wind is able to generate waves. This distance is called the fetch. In Port Phillip Bay, all the waves north of the Great Sands are called 'fetch-limited' due to limitation on the distance the wind can blow over the water.

Extreme events, such as strong winds and waves occurring during high tides, often result in erosion and flooding of sections of coast. Figure 1 shows the different contributors that influence the water level and influence onshore response, including nearshore water-level characteristics of wave setup, runup, and overtopping.

Wave setup is an increase in the mean water level due to the presence of waves, while wave runup is the extra height or extent that broken waves reach as they run up the beach.

Storm surge is the combination of a reduction in atmospheric pressure combined with severe winds during storms. The combination of storm surge and the astronomical tides is called the storm tide. This leads to increased water levels and may result in temporary flooding during a storm event as the increased water levels propagate inland.

Erosion processes can be considered to have varying time scales: short-term and long-term. To manage erosion on the coast, both the short-term and long-term sediment processes must be considered.

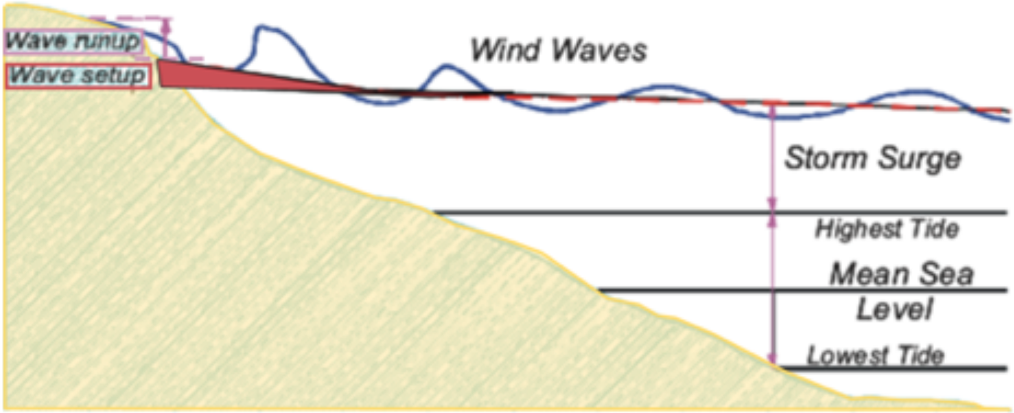


Figure 1: Components of storm tide and breaking wave processes (modified version of CSIRO Storm Tide image)

Short-Term Processes	Long-Term Processes
• response to a single storm • often called 'storm bite' • sediment transported offshore and alongshore • loss of sediment may see shoreline become too steep and unstable. Results in adjustment of profile by slumping	• shoreline advance (accretion) • shoreline retreat (erosion) • gradual response of shoreline over time • change of the alignment of the shoreline

During a storm, wave energy acts in combination with the water level (wave set-up + storm tide) and higher sea level allows the wave energy to reach further inland. This results in sediment being eroded from the shoreline and transported offshore and alongshore. During periods of lower wave-energy, sand is moved back towards the shoreline, rebuilding the beach. The balance between these two processes determines whether the coast is eroding or accreting over the long term.

In Port Phillip Bay, ocean swell from Bass Strait is a driving force of shoreline change only in the southern section of the bay adjacent to Port Phillip Heads. Wind-generated waves, tides and resulting currents shape the coast in the remainder of the bay, between Edwards Point, north of Queenscliff, through Melbourne to Point King, just west of Sorrento (map shown in Figure 2). Storm surges affect all sections of the coast and estuarine areas, even where wave effects may be very small.

Some understanding of coastal processes and key contributors to coastal erosion can assist coastal land managers in anticipating the likely response during and following an individual storm event.

This report will consider only short-term processes.

Long-term processes require analysis of the cumulative effects of numerous storms and other coastal processes, including sediment transport at both a local and regional scale. It is also necessary to include beach rebuilding processes, which occur between storms. This is a complex process involving small changes over long periods of time, generally beyond the scope of most modelling techniques.

There is variability in the astronomical tides. This includes daily cycles, the fortnightly spring-neap cycle and season cycles with so-called 'king tides', which are the highest spring tides, occurring on six-monthly and annual cycles. If a storm surge occurs at a time of neap tides, it may have much less effect on beaches than the same surge occurring at the high water of a large spring tide. This combination is termed 'storm tides'.

2.2. Storm Bite

Sudden loss of material from the coast can trigger a significant maintenance response in order to remedy the state of the beach, minimise risk to beach users, and protect surrounding assets. The amount of sand cut from the coast in a storm event is referred to as 'storm bite', and is considered a short-term erosion process. The beach profile immediately after a storm may have a very steep profile, which can then slump and adjust to a more stable slope as shown in Figure 2.

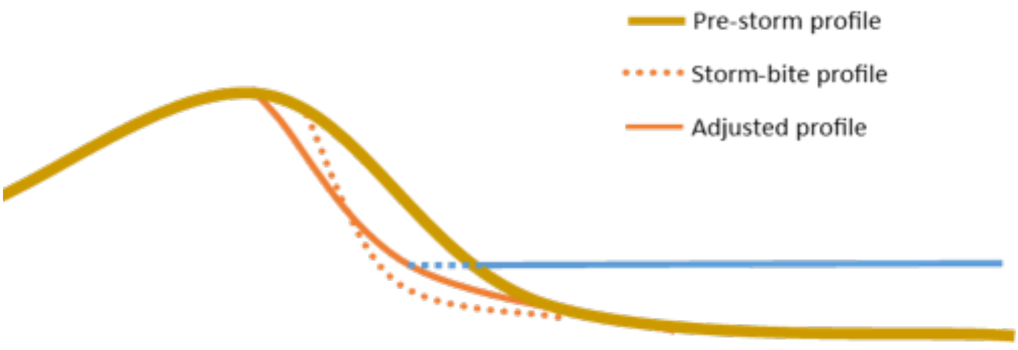


Figure 2: Post-storm beach profile, showing a typical steep 'storm bite' profile directly following storm and the 'adjusted' profile due to instability and resultant slumping.

To assist in the management and readiness of coastal managers, this project aims to quantify the likely volumes and extent of storm bite for the particular beaches around Port Phillip Bay under varying storm conditions.

03. Approach and Method

Aligned with best practice, Cardno implemented a *SBEACH* model using a Monte Carlo approach (see Technical Supplement). This approach supports managing and communicating uncertainty associated with determining the coastal erosion risk level. It was designed to overcome some data availability constraints, synthesising valid data inputs (sea level, winds and resulting waves) for use in this simple and robust erosion model. A modelling framework is shown in 0 and described in more detail in Technical Supplement (Appendix A).

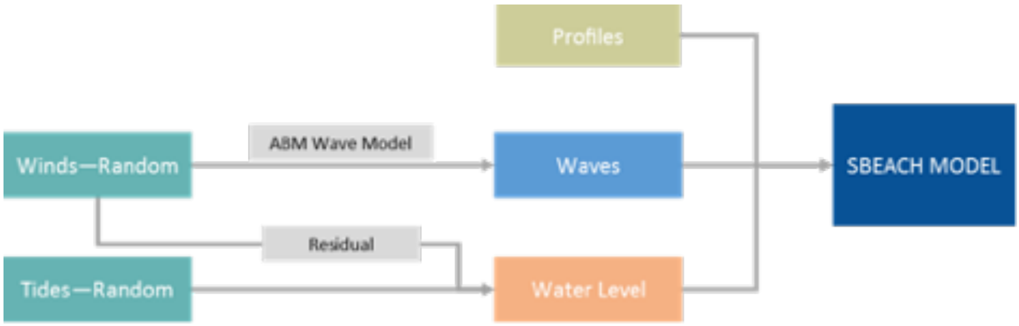
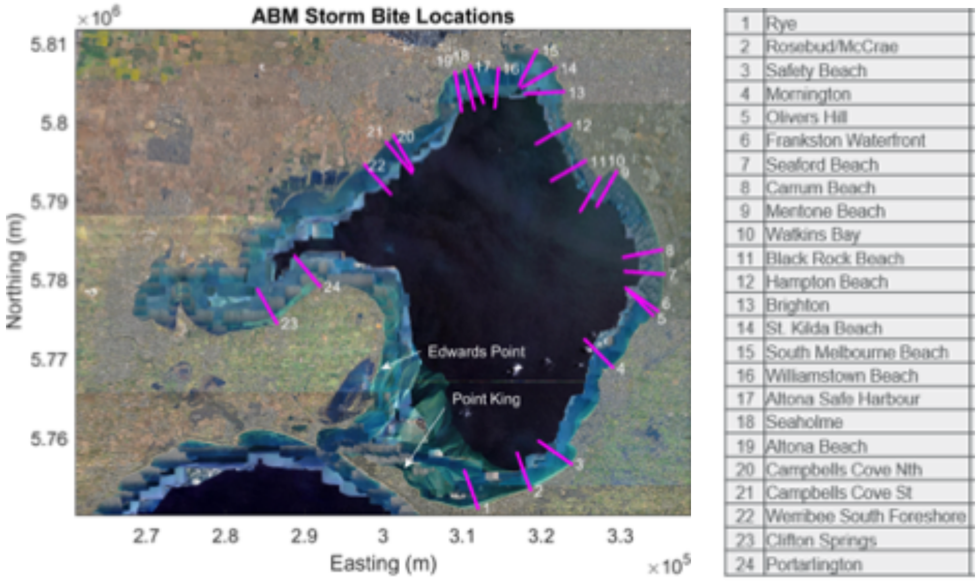


Figure 3: Post-storm beach profile, showing a typical steep ‘storm bite’ profile directly following storm and the ‘adjusted’ profile due to instability and resultant slumping.

Member councils nominated suitable locations to include in the analysis. Twenty-four beach profiles were selected and assessed along the Port Phillip Bay coastline. Figure 4 presents the selected locations.



1	Rye
2	Rosebud/McCrae
3	Safety Beach
4	Mornington
5	Olivers Hill
6	Frankston Waterfront
7	Seaford Beach
8	Carrum Beach
9	Mentone Beach
10	Watkins Bay
11	Black Rock Beach
12	Hampton Beach
13	Brighton
14	St. Kilda Beach
15	South Melbourne Beach
16	Williamstown Beach
17	Altona Safe Harbour
18	Seaholme
19	Altona Beach
20	Campbells Cove Nth
21	Campbells Cove St
22	Werribee South Foreshore
23	Clifton Springs
24	Portarlington

Figure 4: Locations selected for analysis

Cross-sections were taken perpendicular to the coast for each location, extracting elevations from Future Coasts (LADS) bathymetry. Locations were assumed to be beaches composed only of sand (no allowance for underlying rock or similar). Where known, cliffs and seawalls were taken into consideration.

Ten thousand storms were simulated for each location, for present day and under a sea level rise scenario of +0.4 m sea level rise (SLR). A nominal sea level rise of + 0.4 m was selected. It provides an understanding of how storm bite behaviour may potentially change over the next 20 to 30 years, with the intention to aid management actions in the not too distant future. It was not intended to model any specific climate change scenario. The storms were used to generate site-specific wave and water level conditions for each location.

SBEACH used these inputs to calculate resulting beach profiles. It identified the change in beach elevation following a storm, and how much sand is lost or gained on the beach.

Figure 5 is an example of the modelling outputs generated, showing the beach response to all 10,000 individual storm simulations at Rosebud. The beach profile, a cross-section perpendicular to the coast, is shown as elevation along a chainage distance that increases as it extends offshore.

The yellow line shows the elevation of the beach profile pre-storm. The blue lines are the resultant storm bite profiles, showing the change in elevation, and the movement and redistribution of sand after each of the 10,000 simulated storms.

