QCoast2100
COUNCILS LEADING COASTAL ADAPTATION

Cook Shire Council
Coastal Hazard Adaptation Strategy
"The Resilient Cape"

Phase 3: Areas Exposed

May 2020

Table of contents

Table Index

Figure Index

Appendices

List of Acronyms

AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARI	Average Recurrence Interval
CHAS	Coastal Hazard Adaptation Strategy
DEHP	Department of Environment and Heritage Protection (now DES)
DEM	Digital Elevation Model
DERM	Department of Environment and Resource Management (now DES / DNRME)
DES	Department of Environment and Science (formerly DEHP)
DNRM	Department of Natural Resources and Mines (now DNRME)
DNRME	Department of Natural Resources, Mines and Energy (formerly DNRM)
GHD	GHD Pty. Ltd.
HAT	Highest Astronomical Tide
LAT	Lowest Astronomical Tide
LGA	Local Government Area
LGAQ	Local Government Association Queensland
LiDAR	Light Detection and Ranging
MSL	Mean Sea Level
MSQ	Maritime Safety Queensland
MWL	Mean Water Level
PRG	CHAS Project Reference Group
SCEP	Stakeholder Communication and Engagement Plan
SEA	Systems Engineering Australia Pty. Ltd.
SLR	Sea Level Rise
ST	Storm Tide
TC	Tropical Cyclone
TMST	Theoretical Maximum Storm Tide
TMR	Department of Transport and Main Roads

1. Introduction

1.1 Local Government Region

Cook Shire covers over 100,000 km^2 of Far North Queensland, extending from Bloomfield River in the south, to just north of the Jardine River, and occupies 80 % of the Cape York Peninsula. The shire adjoins 13 Aboriginal, regional, shire and town council Local Government Authorities on the north, south and west. Bounding council regions include Douglas, Mareeba and Carpentaria, Aurukun, Torres and Lockhart River. To the east, the Cook Shire is bounded by the Coral Sea as shown in Figure 1-2.

The Cook Shire contains areas of high ecological significance, as it is the geographical meeting place of the Great Barrier Reef, the Wet Tropics and the Outback. It also has many National Parks along with other protected areas and conservation zones. This is a major attraction for tourists, with the number of visitors and residents continuing to increase as road conditions and facilities improve. Other major industries within the Cook Shire include agriculture and fishing.

The Cook Shire is home to approximately 4,200 residents (Census 2016). Over half of this population reside in the Shire's major township of Cooktown. Smaller population centres are located at Marton, Laura, Lakeland, Coen, Ayton, Rossville and Portland Roads, and offshore islands including Lizard Island. Residents also reside throughout the Bloomfield and Endeavour valleys. Many of the coastal communities rely partly on tourism. It is therefore important when considering coastal hazard adaptation strategies to consider the impact on the tourism industries, and to preserve the scenic amenity of important natural coastlines, views and natural aesthetics in the region.

1.2 CHAS Overview

Queensland has a highly dynamic and variable coastal zone, featuring shallow coastal margins and complex estuary systems with significant exposure to coastal hazards including erosion, storm tide inundation and sea level rise. Many of Queensland’s cities and towns are located on the coast and are therefore exposed to such hazards. Climate change projections indicate that the frequency and intensity of storm related hazards will change, along with rising sea levels, and more volatile climate variability.

Queensland Government policy calls for coastal hazard risks to be addressed in planning and development decisions. However, dealing with hazards on a development-by-development basis is inefficient and will not provide a suitable holistic outcome for a community at risk. Adaptation strategies are intended to ensure a planned approach is taken to address coastal hazards for “at risk” communities for the immediate to long term.

The purpose of a Coastal Hazard Adaptation Strategy (CHAS) is to assist and inform local authorities such as Cook Shire Council (CSC) on approaches to minimise risks to:

- Existing infrastructure and properties.
- New development in areas expected to be exposed to coastal hazards both now and through to the year 2100.
- Intangible assets including environmental, social and cultural values.

Therefore, in order to identify risk areas and allow coastal councils to prepare appropriately for these hazards, an approach such as the CHAS is required. An 8-phase process is outlined in the QCoast$_{2100}$ Minimum Standards and Guidelines[1], which was specifically developed to assist Queensland coastal councils and provide a common approach. The 8 phases are outlined in Figure 1-1, modified from LGAQ, 2016.

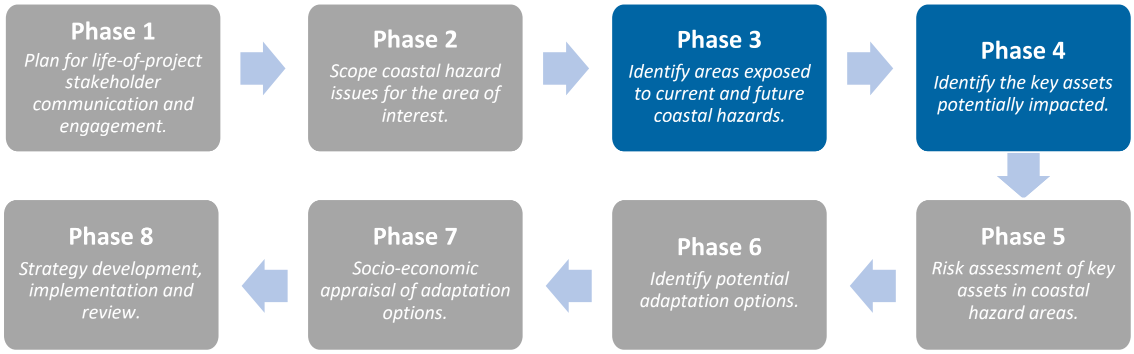


Figure 1-1 CHAS Process Flow Diagram

1.3 CHAS Progress

CSC has successfully completed the first two phases of the CHAS, as detailed in Table 1-1.

[1] Local Government Association of Queensland and the Department of Environment and Heritage Protection (2016). *QCoast$_{2100}$ Developing a Coastal Hazard Adaptation Strategy: Minimum Standards and Guidelines for Queensland Local Governments*. State of Queensland.

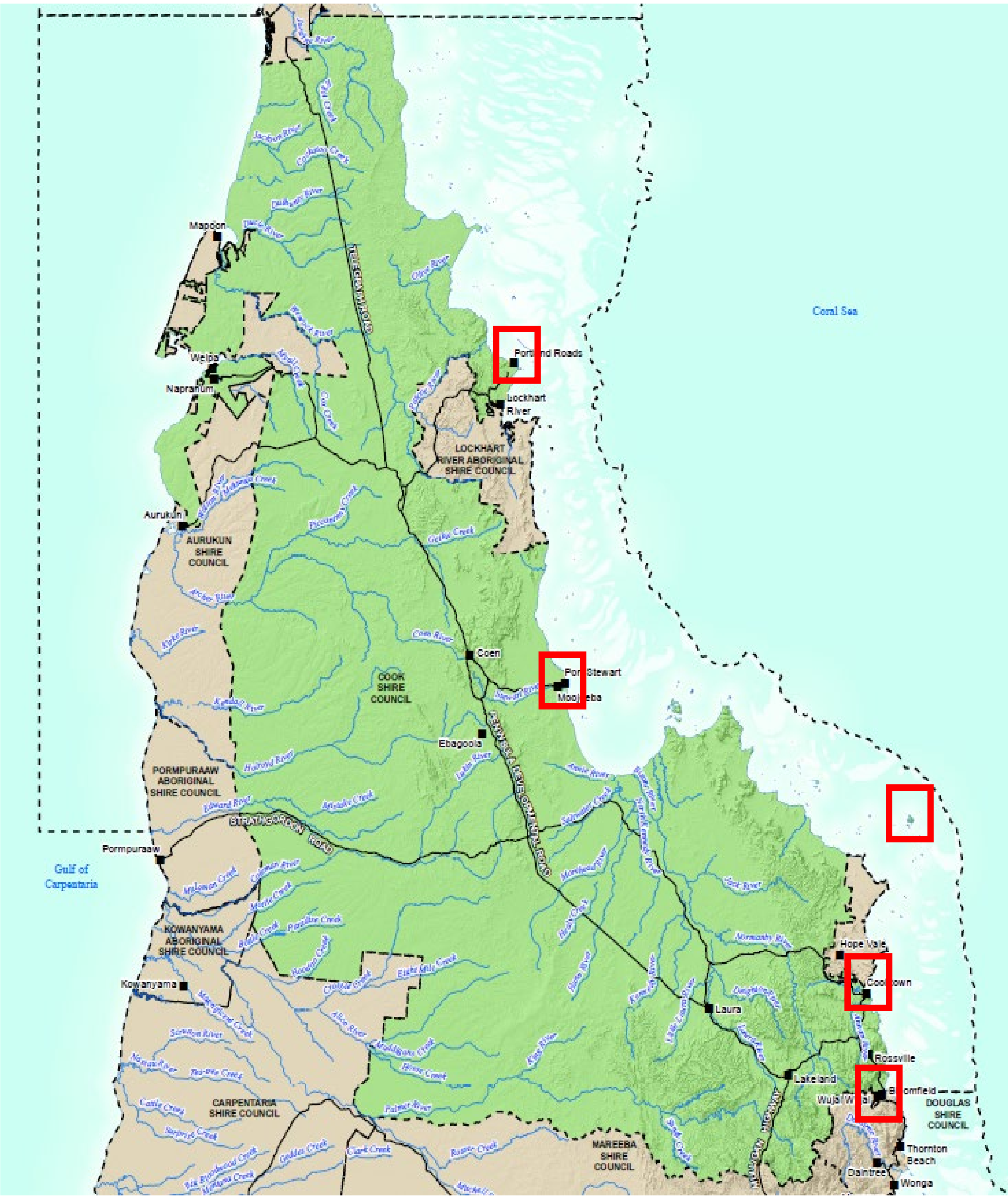


Figure 1-2 Cook Shire LGA with study areas highlighted

Table 1-1 CHAS Progress

Phase	Progress	Description	Reference
Phase 1	✓	Phase 1 set out CSC's roles and responsibilities in communicating and engaging with internal and external stakeholders through the preparation of a Stakeholder Communication and Engagement Plan (SCEP) (LGAQ, 2016). Whilst no stakeholder engagement outside of the PRG was undertaken during this phase, the detailed SCEP was developed to be implemented for Phases 3 to 8 of the CHAS.	*Cook Shire Council Coastal Hazard Adaptation Strategy, Phase 1 Stakeholder Communication and Engagement Plan (GHD, 2017).*
Phase 2	✓	Phase 2 broadly scoped the coastal hazard issues affecting the Cook Shire and identified key objectives and desired outcomes of the CHAS, established the parameters of a CHAS, and identified previous and required studies through a gap analysis.	*Cook Shire Council Coastal Hazard Adaptation Strategy, Phase 2 Scoping Study (GHD, 2017).*
Phase 3	→	This phase is detailed in Section 2 of this document.	This document.
Phase 4	×	To be completed as part of future phases.	-
Phase 5	×	This phase is yet to be commenced.	-
Phase 6	×	This phase is yet to be commenced.	-
Phase 7	×	This phase is yet to be commenced.	-
Phase 8	×	This phase is yet to be commenced.	-

Note that the documents listed should be read in full for appropriate understanding of the assessment and related assumptions.

2. Phase 3: Areas at Risk

The purpose of Phase 3 was to model storm tide, coastal erosion and permanent inundation from sea level rise where required (as deemed necessary by Phase 2) to identify areas at risk of exposure to coastal hazards and the scale of risk.

This section outlines the gaps in coastal hazard models/mapping as identified in Phase 2, and the processes undertaken in this phase to update coastal hazard models/mapping. This information will be used to inform the subsequent CHAS phases.

Table 2-1 lists the key areas of concern as identified from the initial assessment undertaken in Phase 2. As such, these will be the areas of focus to update coastal hazard models/mapping.

Table 2-1 Key Geographical Areas of Concern

Area	Assets / Potentials Concerns	Latitude (Deg.)	Longitude (Deg.)
Ayton/Bloomfield	Rossville/Bloomfield Road (travels adjacent to Bloomfield River) Township/Houses (main township and along the coastline)	-15.91	145.37
Cooktown/Marton/ Quarantine Bay	Cooktown Country Golf Club Quarantine Bay Township Sea Wall and Foreshore Mangrove Area and Old Airstrip Cooktown Airport	-15.44	145.25
Lizard Island	Resort and Airstrip	-14.65	145.44
Port Stewart	~10 Dwellings	-14.05	143.69
Restoration Island	Small Resort	-12.62	143.44
Portland Roads	Small Townships	-12.59	143.39
Haggerstone Island	Small Resort	-12.04	143.30
Hicks Island	Resort and Airstrip	-11.99	143.27

Haggerstone and Hicks Island are located in the far northern area of Cook Shire Council. This area is isolated and has very little inhabitancy. Because of this, only limited aerial imagery coverage is available to provide a worthwhile assessment. DEM models with better than one metre accuracy are also not available at this time for these areas.

Without costly LiDAR over the area there is no way that improved coastal hazard mapping can be created for these two areas and it has been decided to remove them from the Phase 3 focus areas and to re-assess their vulnerability in the Phase 4 stage.

2.1 Areas at Concern

2.1.1 Ayton

Ayton lies to the south of Cooktown on the mouth of the Bloomfield River. The coastal beach is the main area affected by coastal hazards due to the easterly facing beach (Figure 2-1). There are several properties along this section of beach that currently face an erosion risk and may in future be affected by sea level rise inundation from the marshland behind the coastline. The township is located upriver on a high stand with a salt marsh wedge between the coastal beach and the township.

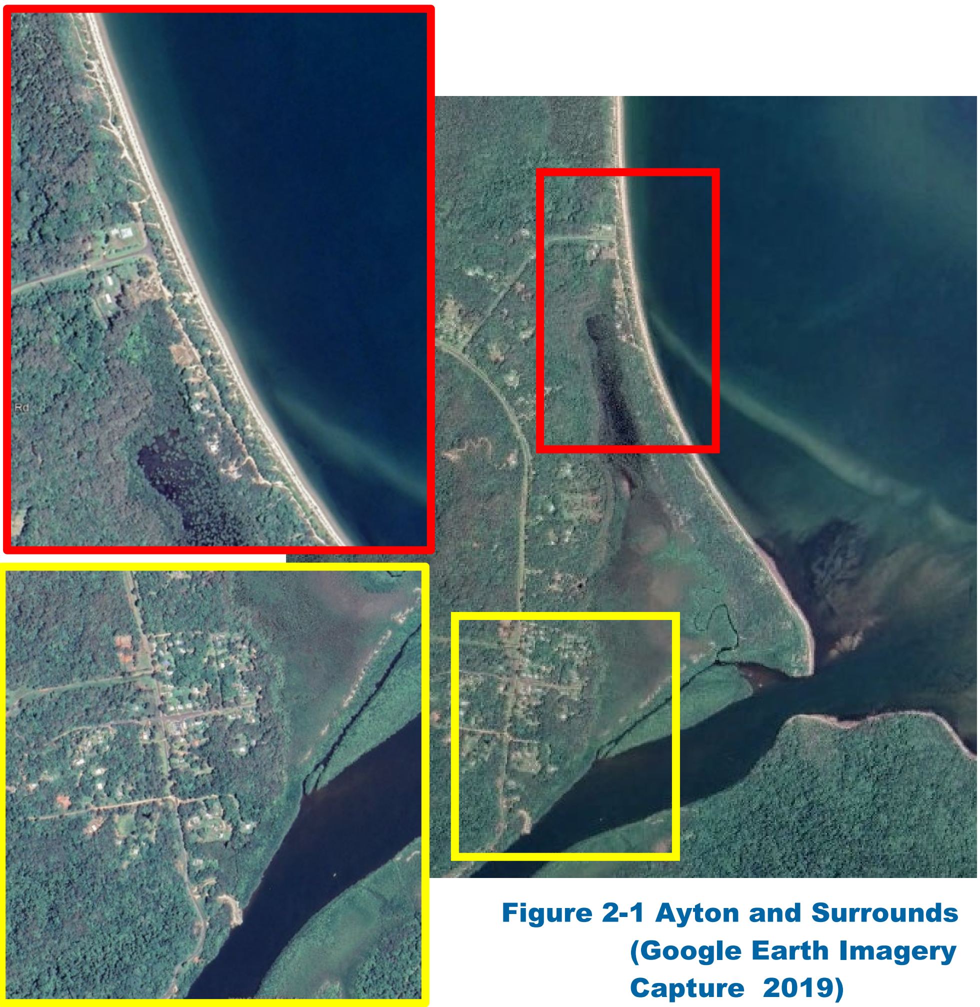


Figure 2-1 Ayton and Surrounds (Google Earth Imagery Capture 2019)