The resulting profiles can be examined to understand the likely erosion response under various scenarios. Some events will move sand offshore, while others may push sand higher back up the beach. From these results, the impacts from different storm events has been quantified, estimating approximate distances and volumes of sand moved offshore.

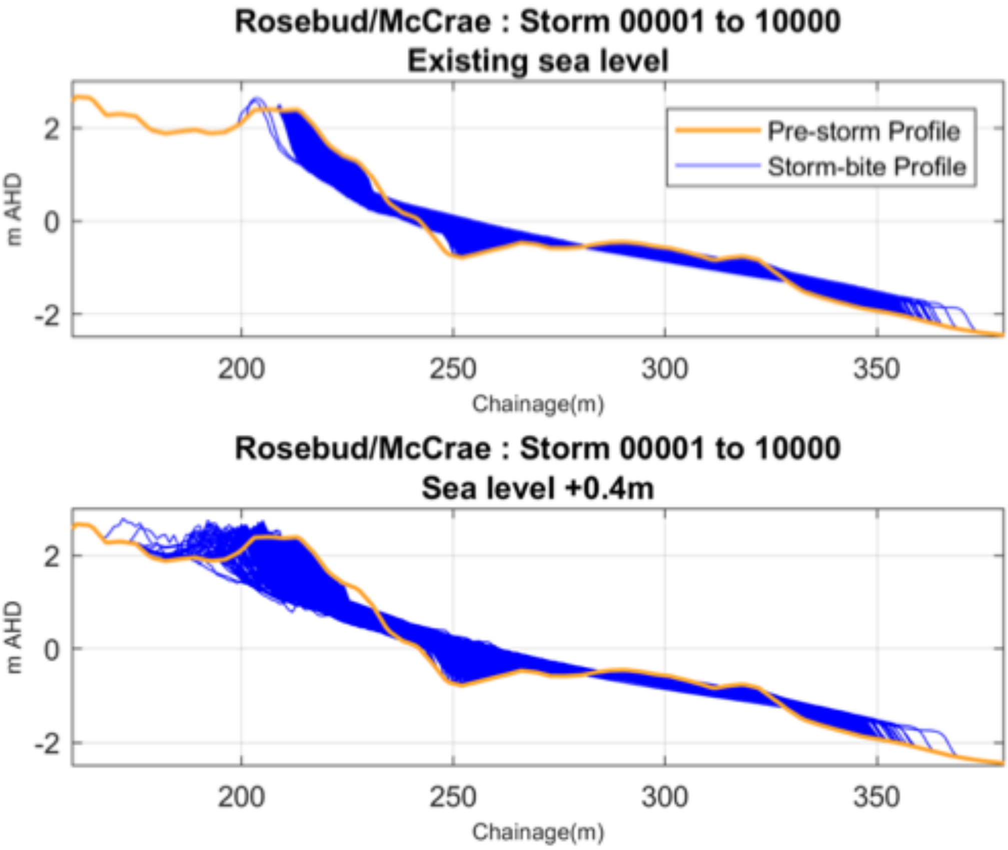


Figure 5: Example of SBEACH results at Rosebud. NB. Each blue line is resultant storm bite profile following an individual storm

Figure 5 (above) also demonstrates the impact of sea level rise, increasing the erosion impacts. Water levels and waves act together in a storm to impact the coast. An increased sea level allows larger waves to reach further onshore, seen in the second example plot for Rosebud. With water levels and waves penetrating further inland, so too has the sediment movement, with the resultant blue lines reaching further landward. This increased erosion results in reduced elevation of a small berm at this location.

3.1. Application of Results

To understand how a beach might respond under a 'typical' or an 'extreme' storm event beach profiles for the 10,000 simulated storms were analysed to determine:

- The portion of the beach profile experiencing sand loss, where sand was moved offshore.
- The volume of sand lost, per one metre of beach front, when sand moved offshore

In general, where the storm bite profiles (shown in blue) are lower than pre-storm profile (shown in yellow), sand has been eroded. On the other hand, where the storm bite profile is above the pre-storm profile, sand has built up, a likely result of erosion happening further onshore.

Using the Rosebud example, **Error! Reference source not found**. shows the approximate extent of beach ('distance') impacted by sand loss. For the majority of the 10,000 simulated storms, erosion impacts were evident across a 20 to 25 metre distance. These results are also representative of the distance the shoreline would retreat, although this is a less well-defined number due to tidal variations day to day. The volume of sand that the change in elevation corresponds to can also be estimate by the change in area under the profile curve. By exception, two events resulted in the berm reshaped and some sand pushed further shoreward.

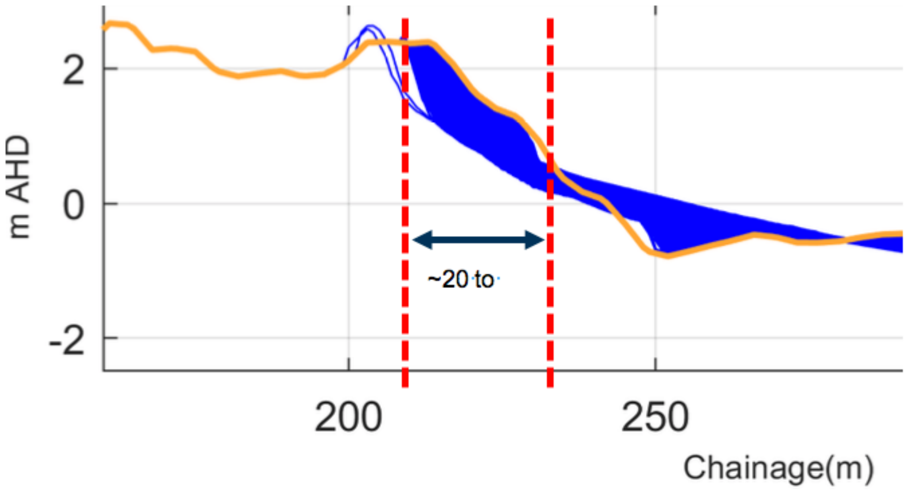


Figure 6: Zoomed resultant profile highlighting the of beach impacted by sand loss ('Distance')

The Average Recurrence Interval (ARI) and the Annual Exceedance Probability (AEP) can each be used as a measure of the likelihood of a particular storm event occurring. The ARI is defined as the average amount of time between events that exceed a particular value (eg. a '100-year ARI' is the value which is exceeded, on average, once every 100 years), while the 1% AEP is a storm event with a 1% chance of occurring in any given year.

For this study, a 63% AEP or 20 % AEP (1-yr or 5-yr ARI) is considered a 'typical' event while a 1% AEP (100-yr ARI) would be an 'extreme' event.

Table 1: ARI & AEP approximate conversion

ARI (yr)	AEP (%)
1	63
5	20
10	10
100	1

SBEACH results are presented for each site, showing the calculated beach response to individual storms. AEP was used to present these statistics by site.

Table 2: SBEACH results showing estimated distances and volumes for 24 locations, ranging from typical to extreme AEP storm events. Under present day and sea-level rise scenarios

		Present Day							
		DISTANCE (m)				VOLUME (m3/m)			
	AEP (%)	63	20	10	1	63	20	10	1
1	Rye	9	10	10	11	1	1	2	3
2	Rosebud/McCrae	11	12	14	17	3	3	4	6
3	Safety Beach	8	8	9	20	2	2	2	7
4	Mornington	5	6	7	15	1	1	1	6
5	Olivers Hill	0	0	0	36	8	8	8	11
6	Frankston Waterfront	6	7	7	18	1	1	1	3
7	Seaford Beach	17	17	17	18	8	8	8	10
8	Carrum Beach	15	16	17	24	2	3	3	5
9	Mentone Beach	7	8	8	10	1	2	2	3
10	Watkins Bay	3	3	4	5	2	3	3	4
11	Black Rock Beach	0	0	0	0	5	6	7	11
12	Hampton Beach	13	14	14	19	5	6	6	9
13	Brighton	10	11	11	12	4	5	5	7
14	St. Kilda Beach	9	10	10	13	1	1	1	1
15	South Melb. Beach	12	13	13	15	3	3	3	5
16	Williamstown Beach	8	9	9.5	11	2	3	3	4
17	Altona Safe Harbour	3	4	5	6	0	0	0	1
18	Seaholme	3	5	5	12	0	0	0	2
19	Altona Beach	0	0	0	4	0	0	0	0
20	Campbells Cove Nth	0	0	0	5	0	0	0	0
21	Campbells Cove Sth	7	7	7	8	3	3	3	3
22	Werribee Sth Foreshore	6	6	7	8	2	2	2	3
23	Clifton Springs	6	7	7	9	1	1	1	2
24	Portarlington (Ramblers Rd)	4.5	5	6	9	1	1	1	3

		Present Day							
		DISTANCE (m)				VOLUME (m3/m)			
	AEP (%)	63	20	10	1	63	20	10	1
1	Rye	10	10	10	13	5	5	5	7
2	Rosebud/McCrae	12	13	14	18	4	5	5	8
3	Safety Beach	12	13	14	21	3	4	4	10
4	Mornington	10	11	12	22	3	3	4	11
5	Olivers Hill	0	0	0	34	8	8	8	11
6	Frankston Waterfront	9	9	10	18	3	3	3	9
7	Seaford Beach	18	18	18	20	9	10	10	15
8	Carrum Beach	22	24	25	30	2	3	3	6
9	Mentone Beach	10	11	11	14	2	2	2	3
10	Watkins Bay	1	1	1	2	6	6	7	10
11	Black Rock Beach	0	0	0	0	7	7	7	14
12	Hampton Beach	18	19	20	25	6	7	7	10
13	Brighton	12	12	13	15	7	8	8	10
14	St. Kilda Beach	15	16	17	21	2	2	2	3
15	South Melb. Beach	14	15	15	19	3	3	4	5
16	Williamstown Beach	12	13	13	15	5	5	5	7
17	Altona Safe Harbour	10	10	10	11	2	2	2	3
18	Seaholme	0	1	2	4	0	0	0	0
19	Altona Beach	0	0	0	1	0	0	0	0
20	Campbells Cove Nth	9	9	10	11	1	2	2	2
21	Campbells Cove Sth	8	8	9	18	4	4	4	6
22	Werribee Sth Foreshore	13	14	14	16	4	4	4	6
23	Clifton Springs	8	9	9	11	2	3	3	5
24	Portarlington (Ramblers Rd)	11	13	14	22	5	6	6	8

Using the Rosebud example, offshore sediment movement occurs over an 11 metre distance of beach, with an estimated volume loss of 3 cubic metres per metre of beach face likely to occur about once per year (63% AEP). Offshore sediment movement over a 17 metre portion of the beach profile, and a volume of 6 cubic metres per metre of beach face is expected about once every 100 years (1% AEP).

Table 3: Offshore sediment movement and volume – comparison of present day and at 0.4m sea level rise

	Present Day								
	DISTANCE (m)					VOLUME (m3/m)			
AEP (%)	63	20	10	1		63	20	10	1
Rosebud	11	12	14	17		3	3	4	6

	Climate Change (Sea Level Rise + 0.4 m)								
	DISTANCE (m)					VOLUME (m3/m)			
AEP (%)	63	20	10	1		63	20	10	1
Rosebud	12	13	14	18		4	5	5	8

A large impacted distance does not always correspond to a large volume of sand loss. Some results showed a small volume of sediment movement detected over a large distance (ie. a shallow layer of sand shifted around). Conversely, a large volume of sand can be lost over a very short distance.

If a beach has a zero distance value, this can indicate a solid structure, such as a cliff, limits beach recession. Such a beach is still able to lose sand due to a lowering in level and hence have a non-zero volume value.

Note: results are presented in 'whole metres'. Thus, some small changes do not show up in the table, being below the level of accuracy of this modelling. This is especially the case for relatively sheltered locations.

3.2. Limitations

This analysis does not consider consecutive storms. It is assumed the beach returns to initial 'normal' profile between storms. There is opportunity to extend the analysis of this report in this regard.

The modelling assumes that the profiles taken from the 2007 LIDAR data set are typical. It is possible that the beaches were not in a 'normal' state at the time of the survey, however investigation of this is beyond the scope of this report and it is likely that the data required does not exist. Elevation changes are likely to have occurred since that survey, particularly in the nearshore zone.

Statistics are on a combined data set of the resulting impact of a single storm on the 'present day' profile (no changes in profile over time).

Sea level rise has been added to water levels, but no other changes have been made to model inputs.

Cliff-backed locations were difficult to calculate with this method in absence of more detailed, site specific geotechnical knowledge.

3.3. Comparing modelling results with site-based observations

Considering how site-based observations following a storm event fit with the modelling results, coastal managers can better understand the extent of change and scale of the event. The combined observation data and modelling analysis can inform management responses.

For example:

If a site is losing significant volumes under typical events, intervention/ protection options may need to be considered.

If a beach suddenly loses a significant amount of sand after a storm event, at a location that had quite low distance and volume values in the modelling analysis, it could be in indication the level of erosion was not anticipated by the modelling, and that some form of erosion management response may be necessary.

If changes to a site are small and occurring regularly, such as a seasonal cycle, there may be opportunity to let the sand come back and rebuild the beach naturally, or consider minor works rather than a large scale engineered response.

Make some observations

After a storm event, look at the change in your beach and consider the following:

- How has it changed? What has changed?
- What width of beach has been impacted?
- Have you lost sand? Is the lost sand in the nearby sand bars or offshore banks?
- How much beach have you got left?
- Does this change happen regularly at this site? Different seasons/times of year?
- This may require routine monitoring, ideally just before and after storm events.

What do these observations mean?

- Was it a typical or more extreme storm event?
- Is likely to statistically occur once every year, once every 10 years, once every 100 years?
- Is the amount of erosion something to be concerned about?
- Are these distances and volumes significant in relation to this section of beach? Is it a wide beach or narrow beach? How much buffer exists?
- Is additional intervention required at this location to protect from storm events? Renourishment, revetments, breakwaters?

Potential actions:

- Do nothing – Let the beach build back up naturally
- Sand Maintenance - Redistribution of sand along the beach or from surrounding beaches
- Renourishment
- Groynes – Timber, rock, polymer, geotextile bags
- Vegetation and planting

04. Conclusions & Recommendations

The aim of this study is to provide coastal managers with a tool to allow them to assess the relative severity of an individual storm at a particular site. It is no intended as a detailed assessment of the impacts of coastal forces on the foreshore, For example, on the beaches with large 'distance' vales, the beaches are relatively flat with low dune backing and thus large variations in shoreline position can expected. Coastal managers need to assess each location for site-specific characteristics that might influence the outcomes of the modelling. Some beaches are relatively sheltered and do not experience significant wave energy, other have cliff or sea-wall backing.

In order to make full use of the information available in this analysis, coastal managers need to know what is happening on their beaches and this requires monitoring through frequent visual inspections or, preferably, beach surveys to quantitatively assess the profile and sediment movements.

This analysis should be seen a preliminary investigation, recognising a much more detailed and comprehensive investigation is required.

Future investigation would require an expanded methodology and input data. This could include:

- Up-to-date and repeated beach profiles to allow calibration and validation of modelling.
- Improved knowledge of joint occurrence of waves and high sea-level.
- More detailed analysis to needed to understand the response of under consecutive storms.
- Consideration of non-storm conditions and natural beach-building processes.
- Location and characteristics of hard features at the back of the beach.
- Consideration of the depth of the sand over hard, erosion resistant surface.
- Inclusion of alongshore variability and sediment movement, regional scale sediment transport processes.
- The interaction of erosion and inundation in low-lying areas.
- More comprehensive analysis of climate-change impacts on sea level, wind, waves and regional sediment transport including natural sediment sources.

05. Appendices

Appendix A - Technical supplement - modelling

Data Inputs

BATHYMETRY

Bathymetric and topographic data for this project came from VicMap Elevation LiDAR data and the LADS surveys undertaken by Department of Sustainability and Environment (now DELWP) in 2007 and 2008/9, as part of the State Government's Future Coasts Project. Onshore and nearshore data has a resolution of 1 metre and was used to generate elevation profiles perpendicular to the coast at each site, extending approximately 2 km offshore.

It is noted that there is a clear limitation to using this data set to define the beach profiles, as the elevations, particularly within the nearshore area (the key area of interest in this study) are likely to have been modified in the 10 years since the survey. It is also possible that the beaches were not in a 'normal' state at the time of the survey, however investigation of this is beyond the scope of this report and it is likely that the data required do not exist. Elevation changes are likely to have occurred since that survey, particularly in the nearshore zone. However, in absence of alternative elevation data, there is still value in using this data as profiles were measured at the same time and are thus consistent over the study area.

This limitation can only be rectified through new survey being under taken for each location and repeating this over time.

WINDS

Wind data are available from a number of locations around the Bay including several 'over-water' sites from Bureau of Meteorology (BoM) - Point Wilson, South Channel Pile, Fawkner Beacon. Based on investigation undertaken by Cardno as part of the *Managing Better Now* Report #4 - Wave Climate (2016) ABM Wave, Point Wilson wind data was nominated to represent winds for the entire bay.

Point Wilson wind data was at a 30-minute interval at 10m above water surface.

WATER LEVELS

There is a permanent acoustic tide gauge at Williamstown, which uses acoustic sensors in stilling wells and records 6-minute average sea levels. This data is held by the National Tidal Centre at the Bureau of Meteorology. This data set provides the predicted, measured and residual water levels at Williamstown (ie. the difference between predicted and measured)

These values were used to establish relationships between storm events and corresponding storm surge based on various wind conditions.

WAVES

This assessment uses the wave model generated as part of *Managing Better Now* Report #4 - Wave Climate (2016). The wave climate for Port Phillip Bay, and in particular the 24 locations of interest, has been generated using the Simulating

WAves Nearshore (SWAN) III model (Booij *et al*, 2004). SWAN is a numerical wave model based on the wave-action balance equation. The model is capable of taking into account wave generation by wind, refraction, white-capping, depth-induced breaking, bottom friction and wave-wave interaction. The model has a flexible mesh grid allowing finer detail along the coast and areas of steep gradients, while reducing the computations in areas where topography is constant in slope and shape. Outputs generated from this model showed reasonable alignment with wave measurements that were available within the Bay.

Technical Rationale

MONTE CARLO

Management of coastal erosion risk along the coastline requires knowledge of likely shoreline response under a range of storm scenarios, from typical small-scale storms events through to extreme events. In general, this approach requires a form of statistical analysis such as Extreme Value Analysis (EVA) to determine event-based responses. However, EVA can only be applied to design conditions that have an average recurrence interval (ARI) of around 2 to 3 times the record length of the dataset that is being analysed.

The Port Phillip Bay wind and wave data available for use in this study only extended out to 25 years, which limits the reliability of this EVA analysis. To overcome this limitation, the study utilised the application of a stochastic simulation technique known as Monte Carlo analysis. The approach involved the generation a synthetic storm data record equivalent of 1,000 years length that could then be used to determine long return period conditions.

The Monte Carlo approach used in this study has been developed based on the assumption that storm event can be simulated from a series of independent, random and other correlated variables, calculated to determine probability distributions for wind and water level in Port Phillip Bay. The distributions applied in the Monte Carlo storm synthesis were developed from analysis of the measured wind and water level data, using records from 1991 to 2014.

Figure 7: Project methodology, including synthesised event generation

This Monte Carlo methodology randomised wind speed, wind direction and water level residual. By introducing multiple avenues of randomisation, it ensures values modelled are realistic while also limiting the level of bias within the synthesised data set in the generated 1000 years of data. Where variables are correlated, the observed relationships were maintained in the parameter selection process

STORM EVENT GENERATION

A process was required to generate input data for each of 10,000 model runs. This process needed to be based on measured data as much as possible, but to consider as wide a range of realistic combinations as possible.

Using 25 years of wind data, peak wind events were selected from the time series based on a defined magnitude threshold (15m/s), leaving 189 events for the EVA.

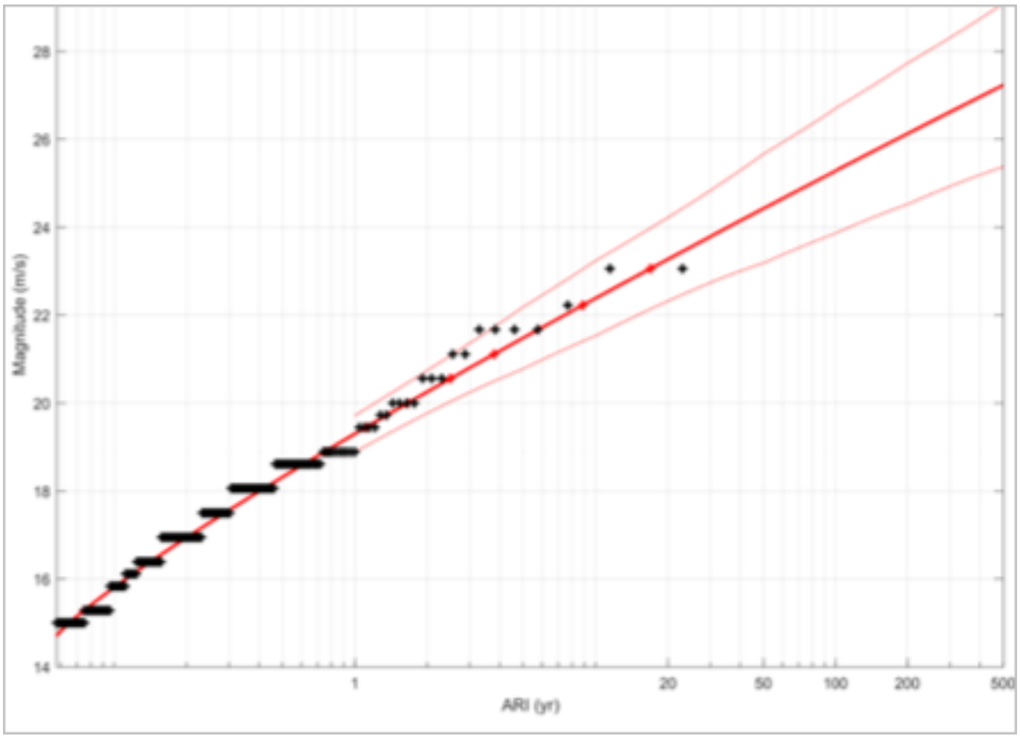


Figure 8: Extreme Value Analysis at Point Wilson

An extreme value distribution was fitted to this data set. This distribution relationship was used to generate a data set of 10,000 random wind speeds corresponding to 10,000 randomly generated probability values.