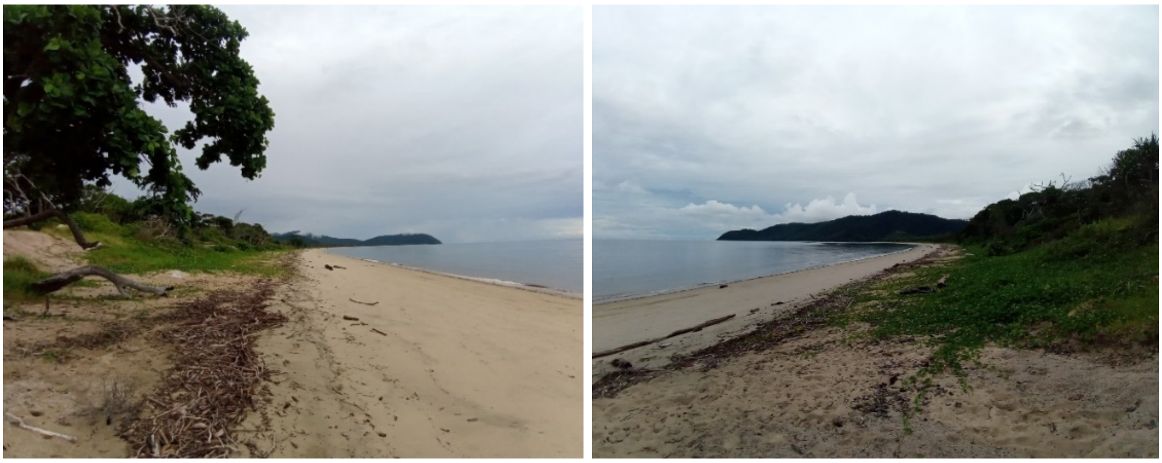


Figure 2-2 Ayton Coast looking North (Left) and South (Right)

2.1.2 Cooktown

Cooktown is the main population centre of Cook Shire Council. It is partially protected by the river mouth opening to the north and a large headland positioned behind the township offering protection from the south-easterly trade winds. Key concerns are inundation and storm tide along the town foreshore and the airport located upstream. The esplanade on the northern end of the town has had a history of protection measures being implemented. The airport lies significantly upstream and is likely at more risk from fluvial flooding then coastal storm tide or sea level rise along the river boundary. On the eastern boundary, the storm tide may affect the airport during large inundation events due to the low marshland present in the area. To the southeast of the town on the open coast lies the Cooktown Country Golf Club, which is potentially impacted by coastal hazards. The club is located landward of a high fore-dune system which has been subjected to erosion and inundation in the past.

Figure 2-3 Cooktown and Surrounds (Google Earth Imagery Capture 2018)

2.1.3 Quarantine Bay

Quarantine Bay is located on the coast east of Cooktown. It has a small population and is a north-east facing beach with a large rock outcrop protecting the bay from the majority of winds from the south. There are several rock structures that can be seen at low tide that may be able to offer some protection from erosion and sediment movement. There are several residences located behind the front dune that may be affected by coastal hazards. The low frontal dune rises rapidly into a hill behind the small township.

Figure 2-4 Quarantine Bay and Surrounds (Google Earth Imagery Capture 2018)

Figure 2-5 Quarantine Bay Beach looking North (Left) and South (Right)

2.1.4 Lizard Island

Lizard Island is positioned north east of Cape Flattery. On the island, there is a small resort and airstrip as well as national park camping and mooring facilities. The resort is on the north west side of the island. The main beaches are offered protection by headlands to the north and south. Because of the remote location, the airstrip is critical to accessibility.

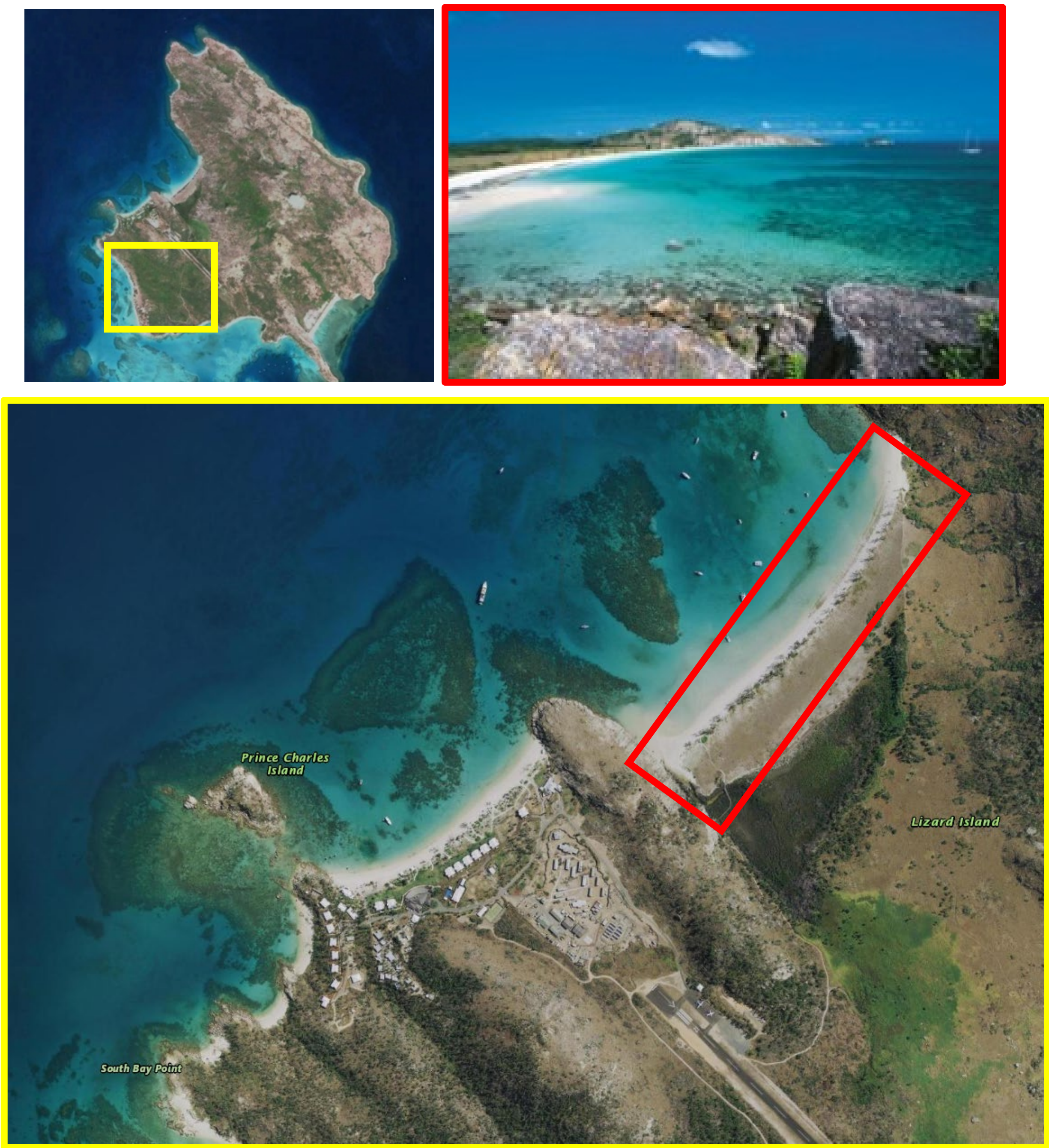


Figure 2-6 Lizard Island and Surrounds (Top Left); Lizard Island Resort and Watsons Bay (Bottom); Watsons Bay (Top Right, DES (2019))

2.1.5 Port Stewart

Port Stewart is located along the coastline of Princess Charlotte Bay, north of Cooktown. Port Stewart has multiple small dwellings and provides access for boating traffic to the bay. It is accessible by a gravel road that connects to the Peninsula Development Road south of Coen. The coastline shows evidence of being mobile over a significant long-term period.

Figure 2-7 Port Stewart and Surrounds; Enlarged area showing small dwellings (Google Earth Imagery Capture 2015)

2.1.6 Restoration Island

Restoration Island sits off the coast east of Portland Roads. It has very little inhabitancy and the key geographical feature of the island is the triangular point facing west. Limited elevation data is available for this site.

Figure 2-8 Restoration Island with enlargement of triangular spit

2.1.7 Portland Roads

Portland Roads has two prominent headlands that have a small number of dwellings on each. The two locations have small bays that have small to medium rock throughout. Both bays are northward facing offering protection from the majority of weather systems, though they remain exposed to cyclonic weather events.

Figure 2-9 Portland Roads and Surrounds; Portland Roads West (Top); Portland Roads East (Bottom) (Google Earth Imagery Capture 2016)

2.2 Permanent Inundation due to Sea Level Rise

The Permanent Inundation due to Sea Level Rise has been mapped using the current day HAT extents with a progressive Sea Level Rise. The rise follows a linear trend to reach HAT +0.8m by 2100. The specific levels used at each site for each time period are shown below in Table 2-2.

Table 2-2 Permanent Inundation due to Sea Level Rise Levels (mAHD)

Location	Present Day	2050	2100
Ayton/Bloomfield	1.50	1.80	2.30
Cooktown/Marton/Quarantine Bay	1.72	2.02	2.52
Lizard Island	1.58	1.88	2.38
Port Stewart	1.87	2.17	2.67
Restoration Island	1.87	2.17	2.67
Portland Roads	1.87	2.17	2.67

The mapping is shown with progressive extents in different colours so that it is easy to identify the increasing extent of the inundation.

2.3 Storm Tide Assessment

Phase 2 identified that existing storm tide models for the Cook Shire were outdated. Therefore, System Engineering Australia Pty Ltd (SEA) was commissioned to update the existing 1 % Annual Exceedance Probability (AEP) storm tide model for the key areas in Table 2-1. This assessment included the following tasks:

- Estimate tropical cyclone (TC) storm tide hazard at each of the nominated communities derived from updated hydrodynamic and statistical storm modelling;
- Analyse non-cyclonic water level statistics from long term gauges representative of the study region; and
- Provide a blended tropical cyclone (TC) and non-cyclonic (non-TC) water level assessment for the study region including both current and future climate scenarios.

The sub-section herein is a summary of the technical storm tide report (SEA, 2019), which should be read in full for appropriate understanding of the assessment and respective assumptions applied (refer Appendix A).

Figure 2-10 indicates the study region, where Cooktown/Marton is the principal community of interest. Numerous minor communities extend northwards from Ayton to near Cape Grenville, with several offshore island localities. The SEA hydrodynamic model coverage and resolution indicated on this figure is consistent with the QCC studies recommendations (Harper et al. 2001).

SEA noted that there were several reasons why the existing studies conducted in 2001-2004 were not as comprehensive as required for the CHAS process, because they excluded for example:

- Waves and wave setup estimates.
- Non-cyclonic storm tide influences.
- Changes to projected climate change criteria (sea level rise etc.).

As such, these were updated in the storm tide model as detailed below.

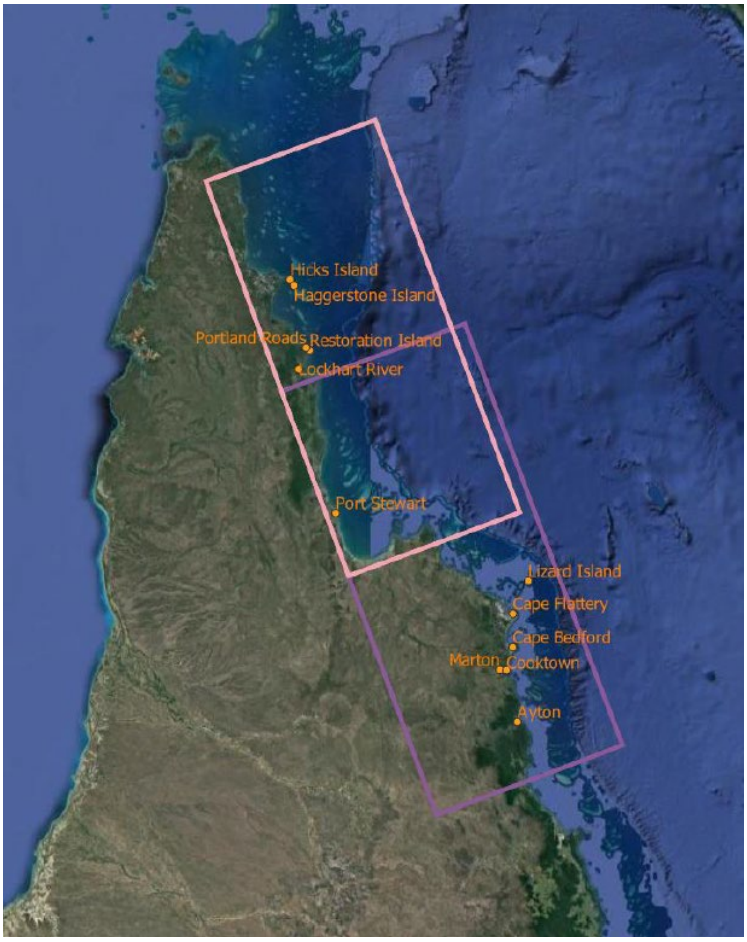


Figure 2-10 The study region sites, other regional locations and SEA B Grid (2.78km) extents (Google Earth™ imagery)

2.3.1 Key Definitions

Storm tide is the combined effects of the astronomical tide, the storm surge magnitude and the wave setup magnitude (refer Figure 2-11). It is an absolute level, referred to Australian Height Datum (AHD). As the astronomical tide varies (up to the Highest Astronomical Tide, or HAT), the total storm tide also varies with the tidal range. Additionally, wave run-up can intermittently reach higher vertical levels if the beachfront has not already been submerged.

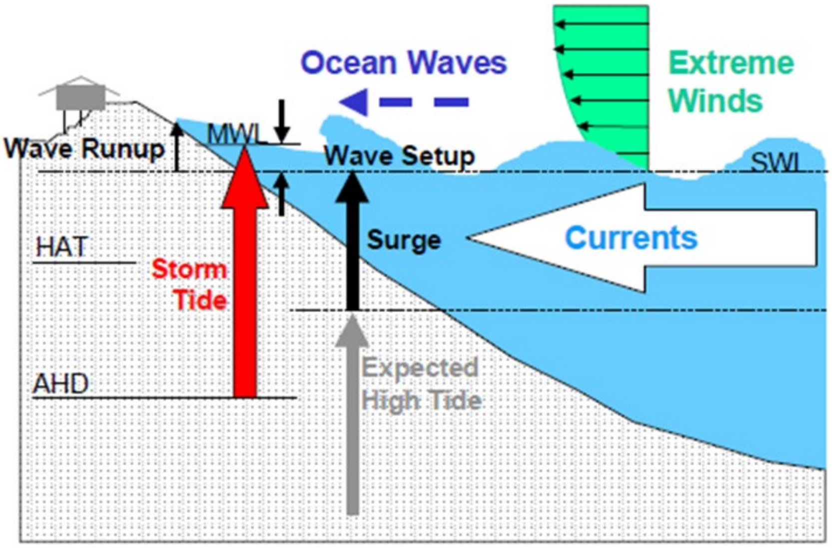


Figure 2-11 Water level components of an extreme TC storm tide

2.3.2 Hydrodynamic Models

The hydrodynamic models utilised in the storm tide study importantly include the complex bathymetry and layout of the extensive Great Barrier Reef structures, which have significant influence on the astronomical tide and act to block deep-sea wave conditions. The relative width of the shallow reef lagoon and the position of significant reef passages also modulates the impact of storm surge generation throughout the region.

2.3.3 Tropical Cyclone Storm Tide Hazard

The hazard mapping was produced using SEAsim, which simulates the long-term statistical storm tide response across many coastal locations. It achieves this by coupling with an Australia-wide synthetic climatology of Tropical Cyclones.

In accordance with State of Queensland design requirements, the following parameters have been included in the hazard mapping for Tropical Cyclone Storm Tides.

Table 2-3 - Year 2050 and 2100 climate change parameters

Planning Year	2050	2100	
MSL Increase	0.3	0.8	m
TC Maximum Potential Energy (MPI) Increase	5%	10%	m/s
	10%	20%	hPa
TC Frequency Change	0%	0%	-

2.3.4 Non-Tropical Cyclone Storm Tide Hazard

Much more frequent but more benign non-cyclonic weather events can significantly influence ocean level statistics up to around the1% AEP. The non-cyclonic response is typically faithfully captured by long-term tide gauges. For this study, astronomical tide data was obtained from Maritime Safety Queensland (MSQ) for the Cooktown site, for the period between 01/01/1989 – 31/12/2017.