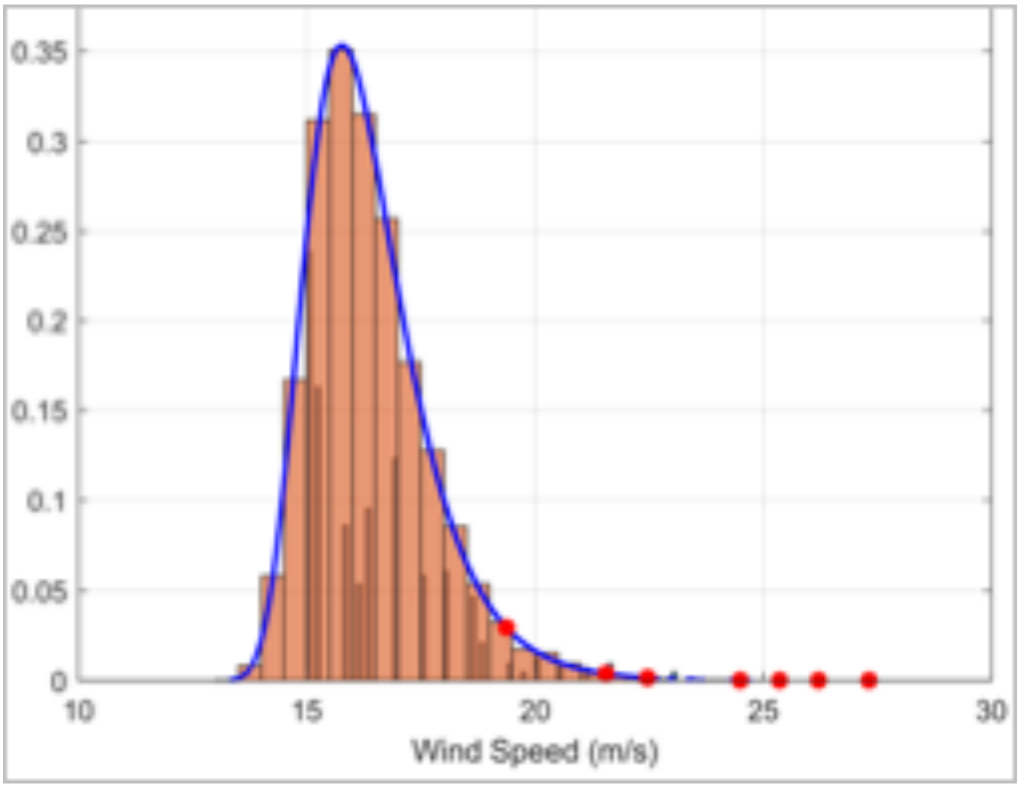


Figure 9: Extreme value distribution fit with Extreme Value Analysis (EVA).

Associated directions for measured peak events were also analysed, where directional data was grouped by wind speed. For example, the data showed 54 actual storm events with wind speeds ranging from 18-19 metres per second. A single event was then randomly selected from the subset of events at this wind speed, providing the wind direction for this run. This resulted in a corresponding synthesised wind speed and direction for each of the 10,000 runs. This approach ensured that only realistic wind directions were considered in the analysis.

Water levels can be predicted based on harmonic analysis using tidal constituents. When a storm occurs, the winds, waves and pressures result in a storm tide, often raising the water level. This generates a difference between the measured and predicted water level, termed the 'residual'. Using the measured residual water levels at Williamstown, the residuals were grouped to the corresponding residual water level data by both wind speed and direction, at 5 metres per second and 45° group spacing. Similar to the approach in selecting the wind direction, the residual for a given run was randomly selected from the relevant grouped data set. For example, at a wind speed of 15-20 metres per second, and at a direction 90° to 135°, there were 13 measured events. These events aligned with specified criteria, and could be randomly selected to provide the residual for the synthesised storm condition.

Taking these synthesised wind and water-level data, location specific significant wave height (Hs) and peak period (Tp) were then generated for the 10,000 storms by aligning this wind data with the existing ABM wave model and extracting resultant wave conditions at each site.

Time series model inputs of Hs, Tp, and water level were created for both present day mean sea-levels and 0.4 m SLR climate change scenario. These time series were used to force the SBEACH model. Each storm lasted 72 hours with the storm peak, including wave heights and water levels, occurring 36 hours into the 3-day storm.

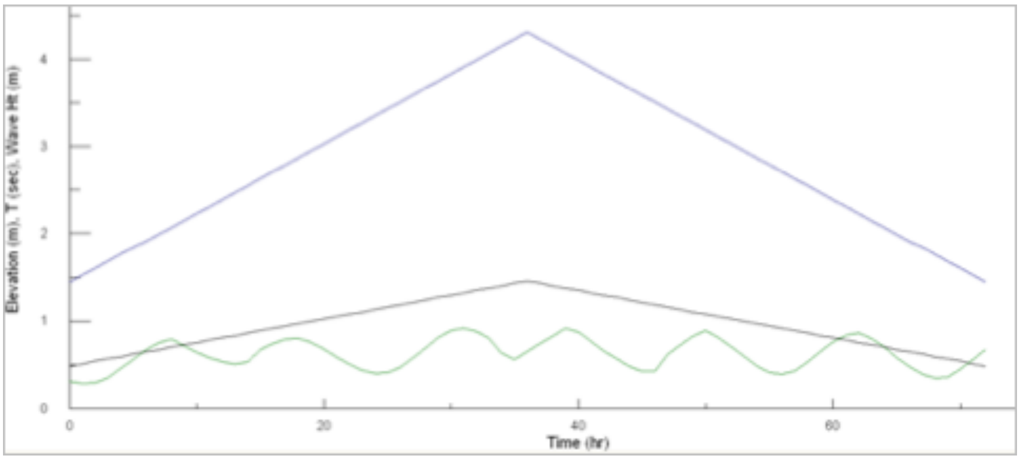


Figure 10: Example storm time series. Wave height (black), wave period (blue), water elevation (green)

Wave height and wave period time series were generated, using peak value to create a triangular shaped time series, starting from one third of the peak condition, rising up to the peak value at 36 hours, and then declining back down to a third of the peak value by 72 hours. Similarly, the residual value was taken as the peak in a triangular shaped time series, rising from zero to the selected value over 36 hours and then falling again to zero in the following 36 hours. This residual time series was added to a predicted tide for a 72-hour period selected at random from a 25-year period. The result was a water-level time series which reflected realistic values of both the astronomical tide and storm surge.

PROFILE SELECTION

ABM member councils submitted suitable locations for inclusion in the analysis. Some locations included known hot spot erosion areas, while others covered key assets in the region. In selecting sites coucils were asked to consider locations that:

- are known to be sandy;
- avoid renourished beaches;
- have limited hard structures, rocks and cliffs; and
- are within the area of Edwards Point to Point King (beyond this extent the hydrodynamic behaviour becomes more complex due to the effects of swell from Bass Strait).

Modelling was undertaken at twenty-four selected locations. Results were tailored to take into account locations where hard or steep structures and features were present (eg. walls and cliffs), as these can distort the results.

SBEACH MODEL

The model Storm-induced BEAch CHange (SBEACH) was used to determine the expected storm bite. SBEACH is a numerical simulation model developed by the US Army Corps of Engineers to calculate beach and dune erosion under storm wave action (Sommerfield et al, 1996).

As part of its calculations, SBEACH assumes that the entire beach profile is made up of sand. It doesn't allow for the presence of vegetation, change in geology or other surfaces such as concrete or bitumen. The analysis also does not take into account the presence of seawalls or other coastal structures. However, where information about these elements was known, allowance were made in unrealistic results.

Results give an approximation of the distances the beach is predicted to retreat and/or advance. Note that these are likely to be exaggerated figures given the assumptions made by the SBEACH model.

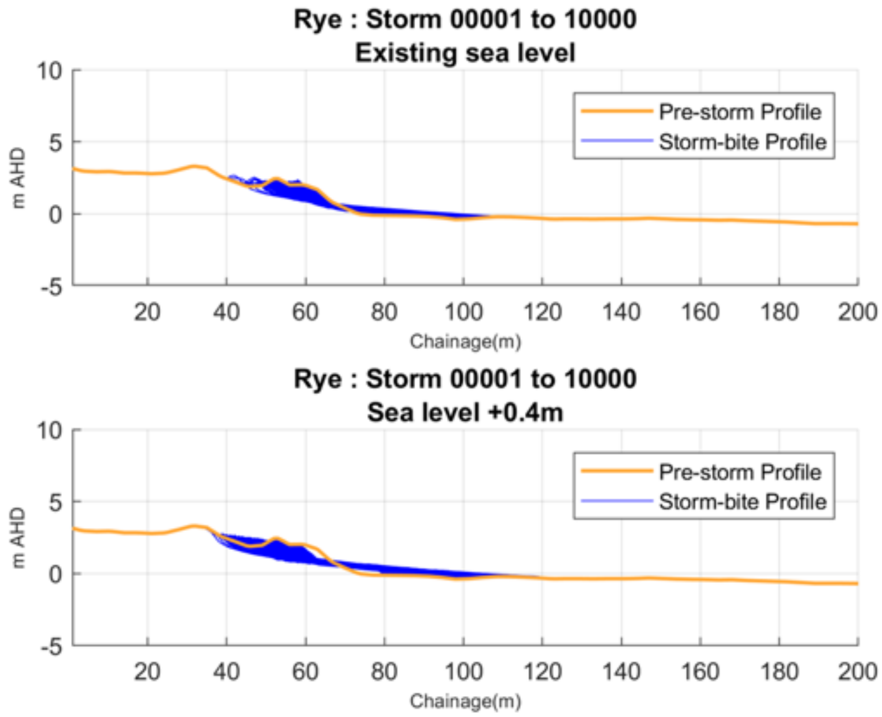
Cardno used Matlab powered executables to generate site-specific storms, and the storms and loop through these 10,000 storms, producing results that are equivalent to a 1000 years of storms for each site.

REFERENCES

Cardno, (2016) Managing Better Now Report #4 – Port Phillip Bay Wave Climate. Prepared for the Association of Bayside Municipalities

Sommerfield et al, (1996) SBEACH-32 Interface Users Manual. Prepared for US Army Corps of Engineer

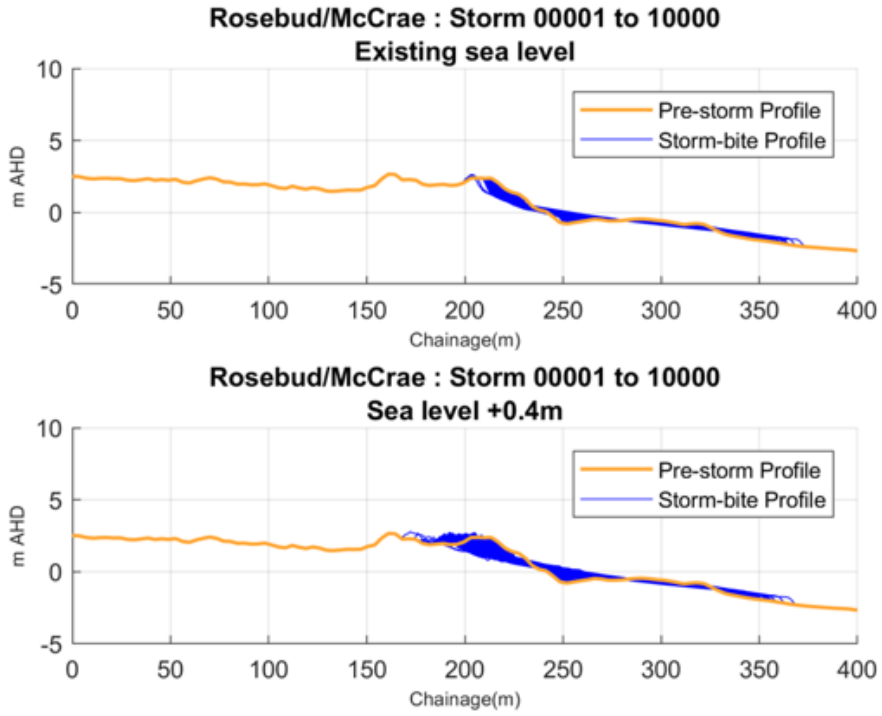
Appendix B - Results: storm bite profiles



Rye : Storm 00001 to 10000
Existing sea level

Rye : Storm 00001 to 10000
Sea level +0.4m

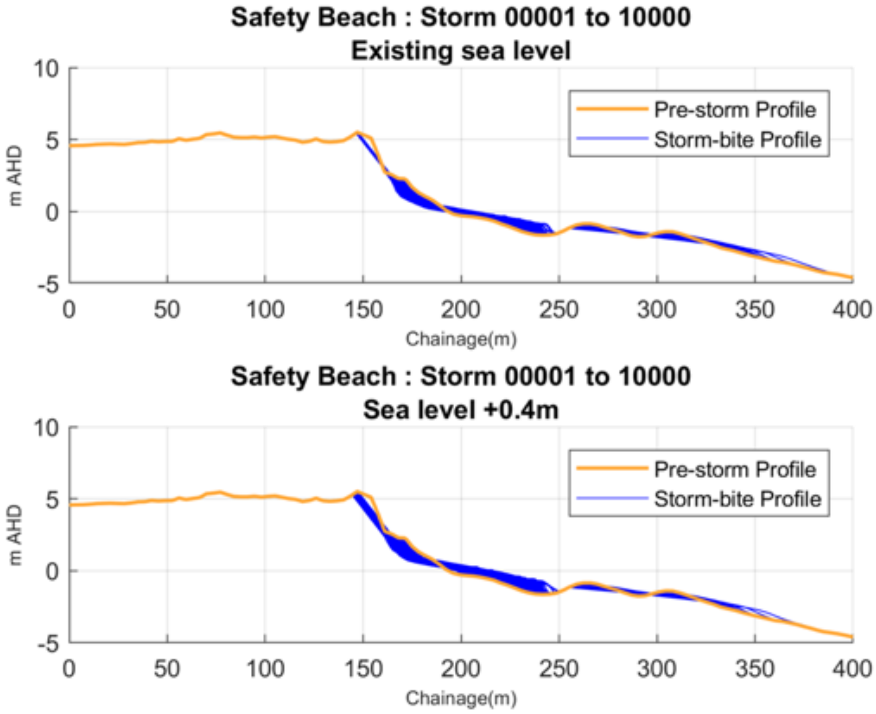
Profile 1: Rye



Rosebud/McCrae : Storm 00001 to 10000
Existing sea level

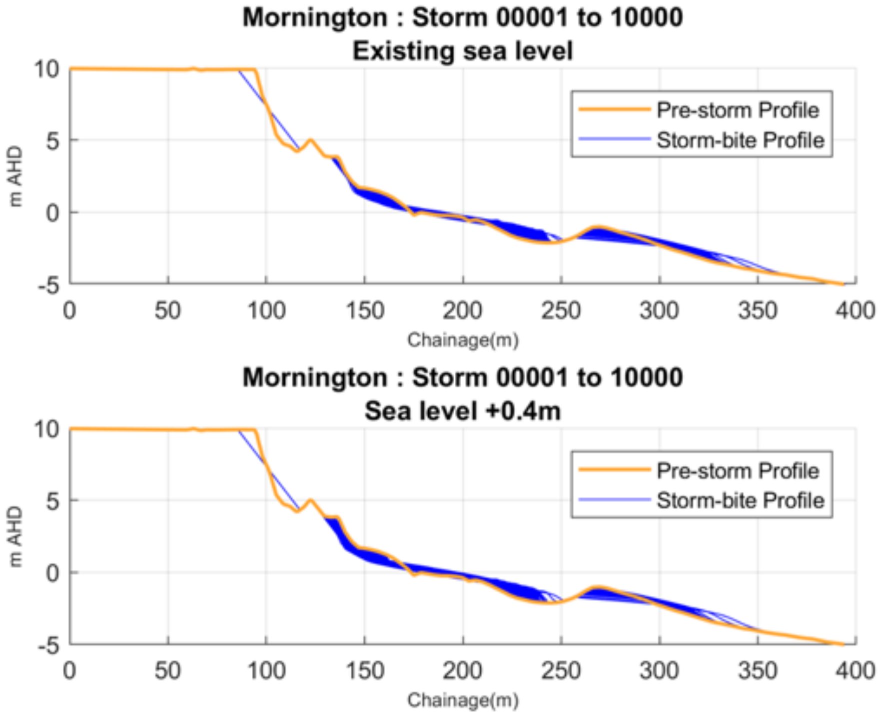
Rosebud/McCrae : Storm 00001 to 10000
Sea level +0.4m

Profile 2: Rosebud/McCrae


Safety Beach : Storm 00001 to 10000
Existing sea level

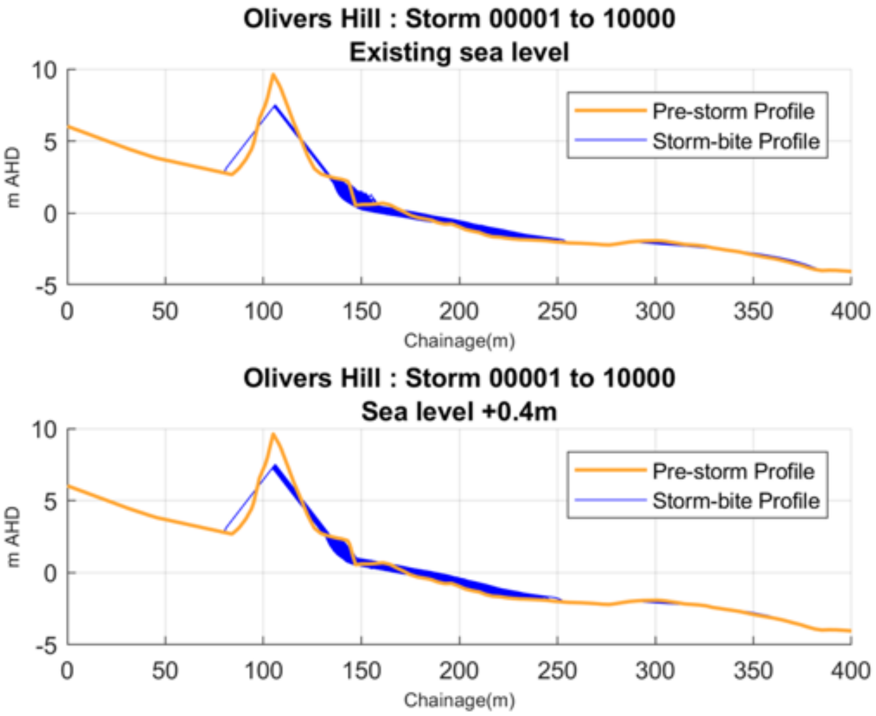
Safety Beach : Storm 00001 to 10000
Sea level +0.4m