The tidal data was subjected to multiple filtering processes (producing a useable period of 28 years) before being used in a re-sampling method to provide 360 likely tides and residual profiles. This produced an approximation of the non-TC water level variability for Cooktown, refer Figure 2-12. This figure shows the simulated estimate predicted for Cooktown (dark blue) and the available measured and ranked annual maximum tide gauge levels (red). Note that periods of TC activity are first removed from the measured records. In light blue are the 360 re-sampled 28-year periods of tide and residuals, which together produce the averaged blue line. The spread of the light blue around the dark blue indicates the sampled natural variability imposed on the system by the effect of random tide phasing combined with the residual signal, which is generally much larger than other components represented by the residual. The measured ARI estimate lies above the estimated mean line beyond the 10yr ARI but it is simply one of all the possible 28-year samples.

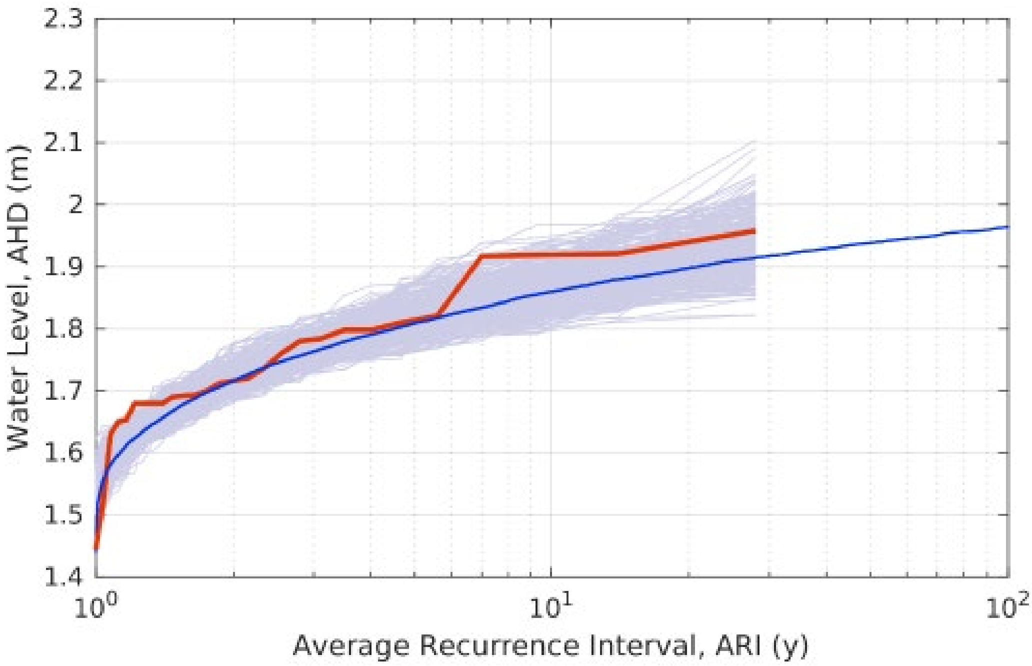


Figure 2-12 Tide-phase imposed non-TC water level variability for Cooktown

2.3.5 Combining TC and Non-TC Water Level Statistics

While the SEAsim model provides TC storm tide statistics of relevance to each geographic site, the only available non-cyclonic water level data applies to the Cooktown site. However, in order to allow for likely variation of the non-cyclonic response as a function of the regional tidal plane variation, the Cooktown statistics are adjusted by the ratio of estimated HAT at each site to that of Cooktown as summarised below, refer Table 2-3.

Table 2-4 - Estimated Astronomical Tidal Plane Variation

Location	Latitude (deg)	Longitude (deg)	HAT (mAHD)	Applied Tide Ratio
Ayton/Bloomfield	-15.91	145.37	1.50	0.87
Cooktown/Marton/Quarantine Bay	-15.44	145.25	1.72	1.00
Lizard Island	-14.65	145.44	1.58	0.92
Port Stewart	-14.05	143.69	1.87	1.09
Restoration Island	-12.62	143.44	1.87	1.08
Portland Roads	-12.59	143.39	1.87	1.09
Haggerstone Island	-12.04	143.30	1.94	1.13
Hicks Island	-11.99	143.27	1.94	1.13

The resulting combined "Total Storm Tide" AEP curve for Cooktown in 2019 climate (yellow) is shown in Figure 2-13, together with the non-TC (blue) and TC (red) components. This illustrates that, due to the significant difference in slopes, the effect of blending is simply to provide a smoothed transition between the two independent probabilities of exceedance near the 1% AEP intersection point. The 2019 HAT line (1.72 m AHD) for Cooktown is also shown.

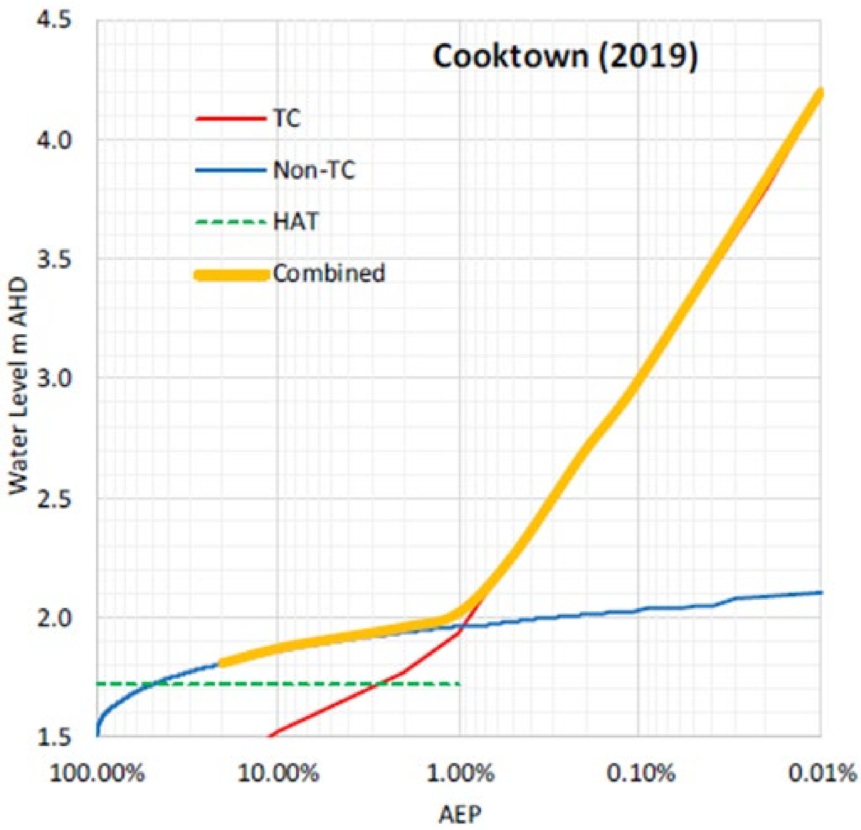


Figure 2-13 - Combined TC and Non-TC Extreme Water Levels

From this, the final tabulation of the blended TC and non-TC Total Storm Tide water levels for present and future projected climate in each key area are provided in Table 2-4, Table 2-5 and Table 2-6. Note that the cyclonic influences only occur from the 1% AEP upwards – more frequent return periods are dominated by non-cyclonic influences.

Table 2-5 – Year 2019 (Present Day) Combined Water Levels (mAHD)

Location	AEP (%)			
	2.0	1.0	0.2	0.1
Ayton/Bloomfield	1.72	1.78	2.34	2.60
Cooktown/Marton/Quarantine Bay	1.99	2.11	2.86	3.00
Lizard Island	1.80	1.82	1.89	1.95
Port Stewart	2.18	2.38	3.10	3.17
Restoration Island	2.13	2.15	2.22	2.27
Portland Roads	2.14	2.17	2.31	2.40
Haggerstone Island	2.21	2.24	2.30	2.31
Hicks Island	2.21	2.24	2.30	2.31

Table 2-6 – Year 2050 Combined Water Levels (mAHD)

Location	AEP (%)			
	2.0	1.0	0.2	0.1
Ayton/Bloomfield	2.00	2.14	2.81	3.10
Cooktown/Marton/Quarantine Bay	2.26	2.34	3.20	3.60
Lizard Island	2.06	2.09	2.20	2.37
Port Stewart	2.46	2.55	3.43	3.75
Restoration Island	2.43	2.46	2.55	2.70
Portland Roads	2.44	2.47	2.60	2.85
Haggerstone Island	2.53	2.55	2.61	2.65
Hicks Island	2.53	2.55	2.61	2.65

Table 2-7 – Year 2100 Combined Water Levels (mAHD)

Location	AEP (%)			
	2.0	1.0	0.2	0.1
Ayton/Bloomfield	2.51	2.73	3.43	3.80
Cooktown/Marton/Quarantine Bay	2.78	2.91	3.90	4.40
Lizard Island	2.53	2.56	2.72	3.00
Port Stewart	3.01	3.16	4.20	4.57
Restoration Island	2.97	3.00	3.12	3.35
Portland Roads	2.98	3.01	3.18	3.50
Haggerstone Island	3.09	3.12	3.18	3.22
Hicks Island	3.09	3.12	3.18	3.22

2.4 Erosion Assessment

The Cook CHAS Phase 2 report identified that there was no site specific, sufficiently detailed, short or long term erosion studies for most locations within the Cook Shire. While state wide erosion mapping covers the Shire, it was deemed likely to be conservative and therefore a more detailed study was recommended to be undertaken for key areas. The conservative approach for the majority of the shoreline was accepted where the presence of built public or private assets did not exist within the declared erosion prone area.

For each area of risk, an analysis of Storm Tide Mapping, Sea Level Rise and current EPA mapping has been considered. Table 2-7 provides a summary of each area at risk, the current erosion prone area assessment and notes regarding the area. These different components will be assessed individually as part of the future stages of the CHAS as impacts and adaptation measures will differ, dependant on the component. For example, erosion and/or permanent inundation due to sea level rise are permanent risks where storm surge is a short term risk from which there can be some recovery.

2.4.1 Overview

The extent of the Erosion Prone Area (EPA) is defined as areas subject to inundation by the highest astronomical tides (HAT) by the year 2100 or at risk from sea erosion.

1. Erosion prone areas are deemed to exist over all tidal water to the extent of Queensland coastal waters and on all land adjacent to tidal water.
2. Erosion prone areas include areas subject to inundation by the highest astronomical tides (HAT) by the year 2100 or at risk from sea erosion.
3. On land adjacent to tidal water the landward boundary of the erosion prone area shall be defined by whichever of the following methods gives the greater erosion prone area width:

a. A line measured 40 m landward of the plan position of the present day HAT level except where approved revetments exist in which case the line is measured 10 m landward of the upper seaward edge of the revetment, irrespective of the presence of outcropping bedrock;

b. A line located by the Erosion Prone Area Width Assessment Formula and measured, unless specified otherwise, inland from:

   – i. the seaward toe of the frontal dune (the seaward toe of the frontal dune is normally approximated by the seaward limit of terrestrial vegetation or, where this cannot be determined, the level of present day HAT); or

   – ii. a straight line drawn across the mouth of a waterway between the alignment of the seaward toe of the frontal dune on either side of the mouth

c. the plan position of the level of HAT plus 0.8 m vertical elevation.

Except:

i. where the linear distance specified in 3b is less than 40 m, in which case section 3a does not apply and the erosion prone area width will be the greater of 3b and 3c; or

ii. where outcropping bedrock is present and no approved revetments exist, in which case the line is defined as being coincident with the most seaward bedrock outcrop at the plan position of present day HAT plus 0.8 m; or

iii. in approved canals in which case the line of present day HAT applies, irrespective of the presence of approved revetments or outcropping bedrock.

'Present day HAT' in the definition is always taken to be the present day level of HAT for the coastline as defined in the Queensland Tide Tables for that year or as defined by empirical methodology at the site. In this way, the landward boundary of the erosion prone area defined above will continue to move landward over time as sea level rises in the future.

The current extent of the erosion prone area where it is defined by 'HAT plus 0.8 m' is the projected HAT coastline at the year 2100. It is determined by the area of land inundated to the HAT level of the nearest adjacent open coast or river tide gauge, plus 0.8 m vertical elevation for projected sea level rise to that time. Site based HAT is not to be used as present day attenuation of inland HAT level due to flow constraints may not persist to 2100 with coastline response to sea level rise.

Table 2-8 – Compartments at risk for Erosion Prone Area Assessment

Location	Coastal/Estuary	Current EPA (m) (DEHP, 2015)	Notes
Ayton (River)	Estuary	40m or HAT + 0.8m-	Road running along the side of the river.
Ayton Township (Mangrove Area)	Estuary	40m or HAT + 0.8m-	Township on a high stand, mangrove area has limited wave action that would cause erosion; main concern is inundation extent.
Ayton (Beach)	Coastal	400m (COS001) 125m (COS002)	Lower half of Ayton beach prone to river mouth movement. The long-term assessment will allow for a more detailed look at where the distinction between the two sections lies.
Cooktown Country Golf Club	Coastal (COS022)	125m (COS022)	This beach is positioned just south of Quarantine Bay and faces the prevailing southeast trade winds and resulting wave action. This beach will also be exposed to cyclonic winds and waves generated by tropical cyclones approaching from the east and northeast. In the long-term the erosion prone area will increase and may place the golf club at risk from coastal erosion in the future.
Quarantine Bay	Coastal	110m (COS024)	Assess.
Cooktown Webber Esplanade	Coastal	0m (COS029)	Seawall present, Will need to upgrade the erosion distance to 10m in line with coastal hazard technical guide.
Cooktown Township Esplanade	Estuary	40m or HAT + 0.8m-	Evidence of intermittent hard structure/Seawalls
Mangrove Marsh Area along Endeavour River	Estuary	40m or HAT + 0.8m-	Investigate long-term imagery to determine if there have been changes in the mangrove extent.
Endeavour River switchback	Estuary	40m or HAT + 0.8m-	Accept 40m or HAT + 0.8m, Likely dominated by Flood mapping.
Cooktown Airport	Estuary	40m or HAT + 0.8m-	Accept 40m or HAT + 0.8m
Lizard Island – Resort Beach	Coastal	40m or HAT + 0.8m-	Assess if possible with available data.

Location	Coastal/Estuary	Current EPA (m) (DEHP, 2015)	Notes
Lizard Island – Watsons Bay	Coastal	40m or HAT + 0.8m-	Assess if possible with available data.
Port Stewart	Coastal	400m (COS099)	Assess.
Restoration Island	Coastal	40m or HAT + 0.8m-	Assess if possible with available data.
Portland Roads (West)	Coastal	129m (COS129)	Assess.
Portland Roads (East)	Coastal	30m (COS135)	Assess.

2.4.2 Calculated Erosion Prone Area Assessment Method

The Coastal Hazard Technical Guide provides a step-by-step approach to assessing erosion. For EPA's along sandy coasts exposed to moderate to high wave energy there is a developed formula that has been adopted by the Department of Environment and Science (DES, formerly DEHP). This formula takes into account long term trends over a defined planning period, short term erosion trends, sea level rise, dune scarping and includes a factor of safety.

$$E = [(N \times R) + C + S] \times (1 + F) + D \quad (2)$$

Where:

E = Erosion Prone Area Width (metres)

N = Planning Period (years)

R = Rate of Long Term Erosion (metres per year)

C = Short Term Erosion from the Design Storm or Cyclone (metres)

S = Erosion due to Sea Level Rise (metres)

F = Factor of Safety (0.4 has been adopted)

D = Dune Scarp Component to allow for slumping of the erosion scarp (metres)

Figure 2-14 shows an example of the erosion factors on an initial and final profile.

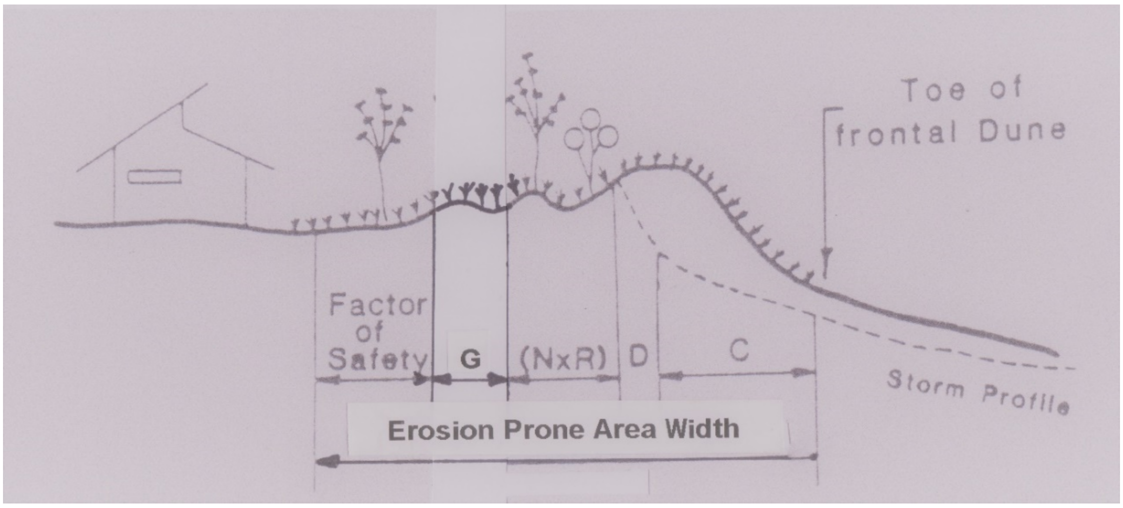


Figure 2-14 Example Beach profile showing indicative erosion factors

The calculation and determination of each factor in the context of this CHAS is outlined below.

2.4.3 Planning Period (N)

Planning period is considered in terms of the assessment of long-term erosion and erosion due to sea level rise. However, as the sea level rise assessment is based on a projected sea level at a future date, the planning period is already inherently considered. Planning period for the purposes of applying the EPA width formula therefore only applies to the assessment of long-term erosion. The assessment has used a planning period relating to the planning horizon where possible. For the 2100 horizon, for some sites, a capped 50-year planning period has been applied due to evidence that the extended timeframe is not appropriate for the site. The long term rate is based on a small data set and relies on information captured at one moment in time in each period, so for the purposes of a CHAS, adopting the same rate over the full planning period is suitable, noting that CHAS assessments should be re-visited at regular intervals, offering the opportunity to reassess as more information becomes available.

2.4.4 Rate of Long Term Erosion (R)

Long-term erosion refers to the annual rate of erosion at a beach assessed using either survey data or georeferenced historical aerial imagery to establish trends. The rate per year is then applied over the future planning period. As beaches often go through natural phases of erosion and recovery, the assessment therefore identifies long-term erosion trends that may not be evident over short time periods. The position of the shoreline is assessed as the seaward toe of the frontal dune, which generally corresponds to the vegetation line.

The aerial imagery available for these sites was difficult to source and use in a robust shoreline analysis. The shoreline analysis software used through ArcGis (DSAS) uses a linear regression method to establish movement trends. If the shoreline does not show a specific trend a movement will still be given, however the accuracy may contain error due to the limited points available. It is expected that due to this the uncertainty within the analysis undertaken could be up to +-10 m. In future coastal hazard studies undertaken for these sites, a more detailed shoreline analysis can be prepared, as more data becomes available

Table 2-8 shows the average movement of the shoreline relevant to the Baseline. The baseline has been taken as the oldest imagery available as there is no presence of hard consistent structures in all locations. Table 2-9 shows several rates, these are; the interval rates between the respective first and second images and the second and third images, overall average rate and the average derived Linear Regression Rates (LRR) from the DSAS software for each beach. Commentary on the rates and the rates to be used for assessment are also included.

Further information including the shoreline movement plots can be found in Appendix B.

Table 2-9 Average Movement of Shoreline relevant to Baseline (m)

Location	Ayton (Beach) (COS001)	Ayton (Beach) (COS002)	Cooktown Country Golf Club	Quarantine Bay	Lizard Island	Port Stewart	Restoration Island	Portland Roads (West)	Portland Roads (East)
1979	0m	0m	-	-	-	-	-	-	-
1982	-	-	-	-	0m	-	-	-	-
1991	-	-	-	-	-	0m	0m	0m	0m
1994	-	-	0m	0m	-	-	-	-	-
2000	0.6m	-12.4m	-	-	-	-	-	-	-
2003	-	-	-	-	-	1.9m	-	-	-
2006	-	-	33.7m	4.1m	-	-	-	-	-
2011	-	-	-	-	-4.5m	-	-	-	-
2012	-	-	-	-	-	-	1.1m	2.4m	-2.2m
2014	-	-	-	-	-	-2.6m	-	2.7m	-
2017	-	-	-	-	-2.6m	-	0.1m	-	-3.9m
2018	8.2m	-13.5m	38.1m	5.4m	-	-	-	-	-

Table 2-10 Movement Rates and Comments on Assessment

Location	Interval Rates (m/yr)	Overall Average Rate (m/yr)	DSAS LRR (m/yr)	Rate Used in EPA Assessment (m/yr)	Comments
Ayton (Beach) (COS001)	0.03 0.42	0.2	0.20	0	River mouth appears to be stable except for the small sand spit at the mouth that moves with the channel. The beach is generally accreting and there is a heavily vegetated spit present.
Ayton (Beach) (COS002)	-0.59 -0.06	-0.3	-0.36	-0.5	Erosion is evident along this stretch of beach in front of the small number of dwellings.
Cooktown Country Golf Club	2.81 0.37	1.6	1.59	0	Accretion present from sediment transport from southern river/coast being captured by headland at the northern end.
Quarantine Bay	0.34 0.11	0.2	0.29	0	Small accretion in analysis that may be within the resolution limits of the imagery used in the analysis.
Lizard Island	-0.15 0.31	-0.1	-0.02	5m (Nominal)	Very small erosion from analysis. Resolution of the imagery limits the accuracy of the analysis and may cause significant variations in the LRR result as the beach appears stable and protected from most weather events. Allow for a nominal 5m erosion for all time periods due to the northerly facing beach.
Port Stewart	0.09 -0.41	-0.1	-0.2	10 (Nominal)	Movement of the Spit entering the river mouth, coastal beach is stable, short term erosion is key driver at this site. Allow for a nominal 10m to account for cyclical movement or a change in long term movement in the future.
Restoration Island	0.05 -0.20	0.0	0.0	0	Stable beach protected from most weather events.
Portland Roads (West)	0.11 0.08	0.1	0.6	0	Accretion in this bay is occurring at present. Accurate analysis is not possible due to low quality images.

Location	Interval Rates (m/yr)	Overall Average Rate (m/yr)	DSAS LRR (m/yr)	Rate Used in EPA Assessment (m/yr)	Comments
Portland Roads (East)	-0.11 -0.34	-0.2	-0.1	5m (Nominal)	Small erosion rate from the analysis. The low quality imagery available for this area made it difficult to accurately define the vegetation line. The beach appears stable and protected. Allow for a 5m nominal movement as the beach is northerly facing and protected.

2.4.5 Short Term Erosion from Design Storm (C)

Generally, for beaches in equilibrium, storm erosion occurs when increased wave heights and water levels result in the erosion of sand from the frontal dune. The eroded sand is taken offshore where it is deposited as a sand bar located near the wave break area. After the storm event the sediment is slowly transported onshore, often over many months or several years, rebuilding the beach. This type of erosion can be extremely damaging to coastal areas.

Design Storm

The Coastal Hazard Technical Guide recommends for a tide-dominated coast where storm tide levels can be large, the parameters adopted for the minimum design storm should be:

- Storm Tide Level corresponding to an average recurrence interval of 1-in-100 years (1 % AEP)
- Wave Height for a moderate storm using the 1-in-20 year (5 % AEP) significant wave height

SBEACH Modelling

To perform the modelling of the identified at-risk sites, SBEACH software was utilised. SBEACH (Storm-induced BEAch CHange) is a numerical simulation model for predicting beach, berm and dune erosion due to storm waves and water levels. The program was developed at the US Army Engineer Waterways Experiment Station, Coastal Engineering and Research Centre (CERC).

Inputs to the model were sourced as follows.

- Storm Tide Levels were used from the SEA report completed for the storm tide mapping (refer Table 2-4).

Table 2-11 Modelled Storm Tide Levels

Location	2019 (mAHD)
Ayton/Bloomfield	1.78
Cooktown/Quarantine Bay	2.11
Lizard Island	1.82
Port Stewart	2.38
Portland Roads	2.17
Restoration Island	2.15

- Beach profiles are from available LiDAR (DNRME 2009 1 m DEM). Bathymetry data is limited, and has been taken from nautical charts for each location (Navionics Nautical Charts). The beach profiles have been extended out to -10 m AHD or 2000 m offshore to allow SBEACH to initiate offshore conditions.
- Wind data was sourced from BOM for three locations (Cooktown, Low Isles and Cape Flattery). An analysis of the data presented summary wind speeds that reflected expected conditions for a 5 % AEP Storm (Table 2-11); as recommended by the Coastal Hazard Technical Guide. This wind data was used and applied to the different areas depending on the closest wind recording station. Wave calculations, utilising site specific fetches carried out using the methodology in the Shore Protection Manual.

Table 2-12 Wind Speeds used in Modelling (BOM, 2019)

	Cooktown	Low Isles	Cape Flattery
5%AEP Wind (m/s)	19.3	25.2	15.8

- Sediment sampling at a number of locations was conducted to identify sediment particle size. From the samples, the median sediment particle size was determined for each site using a particle size distribution graph. These are included in Appendix D. The median (D50) grain size for each sampling location is also included below in Table 2-12. As there were only three locations sampled, analysis relied on existing data where available and where no data was available the generic SBeach parameter was used (grain size of 0.35mm reflecting a mix of coarse and fine sands that may be present along most sandy beaches).

Table 2-13 Sediment Sampling Median Values

Sample	Location	Median Grain Size (mm)
1	Portland Roads	0.04
2	Quarantine Bay	0.99*
3	Port Stewart	0.43

*As seen in Appendix, location was smoothed gravel and there was some sandy substrate below surface, use median grain size with caution

Assumptions in the model are summarised as follows.

- The model was run for a 24 hour period (1440 minutes) to produce a similar result to a non-TC storm acting along a coastline and to allow the model to reach equilibrium. This is in line with the storm tide report (summarised in Section 2.3) showing that the AEP 0.5% design storms are at the blending point of TC and non-TC conditions. TC conditions often give varying waves as they move closer to the coast as waves become fetch limited. Severe storms may move slowly along a coastline over a longer period with consistent conditions.
- There has been no wind included in the modelling as the provided storm tide levels from the SEA report (summarised in Section 2.3) include the effects of wind induced storm surge onto the coast.
- The wave water depth (the point at which the waves are extracted) has been set to 10 m for all design storms, to provide a suitable offshore location for the waves to propagate onshore.
- The wave angle has been presumed to be parallel to the shoreline in all locations. As SBEACH is 1D modelling software, there is no capacity in the program to predict longshore transport.

- The maximum slope of a sand dune after avalanching was set to 18 degrees, as this corresponds to a 1:3 slope. This is generally considered the natural angle of repose for beach sand.
- Where not specifically noted in this report, parameters can be assumed to have been left as the default setting.

The outputs of the assessment consist of:

- The plan position change of the present day HAT contour (approximation of the seaward toe of the frontal dune) to the intersection of the eroded profile with the initial profile. This equates to the short term erosion distance which is defined as the horizontal distance between the point at which the HAT intersects with the original profile, and the point of intersection of the eroded profile.
- Initial and final beach profiles.
- Maximum water elevation level.

2.4.6 Interpreting SBeach Profile where Dune Scarp is formed

While the SBeach outputs provide a detailed analysis of the beach profile under storm conditions, in some cases the computed results may be affected by dune slumping which may not be captured fully in the calculated results. In these case's the computed initial and final profiles are analysed to ensure that the correct erosion parameters had been identified.

A closer analysis of Ayton, Cooktown Country Golf Club, and Lizard Island profiles were undertaken due to dune scarps forming. The analysis was to ensure that the correct parameters were used in the erosion prone area calculations.

Ayton

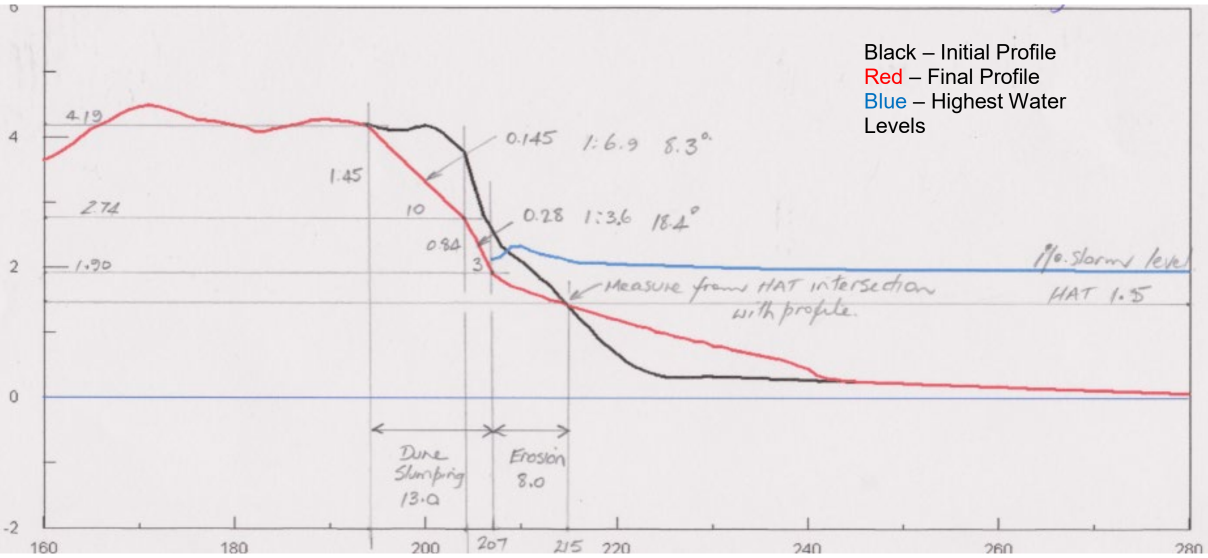


Figure 2-15 Ayton 1 (Run Group A) SBeach Output Analysis (mAHD/Chainage)

This profile was identified as developing a dune scarp after the modelling was undertaken on the initial profile. At the point that the storm tide intersects with the eroded profile, the beach forms a scarp at 1:3 before going to a 1:7 slope. For this case, the short-term erosion component has been taken as the initial position of the HAT contour on the original profile to the final plan position of the beach at the storm tide level, and the dune scarp component is the remainder of the eroded profile landward of this point.

Cooktown Country Golf Club

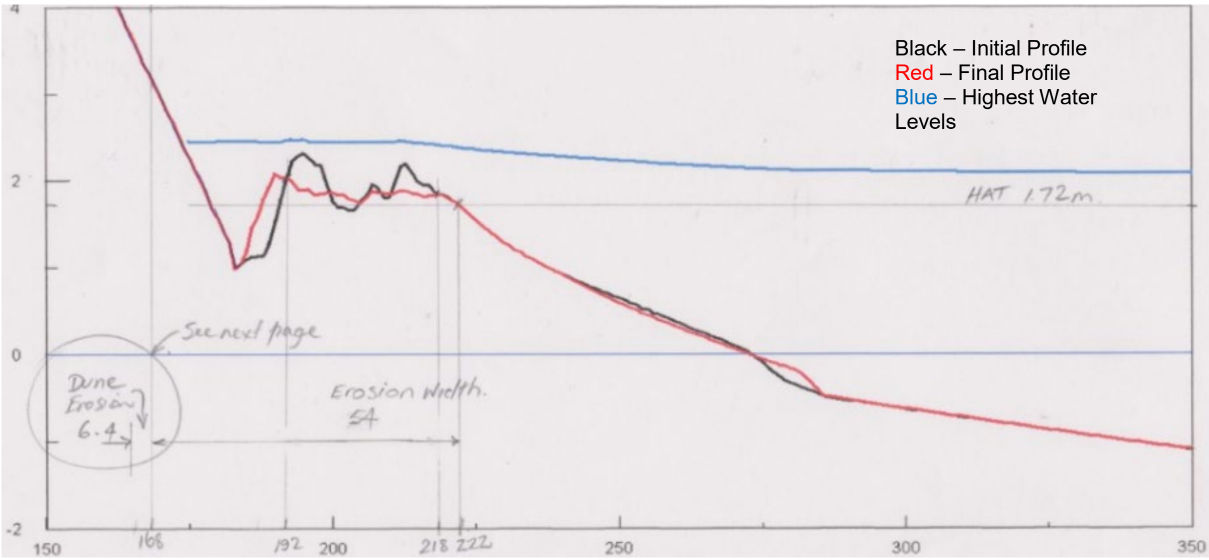


Figure 2-16 Cooktown Country Golf Club (Run Group C) stepped dunes

Cooktown Country Golf Club has a series of stepped foredunes at the top of the beach. These stepped dunes are likely to have been formed and eroded during storm and cyclonic events that would have significant effects on this south east facing coastline.