Profile 3: Safety Beach

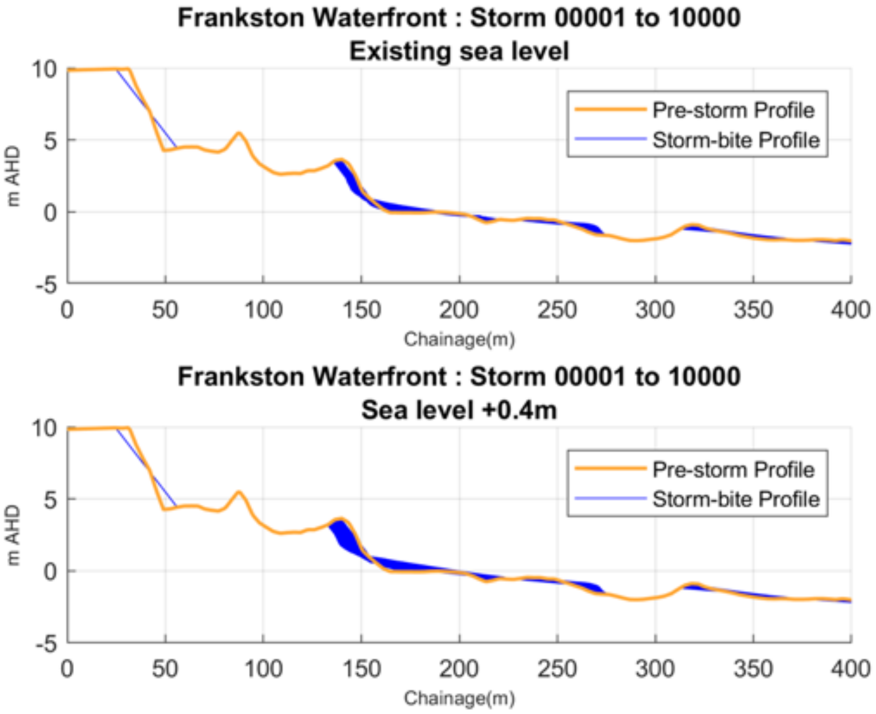

Mornington : Storm 00001 to 10000
Existing sea level

Mornington : Storm 00001 to 10000
Sea level +0.4m

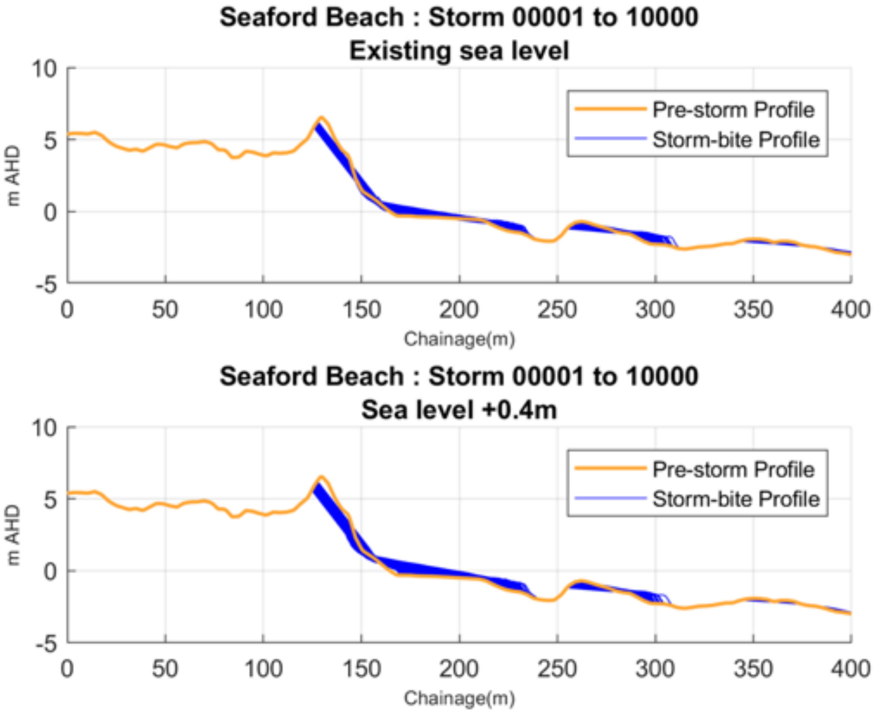
Profile 4: Mornington



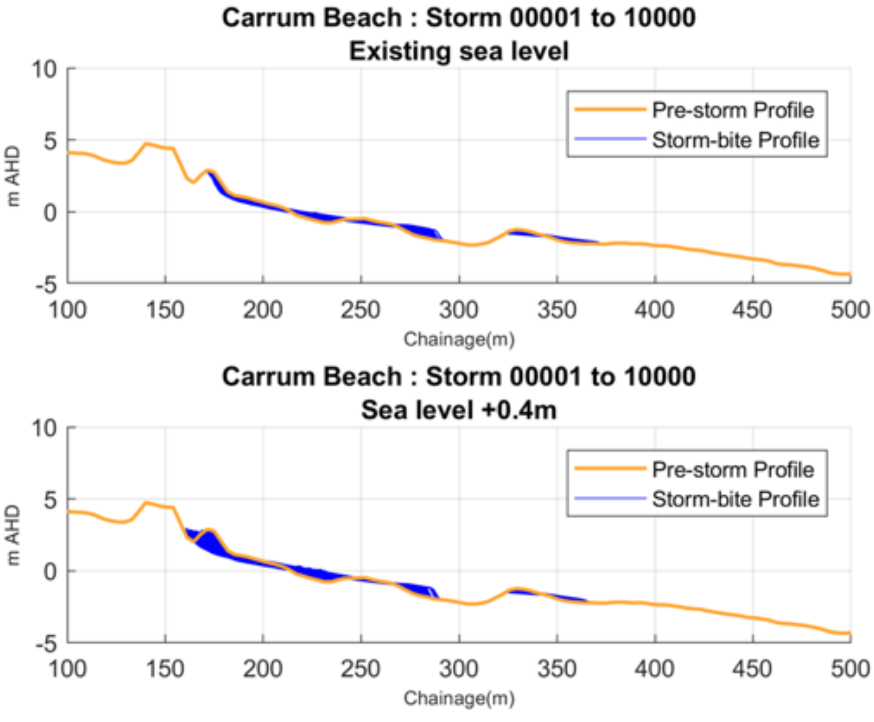
Profile 5: Olivers Hill



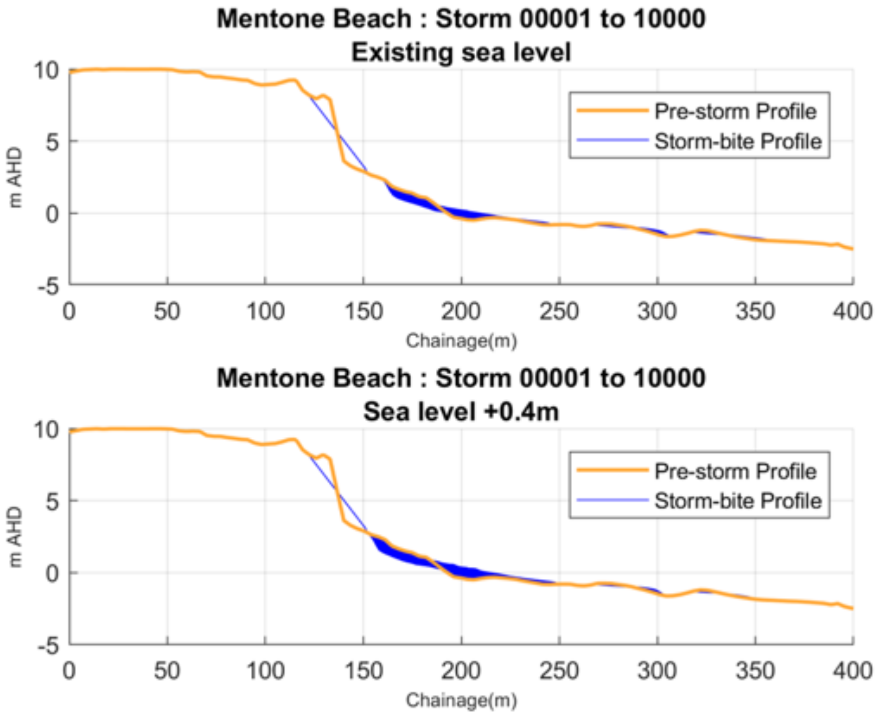
Profile 6: Frankston Waterfront



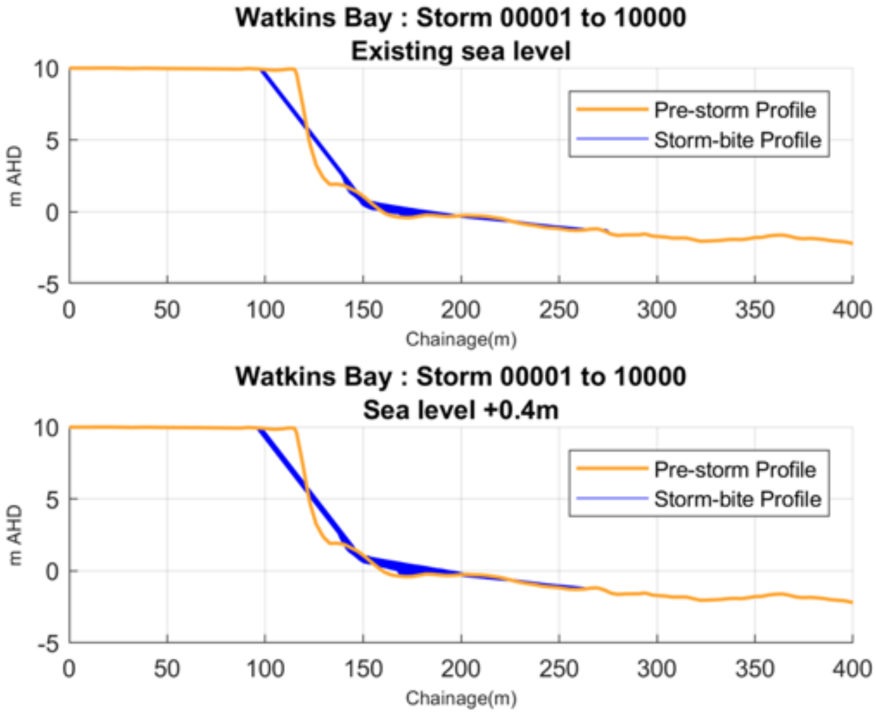
Profile 7: Seaford Beach



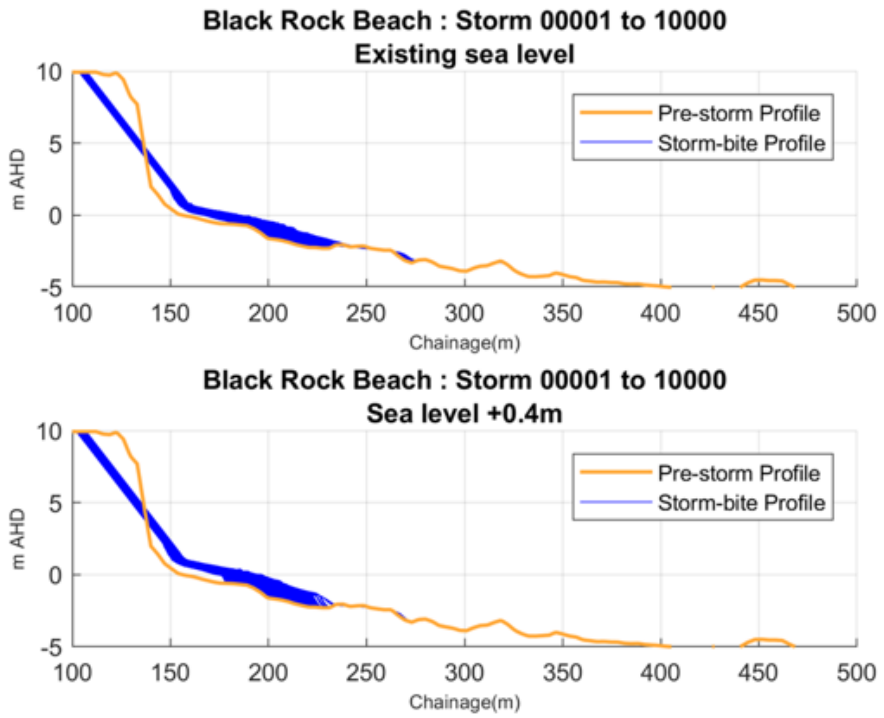
Profile 8: Carrum Beach



Profile 9: Mentone Beach

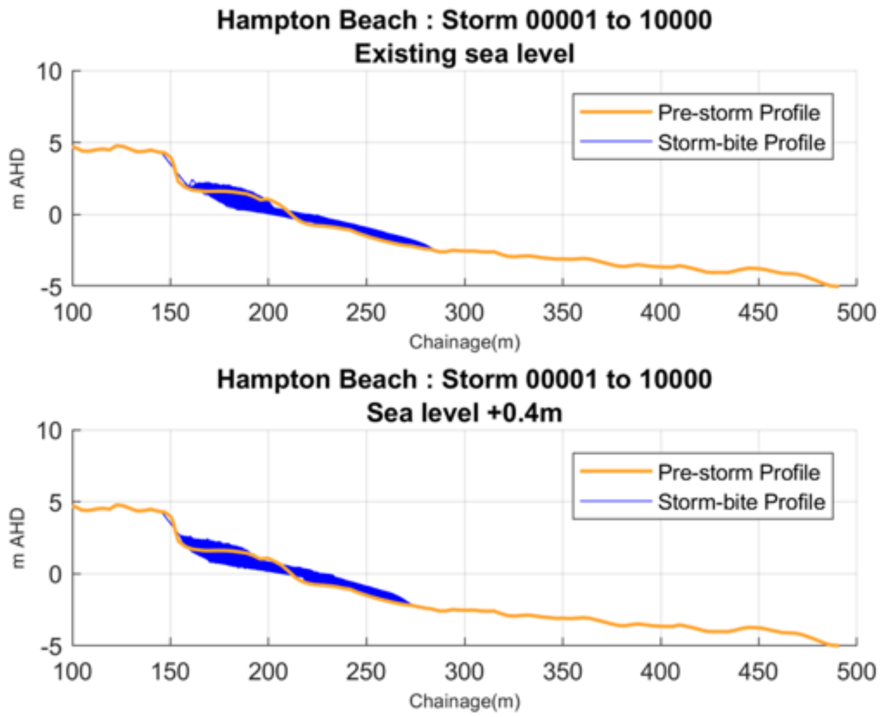


Profile 10: Watkins Bay


Black Rock Beach : Storm 00001 to 10000
Existing sea level

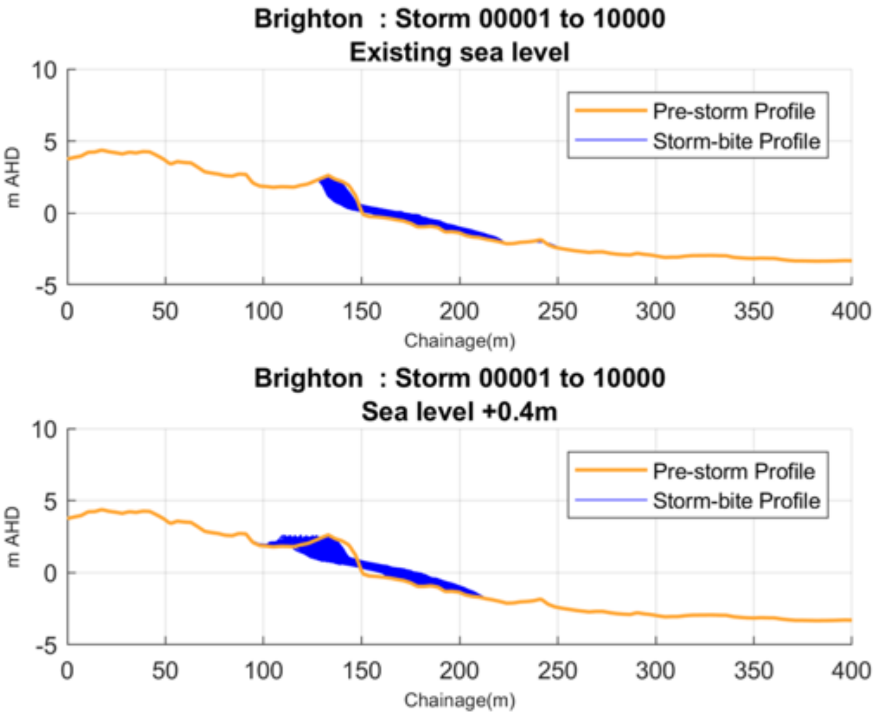
Black Rock Beach : Storm 00001 to 10000
Sea level +0.4m