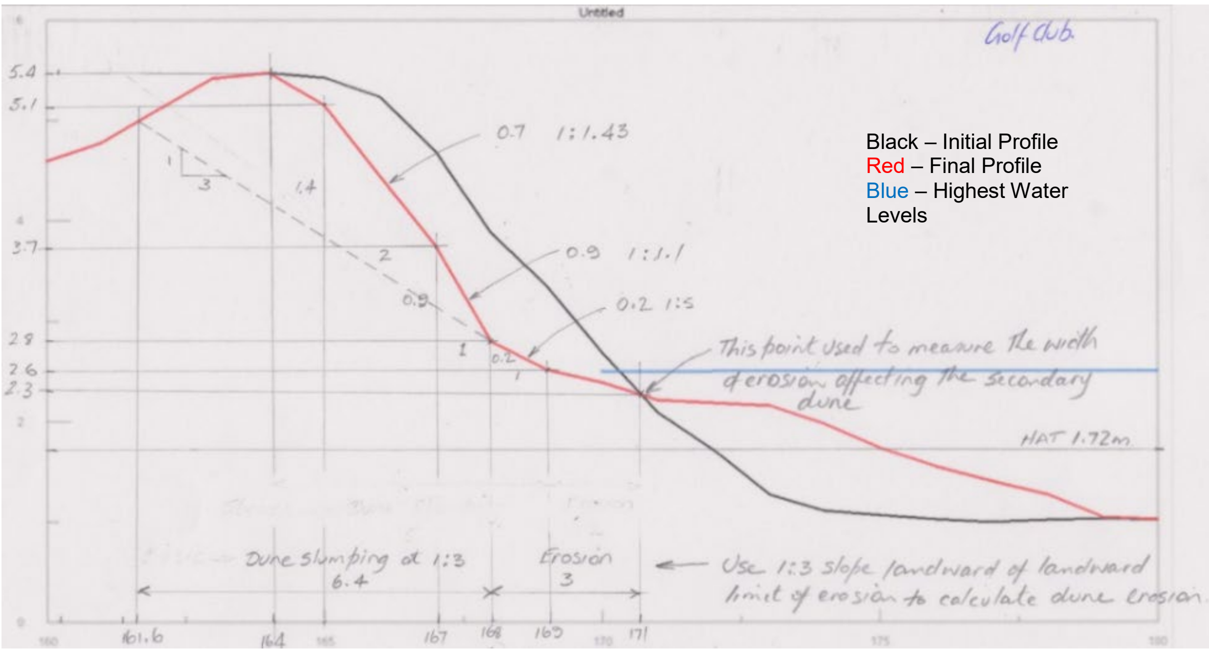


Figure 2-17 Cooktown Country Golf Club (Run Group C) Rear Dune SBeach analysis

The back dune presents as a dune slumping scenario due to the erosion and inundation of the low frontal dune. To ensure that the hazard is fully realised, a dune slump condition of 1:3 has been imposed from the point of identified erosion back until it reaches the initial profile.

Lizard Island

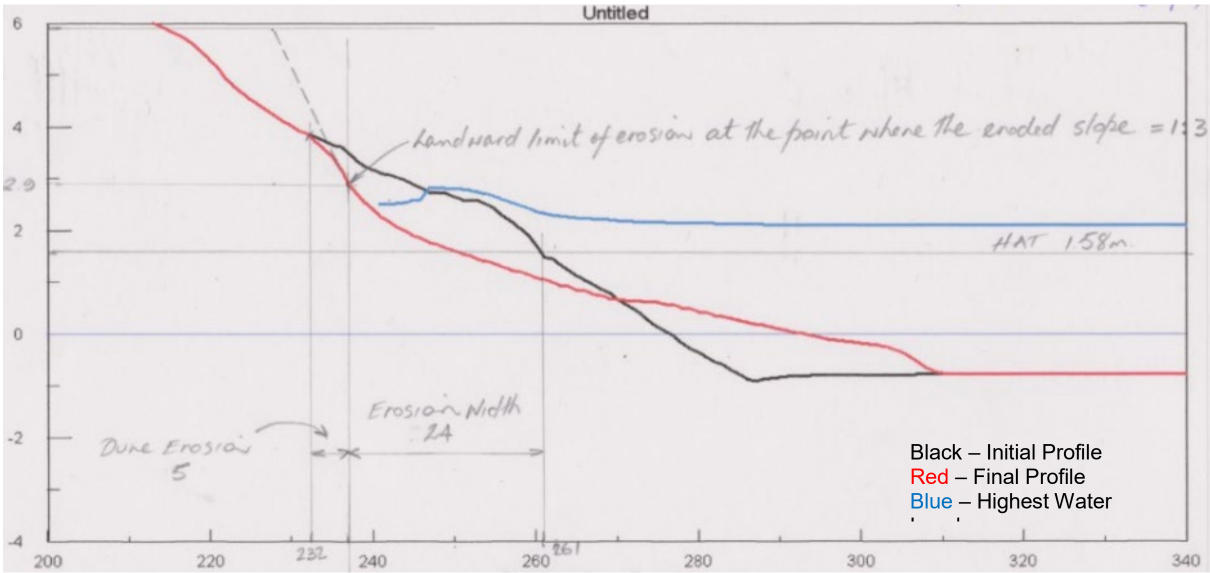


Figure 2-18 Lizard Island (Run Group H) SBeach Analysis

The profile has been identified as having a small dune slump occurring. The short-term erosion has been taken as the location of the HAT contour on the initial profile to the point of apparent erosion before the dune begins to slump above the location of storm tide. The dune erosion is then taken as the distance up to where final profile meets the initial profile.

2.4.7 Shoreline Response to Sea Level Rise (S)

In accordance with the requirements of DEHP (2013) (now DES), a SLR allowance of 0.8 m by 2100 is included in the EPA assessment.

Recession is measured at the level of sea level inclusive of sea level rise. See Figure 2-19 for a graphical explanation.

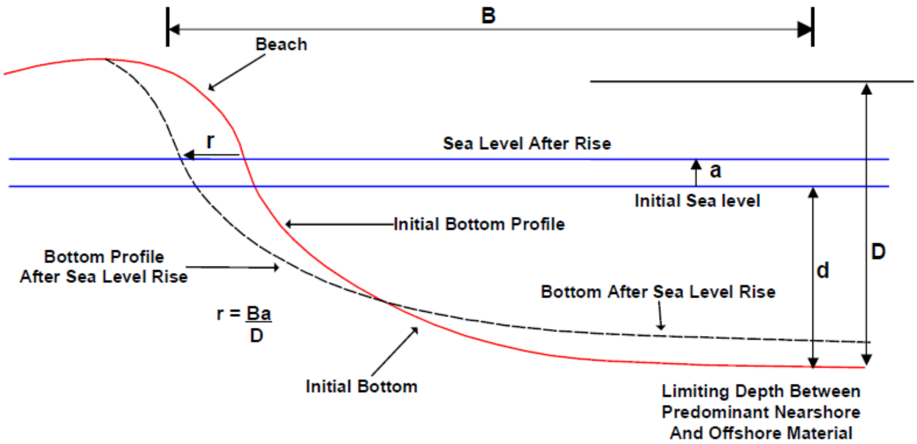


Figure 2-19 Bruun Rule Diagram (Rollason et al, 2010)

The modified Bruun Rule was used to calculate recession. The Bruun rule infers that the beach profile will migrate landward and upward in response to SLR (Bruun, 1962). As it is not certain that wide inter-tidal flats will migrate landward at their current beach slope (as summarised in Rollason et al (2010)), a modified Bruun Rule can be applied to the upper beach profile only in order to calculate shoreline recession (DEHP, 2013). Assuming a closure depth (d) measured from where the profile gradient flattens considerably at approximately 0 m AHD, the modified Bruun rule (Rollason et al, 2010) is:

$$r = Ba/D$$

Where:

r = Recession width (metres)

a = Sea level rise (metres)

d = Depth of closure (metres)

B = Width of bottom influenced by the SLR extending to d

D = Depth of closure including dune height

These parameters for each profile have been included in Appendix D. An extract from the appendix is shown below for three indicative locations to exemplify how the Bruun Rule was calculated. The values are summarised in Table 2-13.

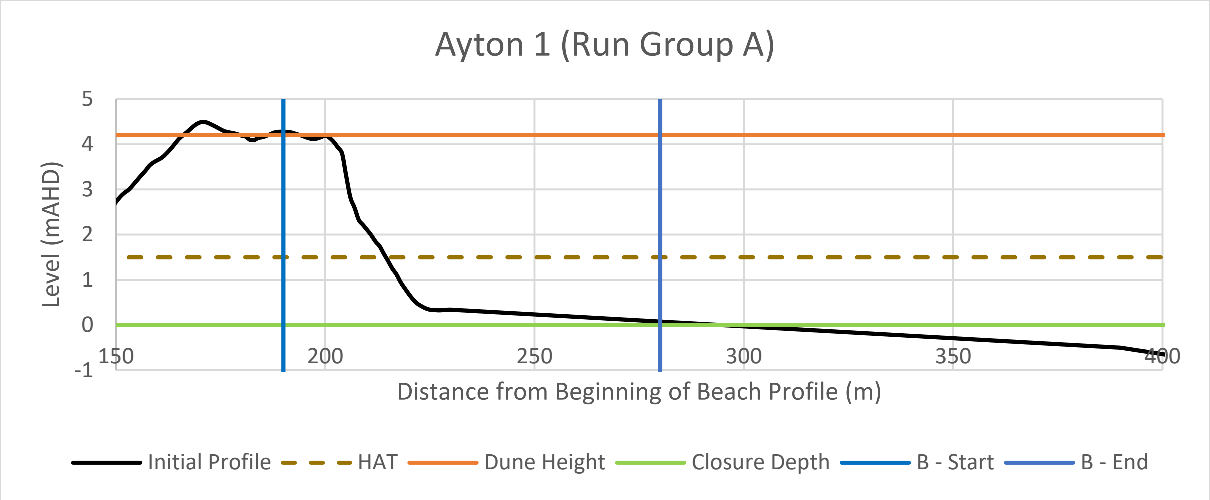


Figure 2-20 Ayton 2019 profile

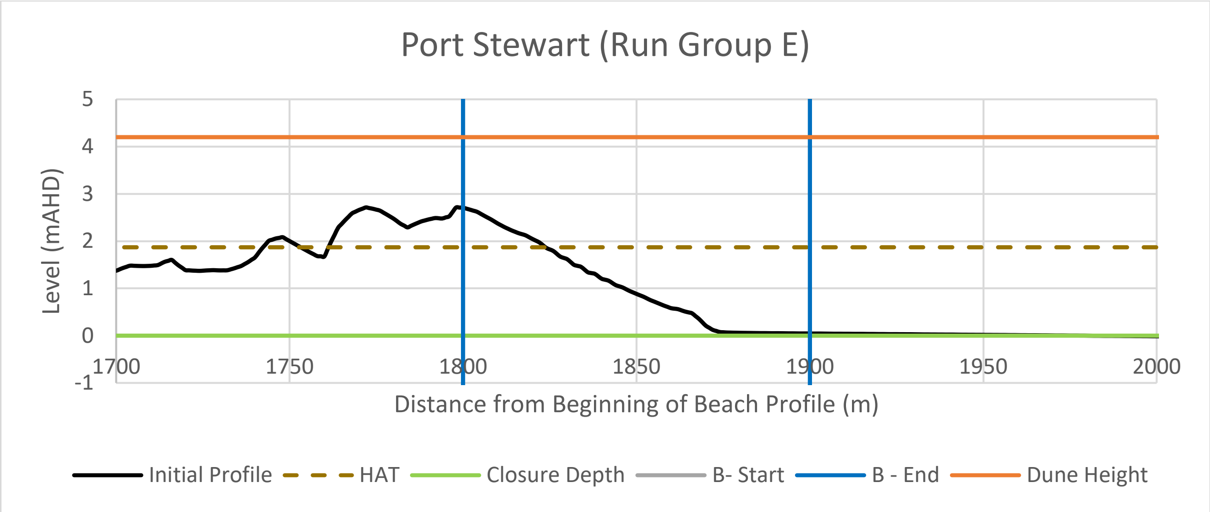


Figure 2-21 Port Stewart 2019 profile

Table 2-14 Example of Bruun Rule parameters

Location	Left extent (x-axis) (m)	Right extent (x-axis) (m)	Width of bottom influenced (B) (m)	Dune Height (mAHD)	Closure depth (mAHD)
A – Ayton 1	190	280	90	4.2	0
E – Port Stewart	1800	1900	150	2.9	0

The values of Sea Level Rise for the three planning horizons considered in this report are shown in Table 2-14. These values will be used in the Bruun Rule calculations to determine the recession of the coastline due to Sea Level Rise at each planning horizon.

Table 2-15 Sea Level Rise for different planning horizons

Planning Horizon	Sea Level Rise
Present Day	0m
2050	+0.3m
2100	+0.8m

2.4.8 Factor of Safety (F)

In accordance with the requirements of the Coastal Hazard Technical Guide (DEHP, 2013), a factor of safety of 40% has been used in the assessment.

2.4.9 Dune Scarping (D)

A dune scarp component is included in EPA calculations to allow for slumping of the dune following a storm event. It is assumed the post-storm dune profile will slump at a 1:3 slope landward from the toe of the erosion scarp, as this is generally considered the natural angle repose of beach sand.

In areas where the level of the dune system is relatively low, large areas of the frontal dune will be subjected to wave action at the peak of the storm tide, resulting in a recession of the coastline (indicated by the landward movement of the HAT line) and a flattening of the dune profile landward of the HAT. In these instances, where there is no distinct erosion scarp on the post-storm dune profile, the dune scarp component is zero.

2.4.10 Calculated Erosion Prone Area Results

A breakdown of the erosion prone area calculation components is provided in Table 2-16, including a comparison of the current EPAs and the calculated EPAs recommended for adoption.

Table 2-16 Erosion Prone Area Results

Location	EPA Beach Code*	Planning Period (N) (yrs)			Long Term Erosion Rate (R) (m/yr)	Short Term Erosion (C)(m)	Sea Level Rise (S) (m)			Factor of Safety	Dune Scarp (D) (m)	Erosion Prone Area (m)			Current EPA Width (DEHP, 2015) (m)
		2020	2050	2100			2020	2050	2100			2020	2050	2100	
Ayton (Beach)	COS001	-	-	-	0	8	0	6	15	0.4	13	25	33	46	400
Ayton (Beach)	COS002	0	30	80	0.5	4	0	9	23	0.4	17	23	57	111	125
Cooktown Country Golf Club	COS022	-	-	-	0	54	0	8	21	0.4	7	82	94	112	125
Quarantine Bay	COS024	-	-	-	0	10	0	4	11	0.4	0	14	20	30	110
Cooktown Webber Esplanade	COS029	-	-	-	-	-	-	-	-	-	-	10[a]	10[a]	10[a]	0
Port Stewart	COS099	-	-	-	10[b]	29	0	15	40	0.4	0	51	72	107	400
Portland Roads (West)	COS129	-	-	-	0	22	0	9	24	0.4	1	32	45	66	129
Portland Roads (East)	COS135	-	-	-	5[b]	25	0	9	24	0.4	0	40	53	74	
Lizard Island (Resort)	-	-	-	-	5[b]	24	0	5	12	0.4	5	44	51	61	40
Lizard Island (Watsons Bay)	-	-	-	-	5[b]	38	0	8	20	0.4	0	59	70	87	40

* - Where an EPA Beach Code is applicable it has been supplied, for areas with no code supplied, refer to Table 2.13 for the Latitude and Longitude of Start and End Points of all beaches.
a – As recommended by the technical guide, where a well maintained, properly designed hard structure (e.g. Council Owned and maintained) is present the Erosion Prone Area is measured 10m landward of the upper seaward edge of the revetment, irrespective of the presence of outcropping bedrock. For locations where a seawall is present but is not maintained or has unknown construction, assume no long term erosion and undertake calculation.
b – A nominal value has been applied across all timeframes where there is no clear erosion n trend however a cyclical seasonal movement is present.

2.4.11 Mapping Guide

The following is a mapping guide for the locations identified in the report that fall within the Cook Shire Council coastline. The segments are arranged from south to north and the 2100 EPA distances calculated above have been included.

Table 2-17 Mapping Guide for Cook Shire Coastline

Location Description (Where applicable)	EPA Beach Code	Segment Start (Lat)	Segment Start (Long)	Segment End (Lat)	Segment End (Long)	2100 EPA (m)
Cooktown Township Esplanade	River	From southern end of Webber Esplanade Revetment to end of protected township, where not revetted, HAT + 0.8m				10
Ayton (Beach)	COS001	-15.9218	145.3629	-15.9086	145.3567	46
Ayton (Beach)	COS002	-15.9086	145.3567	-15.8792	145.3608	111
Cooktown Country Golf Club	COS022	-15.5224	145.272	-15.5021	145.2808	112
Quarantine Bay	COS024	-15.4956	145.2783	-15.4904	145.2749	30
Cooktown Webber Esplanade	COS029	-15.4628	145.2621	-15.4619	145.2496	10
Port Stewart	COS099	-14.0897	143.6927	-14.0618	143.6891	107
Portland Roads (West)	COS129	-12.6122	143.4364	-12.6134	143.4268	66
Portland Roads (East)	COS135	-12.596	143.4117	-12.5714	143.3595	74
Lizard Island (Resort)	Island	-14.6679	145.4453	-14.6658	145.4489	61
Lizard Island (Watsons Bay)	Island	-14.6659	145.4509	-14.6615	145.4548	87

2.5 Erosion Prone Area Assessment Summary

This summary in Table 2-17 outlines some of the calculated erosion prone areas that require further consideration.

Table 2-18 Specific area considerations

Location	Notes
Ayton Beach (COS001)	Ayton Beach COS001 is situated closest to the river mouth and extends north until approximately the southern end of the dwellings, refer to DES mapping for specific coordinates. While the erosion prone area has been indicated as 46m from the formula it should be noted that this area is in the vicinity of a river mouth and may be subject to large movements over a longer time scale than what is available through aerial imagery currently available.
Lizard Island	The Lizard Island erosion assessment has been calculated on the basis of a weather system moving from North to South on the Western side of the island causing damage to the North West facing beaches. This has happened in the recent past where ex TC Oswald moved inland down the Queensland Coast causing damage to normally protected northward facing beaches.
Restoration Island	Restoration Island was assessed with the default parameters with an erosion area of HAT + 0.8m or 40m as there is limited bathymetry for the area. The main beach is also protected from most weather systems and the prominent western facing triangle tip has been present throughout the long-term imagery assessed.
Port Stewart	The erosion at Port Stewart is driven by inundation of the North-South parallel dunes from both the river and from across the beach during a storm tide event. The calculation has been based on a 2050 storm as the high inundation level from a 2100 storm resulted in unstable results from SBeach.

3. Phase 3 Summary

This report summarises the Phase 3 findings for the impacts associated with storm-tide, erosion and sea level rise for all locations. Following is a brief summary of the findings for each of the five focus areas.

Ayton

The Ayton township is generally on a high stand that is protected from coastal hazards. The key hazard area for the Ayton area are the residences located along the coastal spit to the north east of the township and areas along the river frontage not elevated high enough to be clear of inundation.

Quarantine Bay

The Quarantine Bay area is potentially highly affected by different hazards depending on the track and location of the storm. While it is offered some protection by the headland to the immediate east of the bay there is potential for forcing winds and waves to occur from the north. As the climate changes there is also potential that long term and seasonal sand movements may change.

Cooktown

The Cooktown Country Golf Club is located close to the shoreline in a stable embayment that has evidence of being affected by storm events in the past. The high dunes offer the community infrastructure some protection and a buffer from the coastal hazards. Cooktown itself is protected by revetments along most of the length of the Endeavour River compartment of the township. The Webber Esplanade revetment offers protection from most large weather events. Further up river the extent of the inundation may impact the airport. Erosion or change of course of the riverbank on the eastern edge of the airport may cause future issues and should be monitored closely.

Lizard Island

Lizard Island has high protection from coastal hazards due to the majority of the island having a high elevation. While the settlements are in low bays and fall within the erosion prone area in some instances, the key infrastructure such as airstrip, maintenance facilities and major amenities for the resort are set back beyond the reach of coastal hazards in the current climate.

Port Stewart

Due to Port Stewart’s landform a high level of inundation is expected throughout the dune systems. It is possible that fluvial flooding during wet seasons may be of equal or greater cause of concern for this area however, as evidenced by the high number of tributaries indicative of high runoff volumes during large events.

Restoration Island

The small number of inhabitants on the island are expected to adapt over time to potential coastal hazards. The Island is well protected from most coastal hazards.

Portland Roads

The Portland Roads area is somewhat protected from coastal hazards by the system of headlands present at both sites. There is potential that the small number of residences may be affected in the future.

4. CHAS Phase 4

The information in this report will be used to identify impacted assets along the Cook Shire coastline. The impacted assets will be quantified using GIS datasets and layers to overlay critical hazards identified in Phase 3.

These identified impacted assets will be addressed in further stages of the CHAS, outlined in Section 1.2 of this document.

5. References

Conrad Blucher Institute for Surveying and Science (1996), *SBEACH-32 Interface User's Manual*, prepared for U.S Army Corps of Engineers January 1996

DEHP (2013). *Coastal Hazard Technical Guide, Determining Coastal Hazard Areas*, prepared by Environmental Planning, Queensland Department of Environment and Heritage Protection, April 2013. https://www.ehp.qld.gov.au/coastalplan/pdf/hazards-guideline.pdf

Department of Natural Resources Mines and Energy (DNRME), Queensland Globe Database 2019: https://qldglobe.information.qld.gov.au/

GHD 2017. *Cook Shire Council Coastal Hazard Adaptation Strategy, Phase 1 Stakeholder Communication and Engagement Plan*

GHD, 2017. *Cook Shire Council Coastal Hazard Adaptation Strategy, Phase 2 Scoping Study*

Local Government Association of Queensland and the Department of Environment and Heritage Protection (2016). *QCoast$_{2100}$ Developing a Coastal Hazard Adaptation Strategy: Minimum Standards and Guidelines for Queensland Local Governments*. State of Queensland.

Queensland Government (2019), *Cook Shire Local Government Area Erosion Prone Area*: https://www.qld.gov.au/__data/assets/pdf_file/0023/68810/cook-erosion-prone-area-plan.pdf

Systems Engineering Australia Pty. Ltd. (2019) *Storm Tide Hazard for Present and Future Climates*, Report provided to GHD May 2019 (Appendix B)

Appendices

Appendix A – SEA Storm Tide Report

Technical Memorandum

Job:	Cook Regional Council CHAS Phase 3	**Job No:**	J1819
Subject:	Storm Tide Hazard for Present and Future Climates	**Doc ID:**	MO001C
Date:	23/05/2019		
To:	Ms Anita Haigh / GHD Cairns	**Status:**	Final
From:	Dr Bruce Harper / SEA	**Mode:**	Email

1 Introduction

This technical summary report refers to GHD Project 4221024, contract dated 14/03/2019 and SEA's proposal dated 17/10/2018:

Scope of Services:

- Estimate tropical cyclone (TC) storm tide hazard at each of the nominated communities derived from updated hydrodynamic and statistical storm modelling;
- Analyse non-cyclonic water level statistics from long term gauges representative of the study region;
- Provide a blended tropical cyclone (TC) and non-cyclonic (non-TC) water level assessment for the study region including both current and future climate scenarios

SEA's understanding is that the specific communities to be assessed are as follows:

- Ayton/Bloomfield
- Cooktown/Marton/Quarantine_Bay (considered identical site exposures)
- Lizard Island
- Port Stewart
- Restoration Island
- Portland Roads
- Hicks Island
- Haggerstone Island

Figure 1 indicates the study region, where Cooktown/Marton is the principal community of interest. Numerous minor communities extend northwards from Ayton to near Cape Grenville, with several offshore island localities. The SEA hydrodynamic model coverage and resolution indicated on this figure is consistent with the QCC studies recommendations (Harper et al. 2001).

The methodology embodies the principal references cited by Council to underpin the analyses:

- QCoast2100 (2016) minimum standards and guidelines;
- Harper (2001a) the Queensland Climate Change studies (QCC) and the associated:
    - o GHD (2014) NDRP storm tide interpolation study
    - o SEA (2017) Review of Storm Tide Hazard at Selected East Coast Communities, prepared for LGAQ.

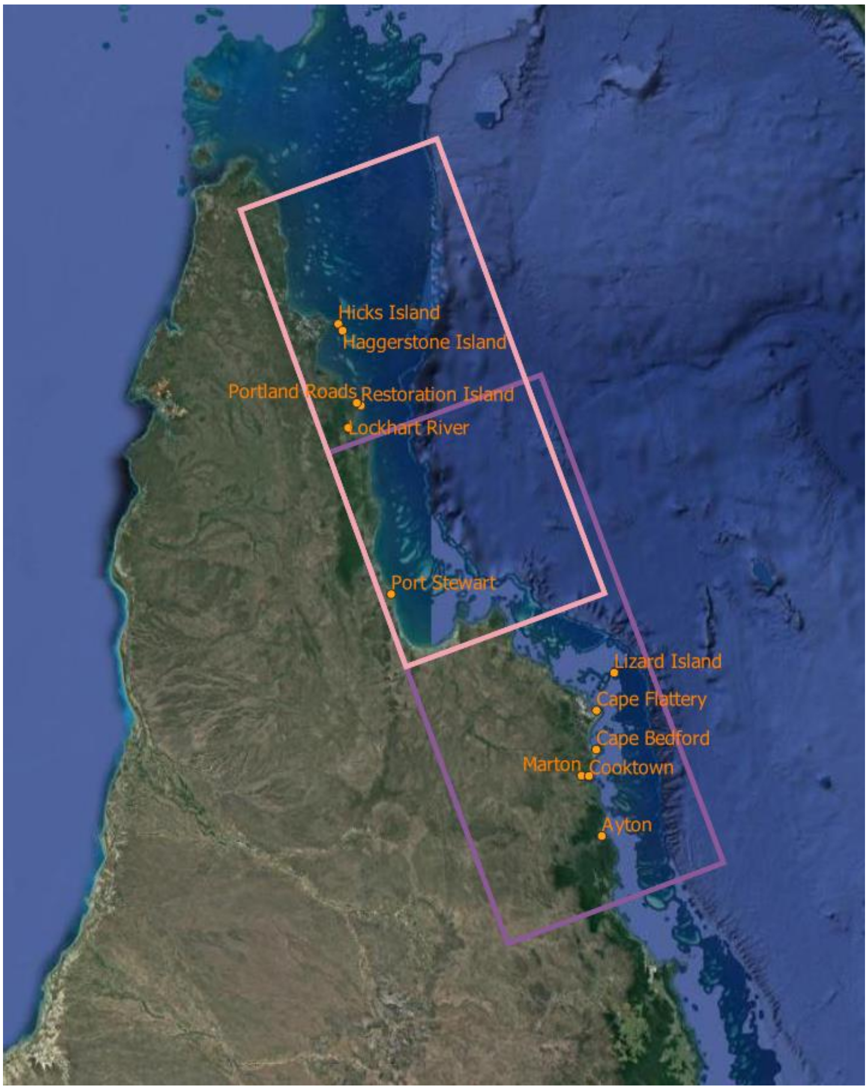


Figure 1 The study region sites, other regional locations and SEA B Grid (2.78km) extents (Google Earth™ imagery)

To note that SEA (2017) was tasked with reviewing all the available storm tide hazard information for many of the Cook Shire communities. It was noted that there were several reasons why the earlier circa 2001-2004 studies, which partially cover these areas, were not as complete as is desirable for a CHAS process, because they excluded for example:

- Waves and wave setup estimates;
- Non-cyclonic storm tide influences;
- Changes to projected climate change criteria (sea level rise etc).

This report addresses all the above issues within the context of performing updated modelling.

1.1 Definitions

Storm tide is the combined effects of the astronomical tide, the storm surge magnitude and the wave setup magnitude (refer Figure 2). It is an absolute level, referred here to Australian Height Datum (AHD). Because the astronomical tide varies (up to the Highest Astronomical Tide, or HAT), the total storm tide also varies with the tidal range. Additionally, wave runup can intermittently reach higher vertical levels if the beachfront has not already been submerged.

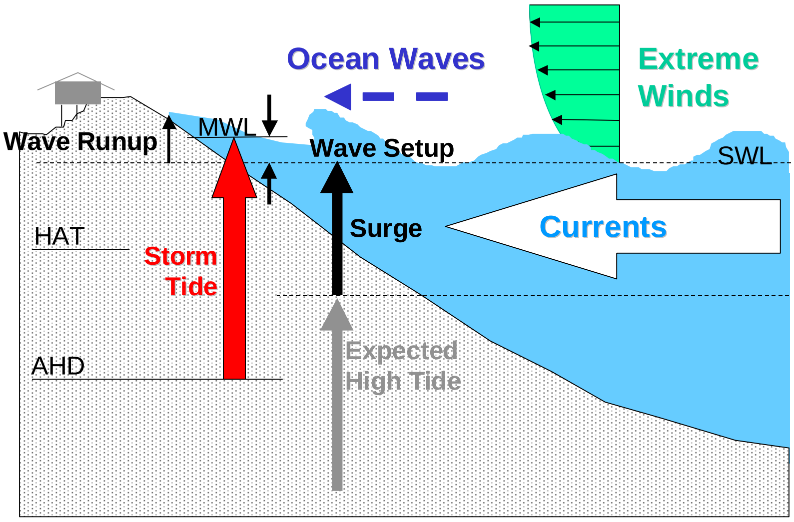


Figure 2 Water level components of an extreme TC storm tide (after SEA 2005).

1.2 Hydrodynamic Models

The hydrodynamic models utilised in this study importantly include the complex bathymetry and layout of the extensive Great Barrier Reef structures on the eastern Cape York Peninsula, which have significant influence on the astronomical tide and the blocking of deep-sea wave conditions. The relative width of the shallow reef lagoon also modulates the impact of storm surge generation throughout the region.

2 Basis of the Tropical Cyclone Storm Tide Hazard

2.1 Present Climate (2019)

This tropical cyclone hazard is based on analyses using the recently developed SEAsim model, which is a variant of the real-time storm tide forecasting model SEAtide (SEA 2018) currently utilised by the Bureau of Meteorology (BoM) in Queensland and Northern territory and also the Queensland State Government. SEAtide is a further development of BoM-sponsored parametric tropical cyclone (TC) storm surge model development following the Queensland Climate Change (QCC) Study initiative (e.g. Harper 2001; SEA 2002).

SEAsim differs from SEAtide in that, rather than simulating the effects of individual real-time TCs, it simulates the long-term statistical storm tide response across many coastal locations. It achieves this by coupling with an Australia-wide synthetic climatology of TCs (Harper and Mason 2016). SEAsim has been used to simulate storm tide risks around the entire Australian coastline that is subject to TC impacts. For example, the Northern Territory Government Dept of Land Resource Management (SEA 2016) recently utilised SEAsim estimates for risk assessment of remote indigenous communities across the “Top End”.

SEAsim replaces and extends the earlier functionality of the SATSIM model that has provided statistical storm tide design water levels throughout Australia since the mid-1980s (e.g. Harper 2001). The new model combines regional storm tide response models with the synthetic TC climatology and the astronomical tide variability to generate the equivalent synthetic time history of storm tide events, including nearshore wave conditions and estimated breaking wave setup.

2.1.1 Hydrodynamic Models

SEAsim is built on TC scenarios modelled by the 2D barotropic hydrodynamic model MMUSURGE and the 3rd Gen spectral wave model WAMGBR with 24 directions and 25 frequencies (each described in Harper 2001). Both models are built on published navigation chart soundings and implement sub-grid reef and bank representations. A nested uniform (spherical) grid system is used, with details near the study sites shown in Figure 1 at the adopted “B” grid 2.78 km resolution, which is adequate for reproducing the regional long-wave storm tide response. An associated outer 12.8 km “A” grid encompasses 1500 km alongshore and 650 km offshore. The model provides statistical storm tide estimates for a wide range of Annual Exceedance Probability (AEP) (and/or Average Recurrence Intervals ARI) at each of the indicated grid locations.