Profile 11: Black Rock Beach

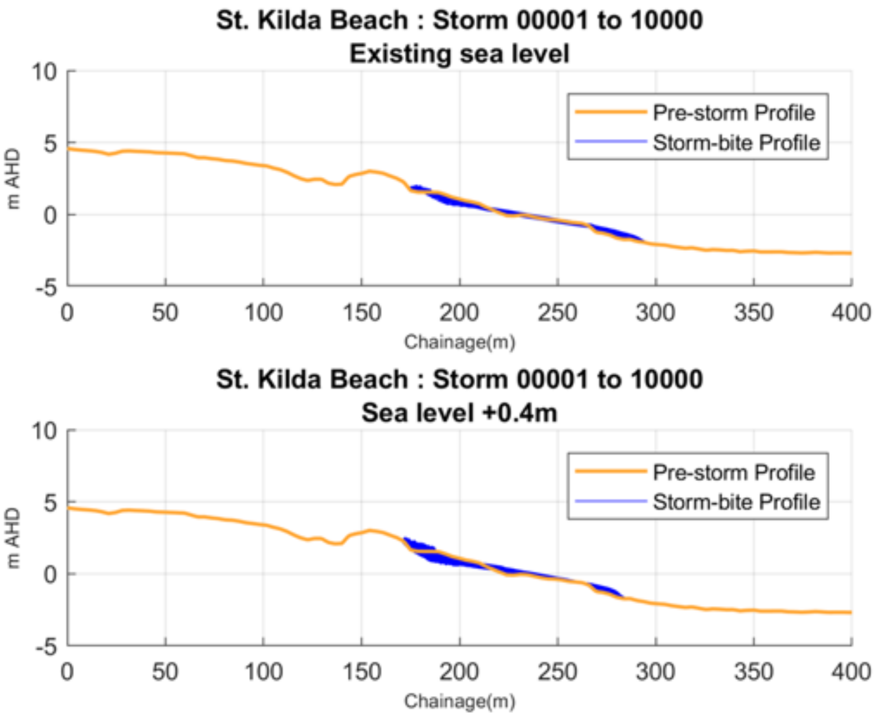

Hampton Beach : Storm 00001 to 10000
Existing sea level

Hampton Beach : Storm 00001 to 10000
Sea level +0.4m

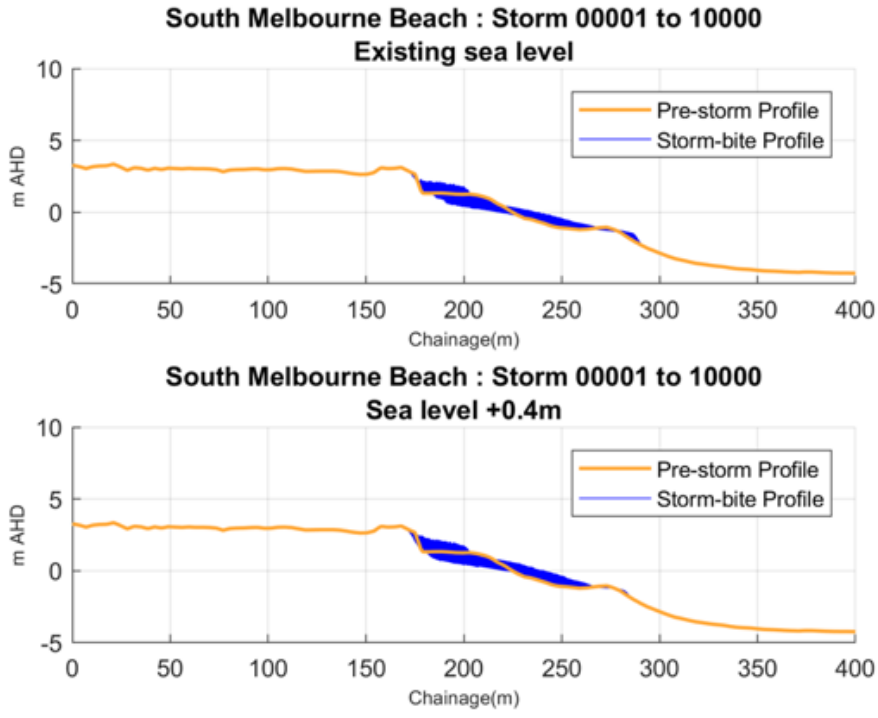
Profile 12: Hampton Beach



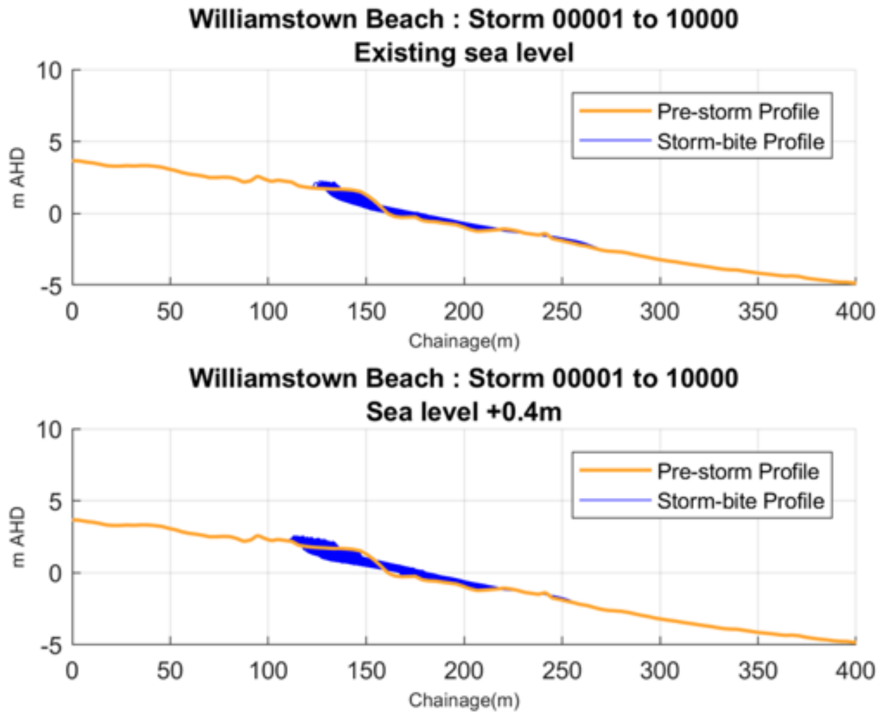
Profile 13: Brighton



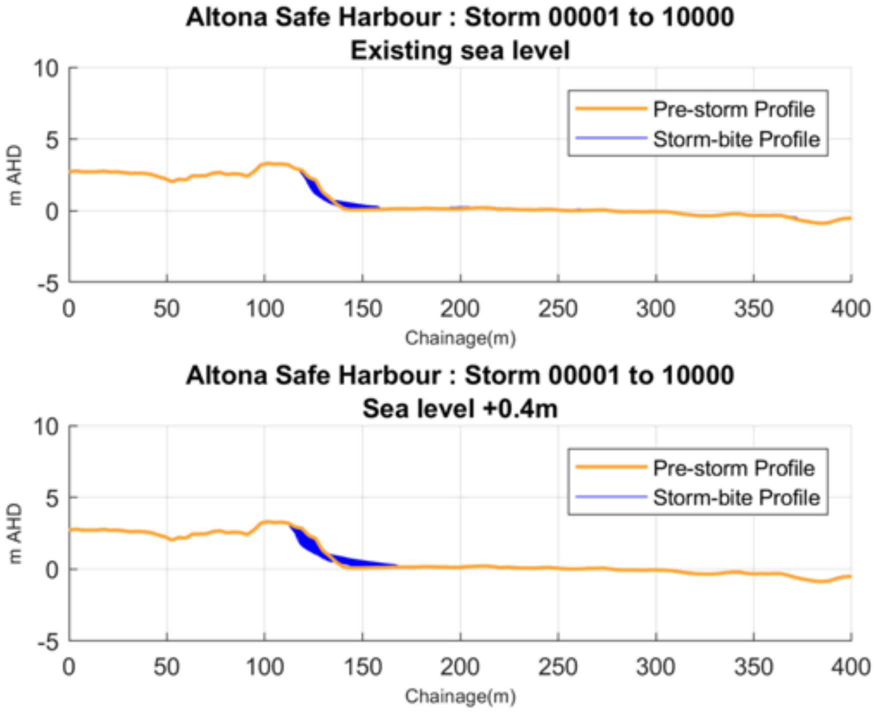
Profile 14: St. Kilda Beach



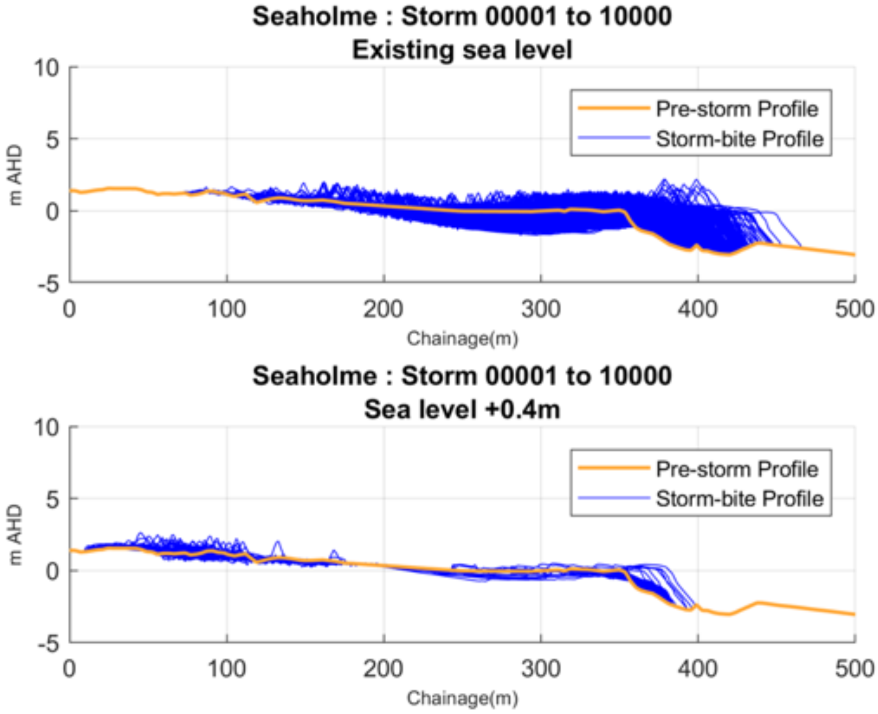
Profile 15: South Melbourne Beach



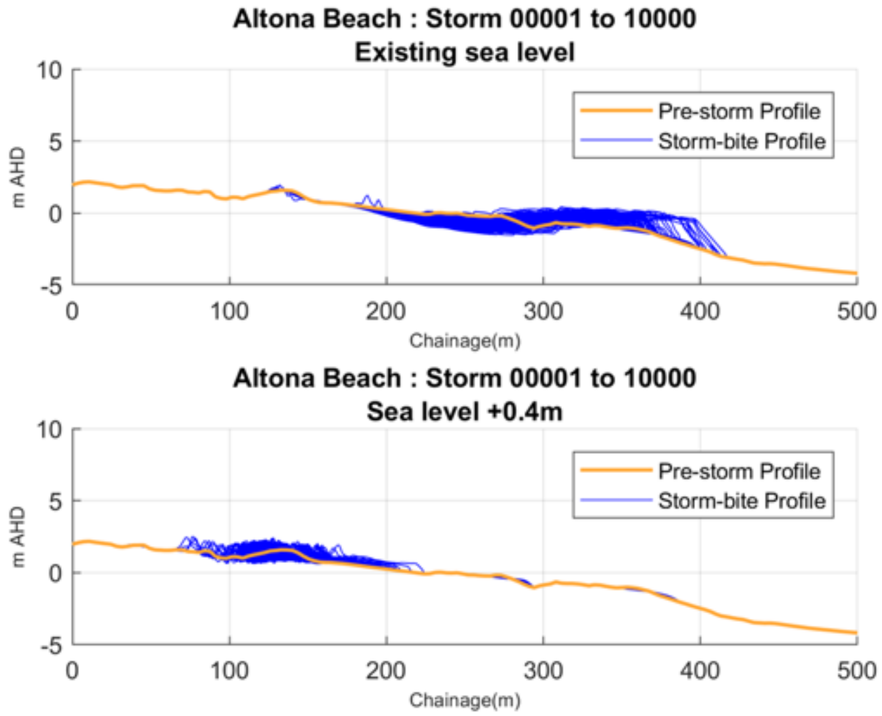
Profile 16: Williamstown Beach



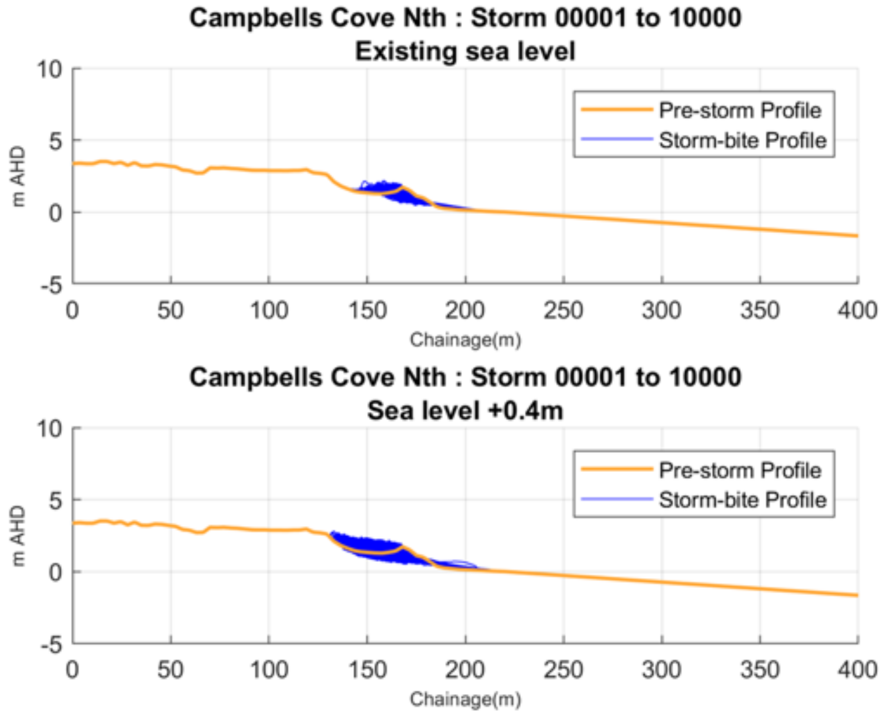
Profile 17: Altona Safe Harbour