2.1.2 Astronomical Tide

Tides throughout the study region are mixed semi-diurnal and have a range of between 2.5 to 3.5 m, which provide a degree of protection against storm surge inundation. SEAsim utilises interpolation between published tidal constituents where available and combines statistically-sampled tidal time series with the estimated storm surge to produce the storm tide response needed for determining the probability of exceedance of the hazard.

2.1.3 Synthetic Tropical Cyclone Climatology

SEAsim utilises a unique synthetic TC climatology founded on a “double Holland” wind profile that has produced well-verified extreme winds speeds across Australia (refer Harper and Mason 2016). Figure 3 shows a comparison between historical TC tracks for Australia and an equivalent period of the synthetic tracks.

2.1.4 SEAsim Simulation

There are two modes of operation: parametric and discrete. In the parametric mode, the predicted wind, surge and wave magnitude response at each of the sites of interest is generated by parametric models[1] for each synthetic TC, interpolating as necessary between the available modelled scenarios. In the discrete mode, full hydrodynamic surge and wave responses are used. The parametric mode is utilised in this study.

The estimated surge time history is then superimposed on a site-specific generated background astronomical tide for that date in time, with allowance for surge-tide interaction. The wave height and period estimate is converted into a breaking wave setup height that is sensitive to the total water depth and then combined with the combined surge and tide time history. This is repeated for at least 10,000 years of synthetic storms and associated tide sequences. The exceedance statistics of the combined total water level at each site for each TC event then forms the basis of the probabilistic storm tide level predictions.

An example of the SEAsim model application to the study region is given as Figure 4 and has been shown to reproduce many historical TC events to a high accuracy.

---

[1] The parametric models are derived from pre-computed full hydrodynamic time series for a wide range of conditions.

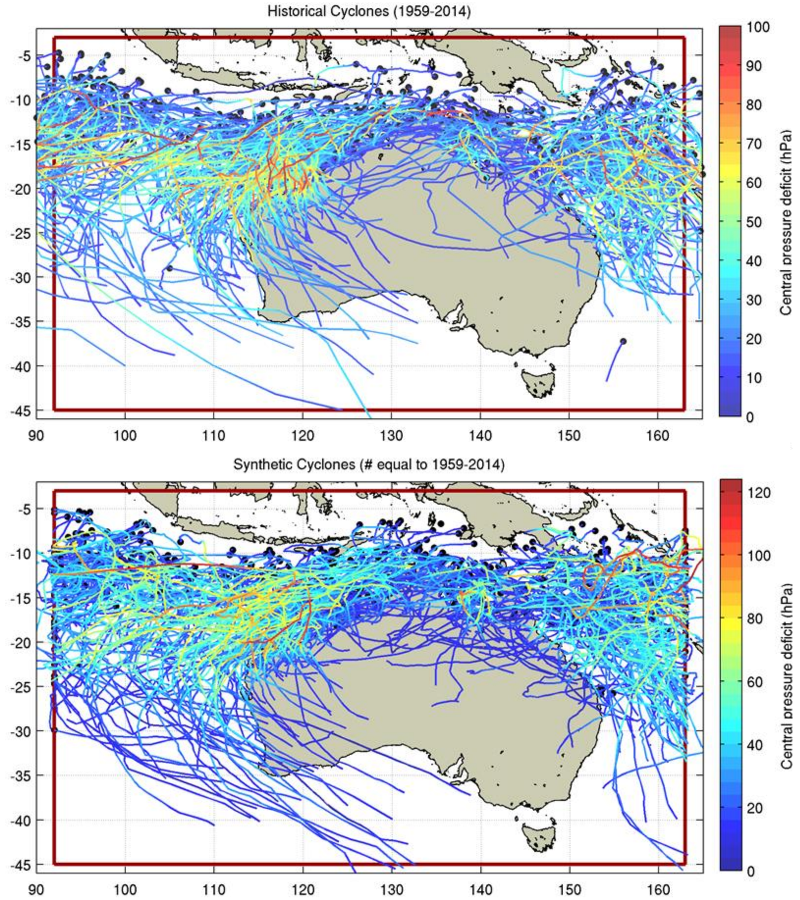


Figure 3 Example of the synthetic TC climate modelling; Top: full sample of the BoM historical tracks and intensities from 1959-2014; Bottom: an equivalent randomly selected number of years sample extracted from the synthetically generated dataset. The colour scale is intensity in MSL central pressure deficit (hPa).

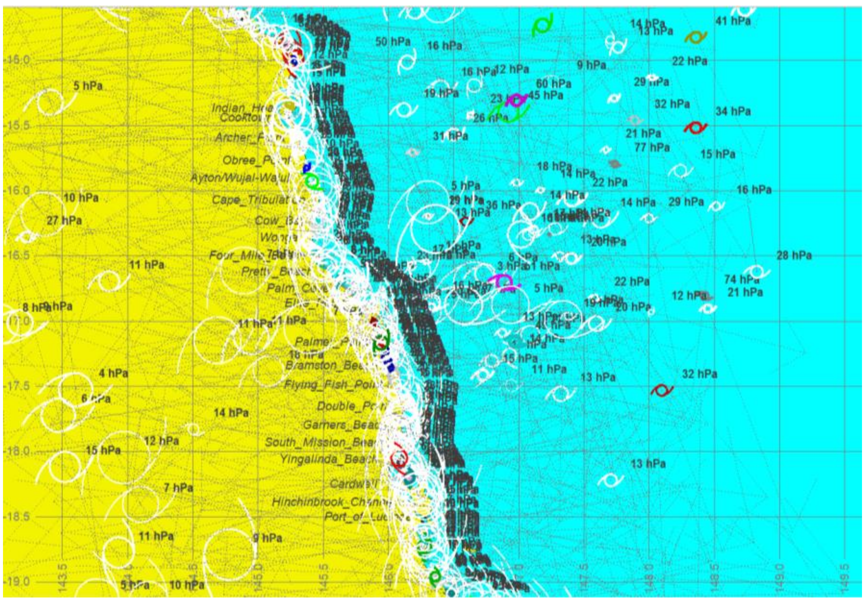


Figure 4 Example of the operation of the SEAsim storm tide simulation model in the region.

2.2 SEAsim Storm Tide Estimates for Projected Future TC Climates

The applied future climate design condition (Table 1) follows State of Queensland planning requirements that specify an allowance for a 0.8 m SLR increase by 2100, relative to 1990 (DSDMIP 2018; Table 10.3.1) and an allowance for a 10% increase in TC maximum wind speed. No change in TC frequency is recommended by DSDMIP.

Table 1 Year 2050 and 2100 climate change parameters

Planning Year	2050	2100	
MSL Increase[2]	0.3	0.8	m
TC Maximum Potential Energy (MPI) Increase	5%	10%	m/s
	10%	20%	hPa
TC Frequency Change	0%	0%	-

3 Non-Cyclonic Extreme Water Levels

While TCs represent the greatest threat of storm tide inundation they are also quite rare events and much more frequent but more benign non-cyclonic weather events can significantly influence ocean level statistics up to around the 100 y ARI (above the 1% AEP). Although almost impossible to numerically model because of their complexity, thankfully the non-cyclonic response is faithfully captured by long-term tide gauges.

3.1 Tide and Tidal Residual Recombination Modelling

This analysis is used to determine statistics for common non-extreme events and follows the method briefly described in Hardy et al. (2004) used for estimating extra-tropical storm surge contributions in the Townsville region. Termed here the TRRM (Tide and tidal Residual Recombination Model), it is based on the re-sampling of the tidal residual (residual) event record from suitably long and reliable tide gauge records in the region of interest. It is assumed that the residual and the astronomical tide are uncorrelated and occur in random combination to produce the total storm tide level recorded by each gauge. Recombination of the randomly re-sampled residual excluding TC events effectively extends the available record.

The incidence of the non-TC storms of interest, whose intensity is typically limited to storm force only, is relatively frequent and a data record of the order of 30 years is highly likely to have sampled close to the maximum ocean forcing possible from these events. Implicitly it is then assumed that the available record of ocean water levels from tide gauges has sufficiently captured the inherent range of variability of non-TC storm surges in the region. It does not allow for any extrapolation of storm surge magnitudes beyond those already measured but, as the analysis shows, this is not a constraint on the effectiveness of the technique to represent water level statistics at ARIs higher than available from the original record. Because deemed-TC storm surge are excluded from this analysis, Non-TC statistics can be computed independently of the TC surge statistics. Once available, the separate statistics can then be statistically added to produce a total storm tide statistic.

---

[2] Specified MSL changes are relative to the nominal 1990 sea level. The SEAsim model uses MSQ published MSL and HAT values that are relative to the current (1992-2011) tidal epoch midpoint of 2001/2002. Tidal predictions apply an annual increase of 2.2 mm/y since 2002, such that in 2018 the increase would be 0.04 m approx. Using this approach, the SLR since 1990 is therefore assessed to be of the order of 0.05 m and the nominal projected future climate SLR values here have not been adjusted for this relatively small component.

3.2 Analysis of Tidal Data

Astronomical tide data was obtained from Maritime Safety Queensland, as per Table 2.

Table 2 Astronomical tide station datasets

Tidal Station	Record
Cooktown	01/01/1989 – 31/12/2017

The data consisted of tidal heights at hourly intervals from the Cooktown Storm Surge Gauge[3]. The tide predictions were based on 152 constituents derived from each section of the raw tide data at each gauge site. The residuals were then filtered with a low-pass filter (cutoff=24h) to remove any residual tide and "bad" data, which are often seen as spikes in the residual.

Figure 5: Cooktown tidal residual with TC events removed.

TC events are then removed from the records by identifying periods when the historical tracks of such storms were within 5 degrees of latitude (≈550 km) of the study region. The resulting amalgamated tidal residuals shown in Figure 5 can be seen to be both positive and negative in magnitude with a large number of maxima occurring each year. Additionally, a number of multi-year variations in water levels are evident in the record, undoubtedly associated with large scale climate processes such as El Niño.

The recombination process requires whole-year periods be available in the record to ensure any correlation between seasonal variation in tide and storm occurrence is accommodated. The analysis yielded 28 years of data for use in the recombination process.

3.3 Simulation of Synthetic Water Level Time Histories

A fundamental assumption of TRRM is that the timing of the tide and the tide spring/neap cycle is uncorrelated to the residual but that there may be some correlation between the annual cycle of storm events and the annual patterns in the tide. It also assumes that the astronomical tide is largely predictable, and that tide and residual can be linearly added to produce a combined result with only small errors.

Firstly, for each station, thirty (30) separate tidal predictions were generated with each prediction set arbitrarily 50 years apart but starting on the same hour, day and month as the original set and with an hourly interval and duration that matches the amalgamated residual sets. This is simply a

[3] https://data.qld.gov.au/dataset/cooktown-tide-gauge-archived-interval-recordings

means of separating and sampling the natural tidal variability and providing a long time-base for overlaying the measured residuals.

Next, each tidal prediction was recombined with the measured residual but with the starting date of the residual randomly offset by up to ±1 week (±168 h). The random offset was in 1-hour intervals equivalent to the time step of the residuals. The maximum of 1-week offset is small enough to ensure retention of the principle seasonal couplings between tide variability and the occurrence of storms of interest. Finally, this tide+residual recombination process was repeated 12 times with different time offsets to provide a synthetic water level record of around 10,000-y. The yearly maxima were then extracted and ranked to produce the summary statistical plots as shown below in Figure 6 in terms of ARI (Average Recurrence Interval).

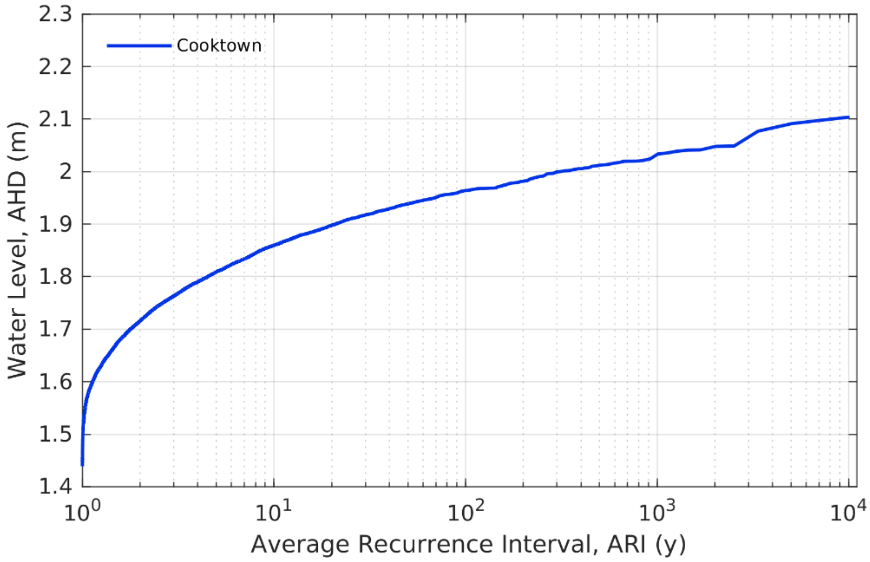


Figure 6: Non-Cyclonic water level statistics for Cooktown

The re-sampling method can be directly used to estimate the variability of the ARI estimates, as shown in Figure 7. This shows, in dark blue, the simulated estimate predicted for Cooktown and, in red, the available measured and ranked annual maximum tide gauge levels. Note that periods of TC activity are first removed from the measured records. In light blue are then the 360 re-sampled 28-year periods of tide and residuals, which together produce the averaged blue line. The spread of the light blue around the dark blue indicates the sampled natural variability imposed on the system by the effect of random tide phasing combined with the residual signal, which is generally much larger than other components represented by the residual. The measured ARI estimate lies above the estimated mean line beyond the 10 y ARI but it is simply one of all the possible 28-year samples.

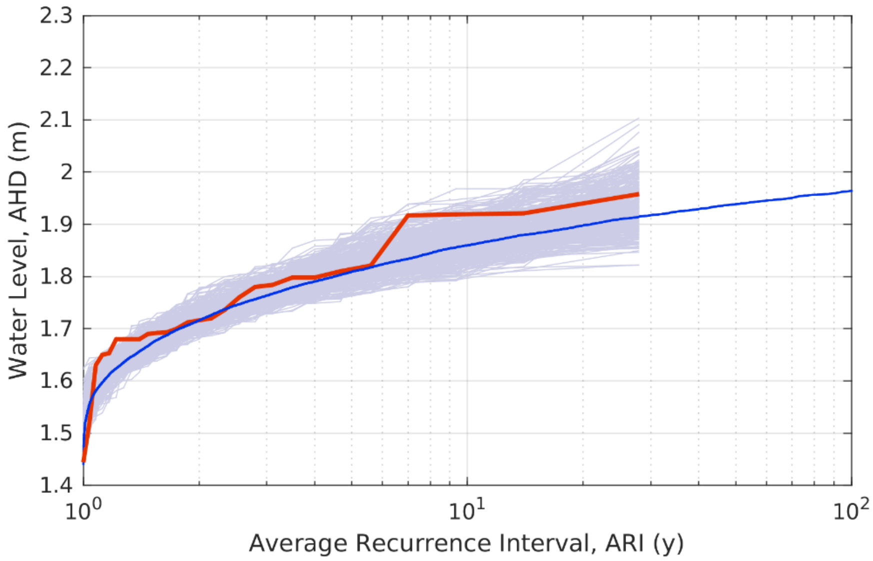


Figure 7: Tide-phase imposed non-TC water level variability for Cooktown

4 Combining TC and Non-TC Water Level Statistics

While the SEAsim model provides TC storm tide statistics of relevance to each geographic site, the only available non-cyclonic water level data applies to the Cooktown site. However, in order to allow for likely variation of the non-cyclonic response as a function of the regional tidal plane variation, the Cooktown statistics are adjusted by the ratio of estimated HAT at each site to that of Cooktown as summarised below.