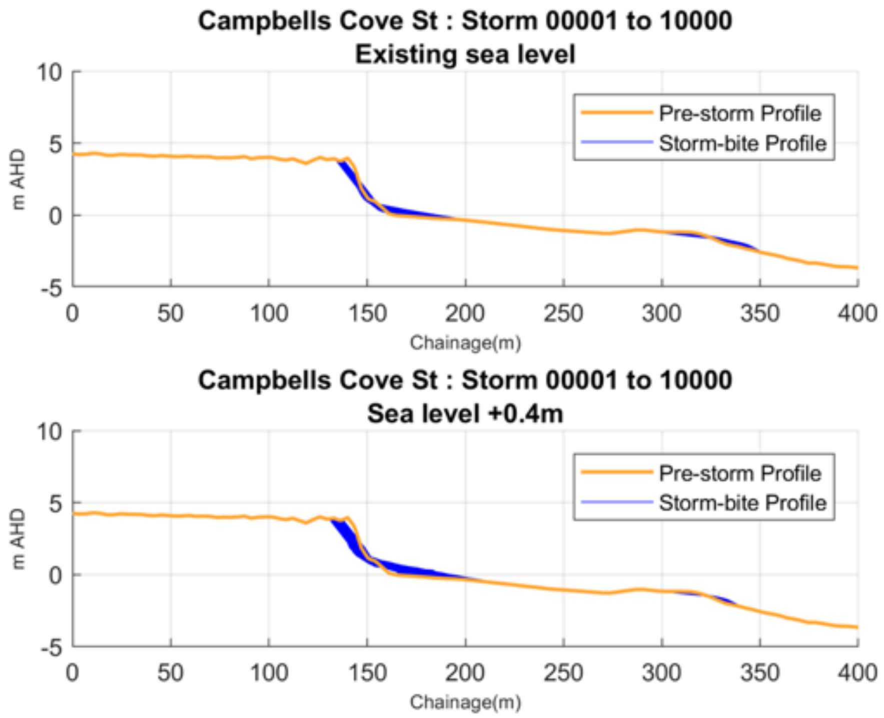
Profile 18: Seaholme



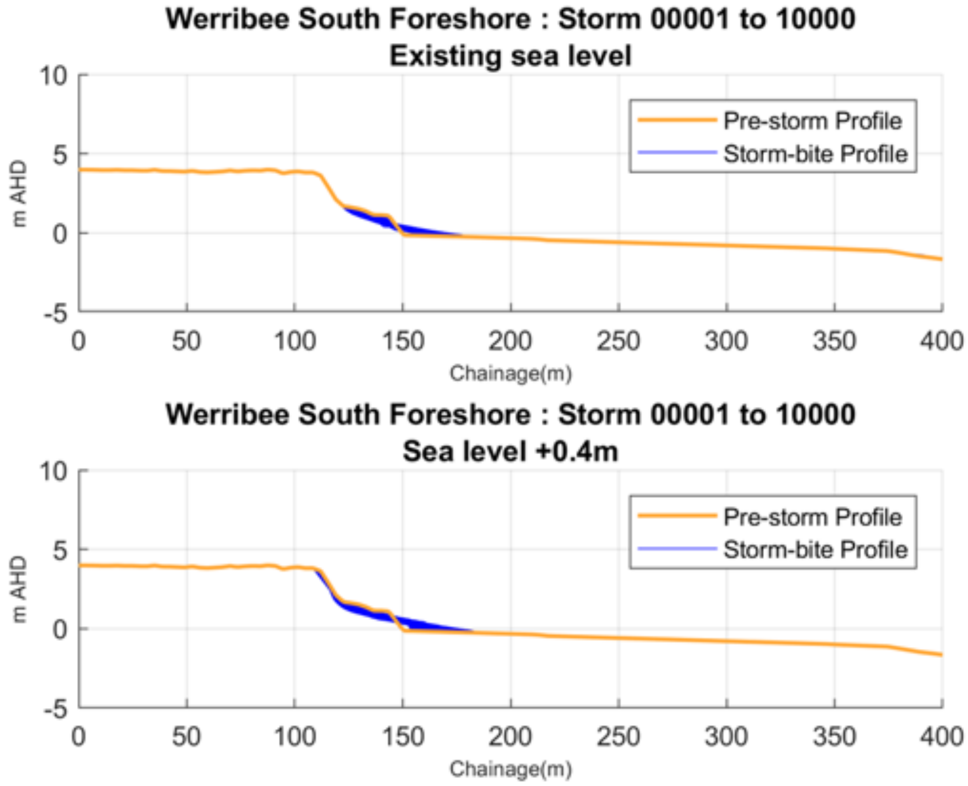
Profile 19: Altona Beach



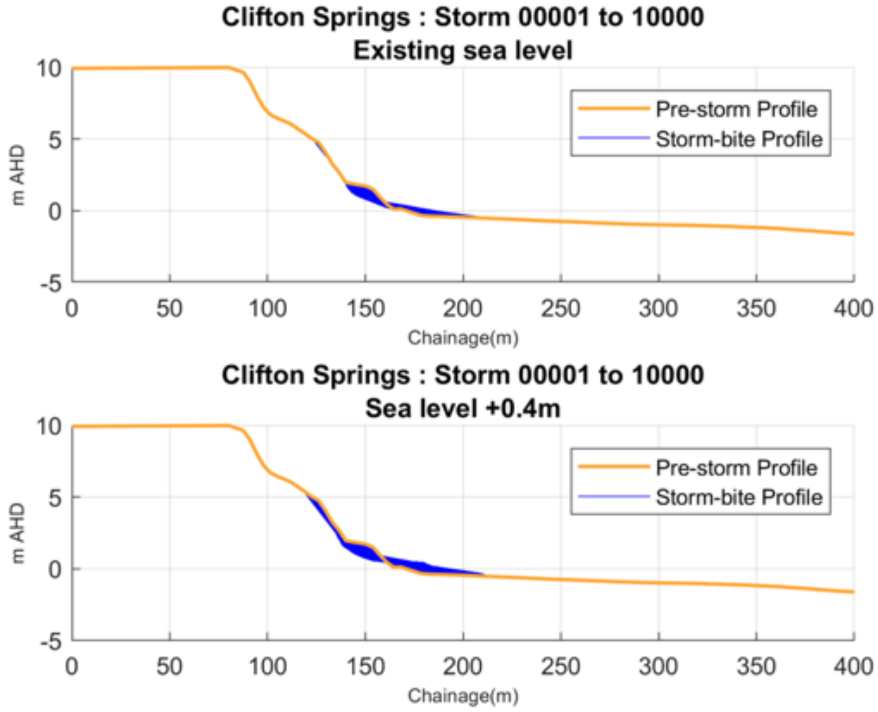
Profile 20: Campbell’s Cove North



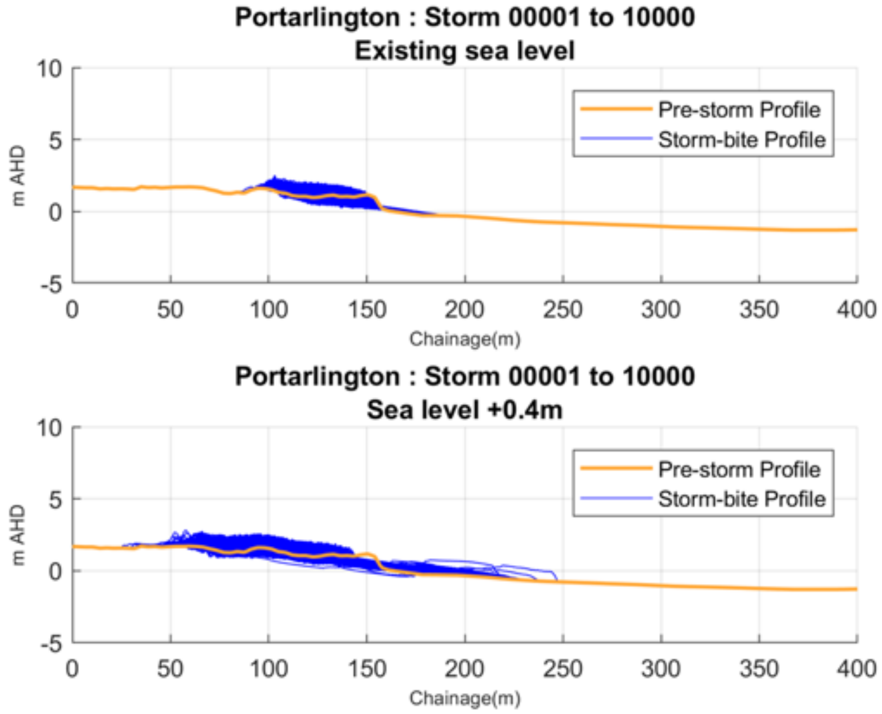
Profile 21: Campbell's Cove South



Profile 22: Werribee South Foreshore



Profile 23: Clifton Springs



Profile 24: Portarlington (NB. Site actually closer to Ramblers Rd, West of Point Richards

ASSOCIATION OF BAYSIDE MUNICIPALITIES

Level 12, 60 Collins Street
Melbourne 3000
GPO BOX 4326PP
MELBOURNE VIC 3001

Phone (03) 96675536
Email abm@mav.asn.au
Website abm.org.au