Table 3 Estimated astronomical tidal plane variation

Location	Lat (deg)	Lon (deg)	HAT (m AHD)	Applied Tide Ratio
Ayton/Bloomfield	-15.91	145.37	1.50	0.87
Cooktown/Marton/Quar. Bay	-15.44	145.25	1.72	1.00
Lizard_Island	-14.65	145.44	1.58	0.92
Port_Stewart	-14.05	143.69	1.87	1.09
Restoration_Island	-12.62	143.44	1.87	1.08
Portland_Roads	-12.59	143.39	1.87	1.09
Haggerstone_Island	-12.04	143.30	1.94	1.13
Hicks_Island	-11.99	143.27	1.94	1.13

The combined extreme water level hazard due to each of the independently derived TC and Non-TC events can then be statistically combined as follows:

$AEP = AEP_{tc} + AEP_{nc} - (AEP_{tc} \times AEP_{nc})$

where:

AEP_{tc} = the AEP of the cyclonic water level

AEP_{nc} = the AEP of the non-cyclonic water level

The resulting combined "Total Storm Tide" AEP curve for Cooktown in 2019 climate (yellow) is shown in Figure 8, together with the non-TC (blue) and TC (red) components. This illustrates that, due to the significant difference in slopes, the effect of blending is simply to provide a smoothed transition between the two independent probabilities of exceedance near the 1% AEP intersection point. The 2019 HAT line (1.72 m AHD) for Cooktown is also shown.

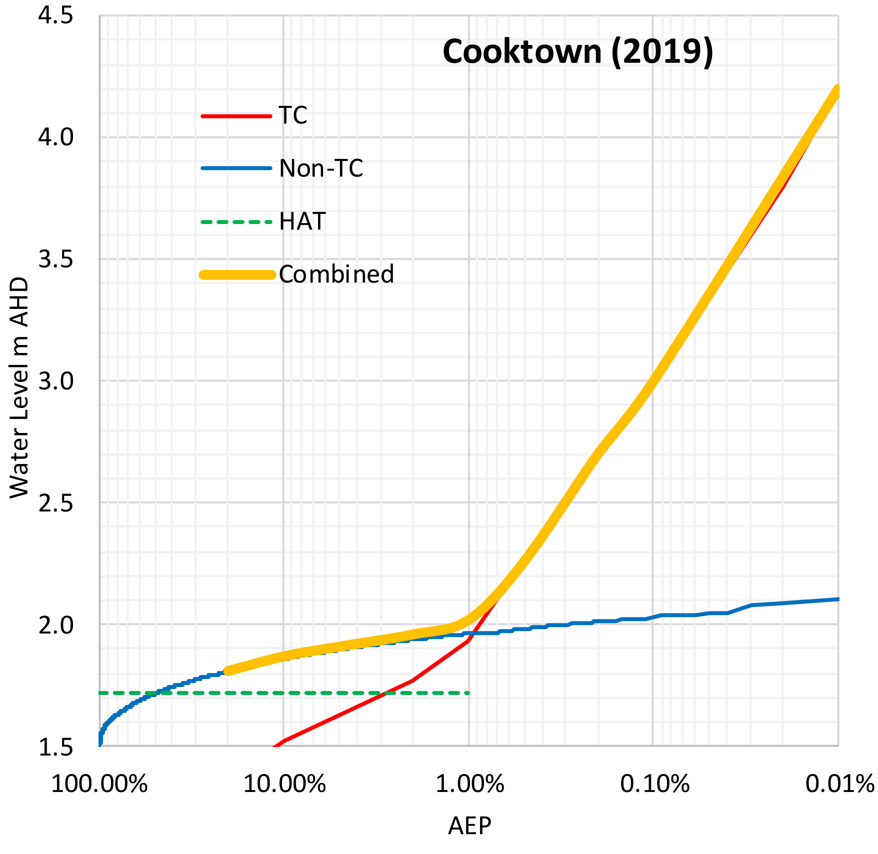


Figure 8: Combined TC and Non-TC extreme water levels for Cooktown in 2019.

The final tabulation of the blended TC and non-TC Total Storm Tide water levels for present and future projected climate is given as Table 4.

Table 4 Combined Total Storm Tide AEP water levels

	2019			
Location / AEP	2%	1.0%	0.2%	0.10%
Ayton/Bloomfield	1.72	1.78	2.34	2.60
Cooktown/Marton/Quar. Bay	1.99	2.11	2.86	3.00
Lizard_Island	1.80	1.82	1.89	1.95
Port_Stewart	2.18	2.38	3.10	3.17
Restoration_Island	2.13	2.15	2.22	2.27
Portland_Roads	2.14	2.17	2.31	2.40
Haggerstone_Island	2.21	2.24	2.30	2.31
Hicks_Island	2.21	2.24	2.30	2.31

	2050			
Location / AEP	2.0%	1.0%	0.2%	0.1%
Ayton/Bloomfield	2.00	2.14	2.81	3.10
Cooktown/Marton/Quar. Bay	2.26	2.34	3.20	3.60
Lizard_Island	2.06	2.09	2.20	2.37
Port_Stewart	2.46	2.55	3.43	3.75
Restoration_Island	2.43	2.46	2.55	2.70
Portland_Roads	2.44	2.47	2.60	2.85
Haggerstone_Island	2.53	2.55	2.61	2.65
Hicks_Island	2.53	2.55	2.61	2.65

	2100			
Location / AEP	2.0%	1.0%	0.2%	0.1%
Ayton/Bloomfield	2.51	2.73	3.43	3.80
Cooktown/Marton/Quar. Bay	2.78	2.91	3.90	4.40
Lizard_Island	2.53	2.56	2.72	3.00
Port_Stewart	3.01	3.16	4.20	4.57
Restoration_Island	2.97	3.00	3.12	3.35
Portland_Roads	2.98	3.01	3.18	3.50
Haggerstone_Island	3.09	3.12	3.18	3.22
Hicks_Island	3.09	3.12	3.18	3.22

It is recommended that these water levels, which conservatively include a small wave setup component, be used to map potential inundation surfaces by simple extension shoreward in each community. Any additional “freeboard” allowance is at the discretion of the CHAS impact analyst but is not recommended to be applied universally across the mapped surface or to extend the footprint of the above. Ideally, any “freeboard” would only be applied at the conclusion of the CHAS process after the “acceptable level of risk” AEP has been determined for each community.

5 References

Cook Shire Council (2018) Request for Quotation for Consultancy Services - Coastal Hazard Adaption Strategy (CHAS) – Stage 3 and 4. Q1218, Oct.

DSDMIP (2018) Department of State Development, Manufacturing, Infrastructure and Planning https://dsdmipprd.blob.core.windows.net/general/sdap-1-10-module-10.pdf]

Hardy T.A., Mason L.B. and Astorquia A. (2004) Queensland climate change and community vulnerability to tropical cyclones - ocean hazards assessment - stage 3: the frequency of surge plus tide during tropical cyclones for selected open coast locations along the Queensland east coast. Report prepared by James Cook University Marine Modelling Unit, Queensland Government, August, 61pp.

Harper B.A. (ed.), (2001) Queensland climate change and community vulnerability to tropical cyclones - ocean hazards assessment - stage 1, Report prepared by Systems Engineering Australia Pty Ltd in association with James Cook University Marine Modelling Unit, Queensland Government, March, 375pp. [available from: http://www.longpaddock.qld.gov.au/about/publications/pdf/climatechange/vulnerabilitytotropicalcyclones/stage1/FullReportLowRes.pdf]

Harper B.A. and Mason L.B. (2016) A tropical cyclone wind event data set for Australia. Proc. 18th Australasian Wind Engineering Society Workshop, 6-8 July, McClaren Vale, SA.

QCoast2100 (2016) Developing a Coastal Hazard Adaptation Strategy: Minimum Standards and Guideline for Queensland Local Governments. Prepared by: The Local Government Association of Queensland and The Department of Environment and Heritage Protection, State of Queensland, Oct, 68 pp.

SEA (2002) Parametric tropical cyclone wave model for Hervey Bay and South East Queensland. Queensland Climate Change and Community Vulnerability to Tropical Cyclones: Ocean Hazards Assessment - Stage 2 (Appendix G). Prepared by Systems Engineering Australia Pty Ltd for James Cook University Marine Modelling Unit, Mar.

SEA (2016) NT remote communities storm tide study and inundation mapping. Prep by Systems Engineering Australia Pty Ltd for the Northern Territory Dept of Land Resource Management, Darwin. SEA Report J1507-PR001B, July, 87pp.

SEA (2017) Review of Storm Tide Hazard at Selected East Coast Communities. QCoast2100 report for the Local Government Association of Queensland and the Dept of Environment and Heritage Protection. May, 48pp.
[available from:
[http://www.qcoast2100.com.au/documents/6143606/6155749/QCoast_BruceH_StormTide_170512.pdf]

SEA (2018) SEAtide V3.3 user guide (Qld-Gulf). Jul, 76pp.

Bruce Harper
BE PhD FIEAust CPEng NER RPEQ
Managing Director
Systems Engineering Australia Pty Ltd
PO Box 3125, Newstead, QLD, 4006.

ABN 65 075 544 439

Tel: (07) 3254 0782
Email:
bruce.harper@systemsengineeringaustralia.com.au
WWW:
http://www.systemsengineeringaustralia.com.au

Appendix B – Long Term Assessment

1. Long Term Assessment

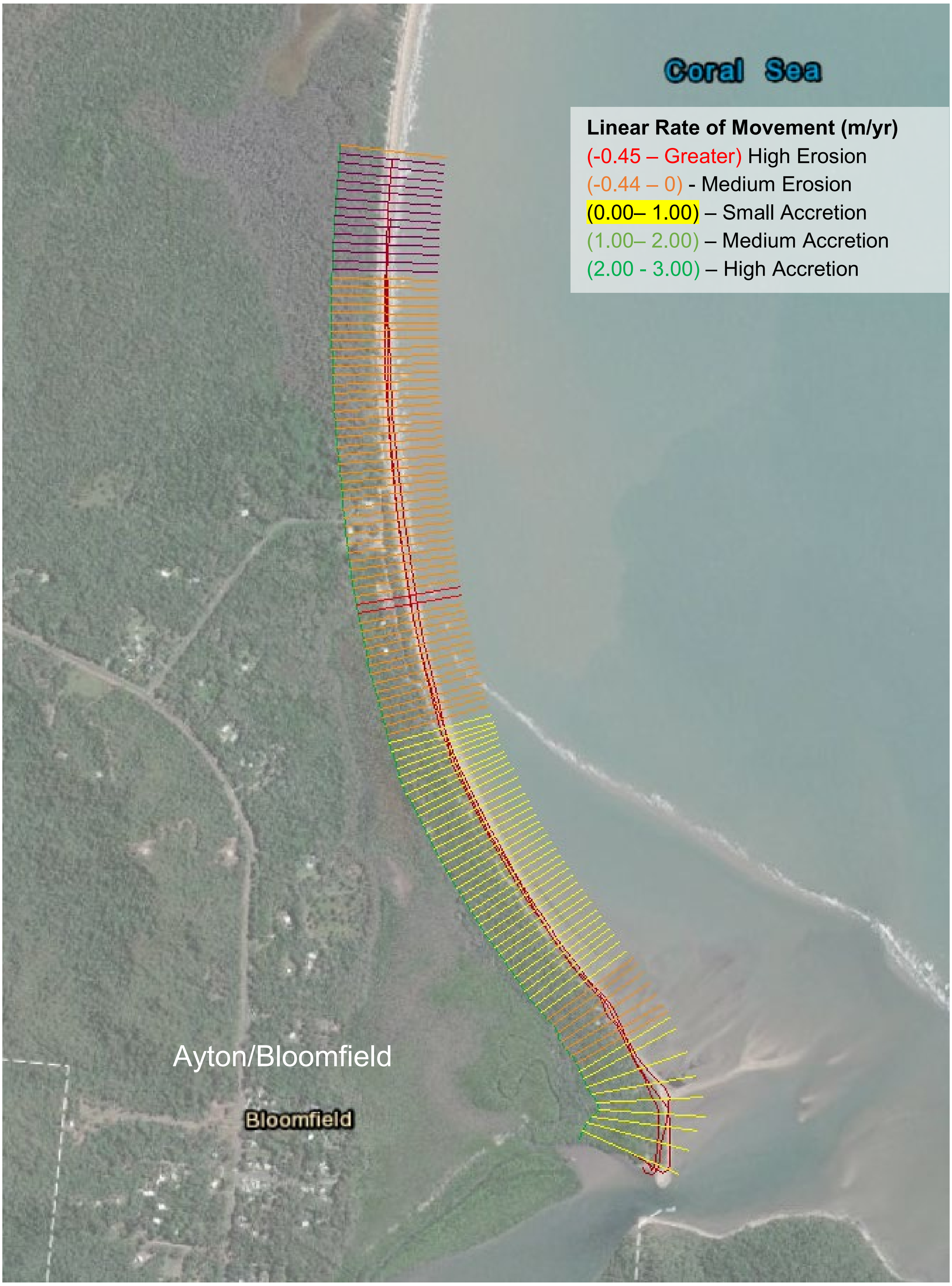


Figure 1-1 Ayton Long Term Assessment (Base Map 2015 ESRI)

.

Figure 1-2 Cooktown Country Golf Club Long Term Assessment (Base Map 2015 ESRI)

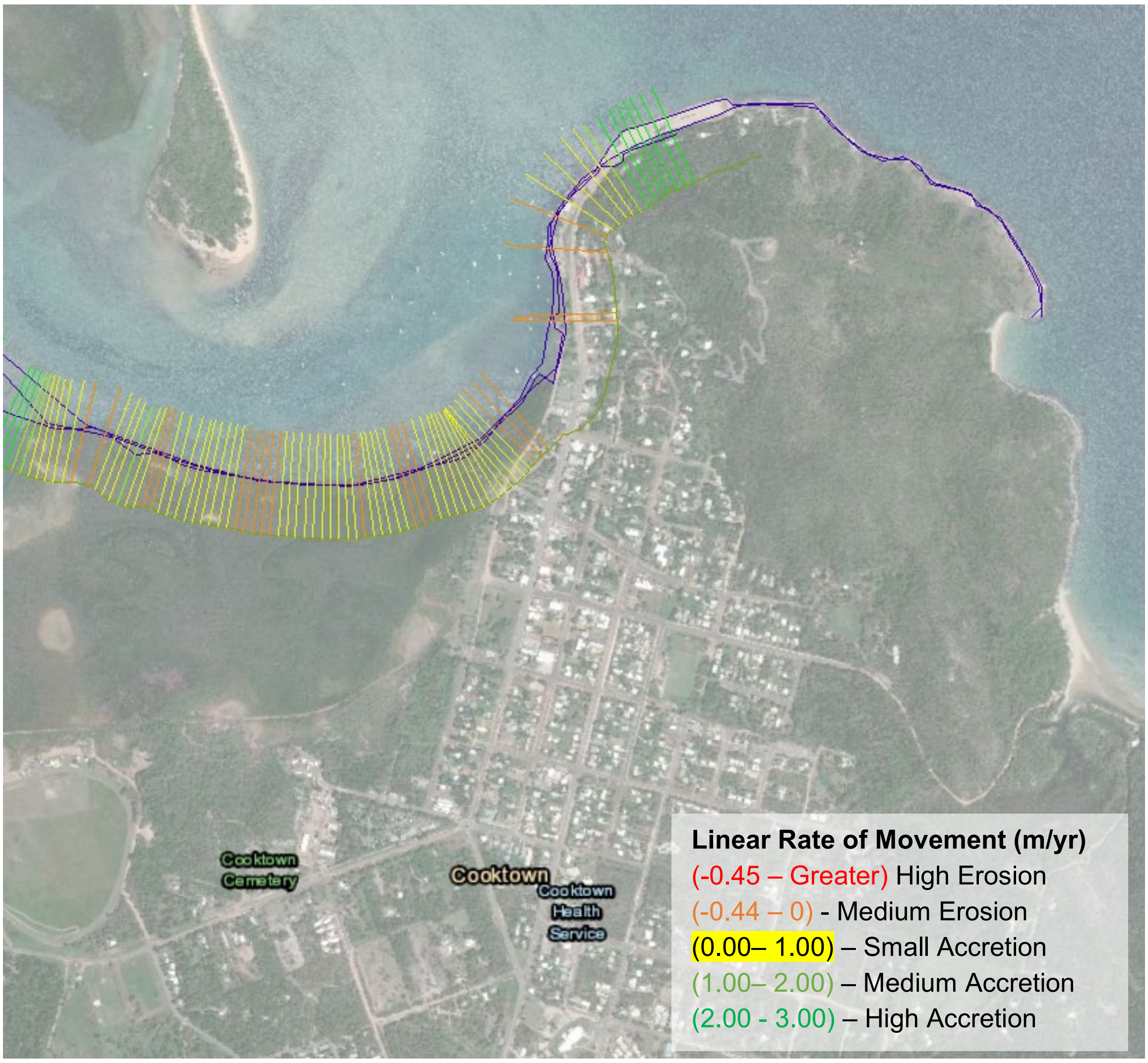


Figure 1-3 Cooktown Long Term Assessment (Base Map 2015 ESRI)

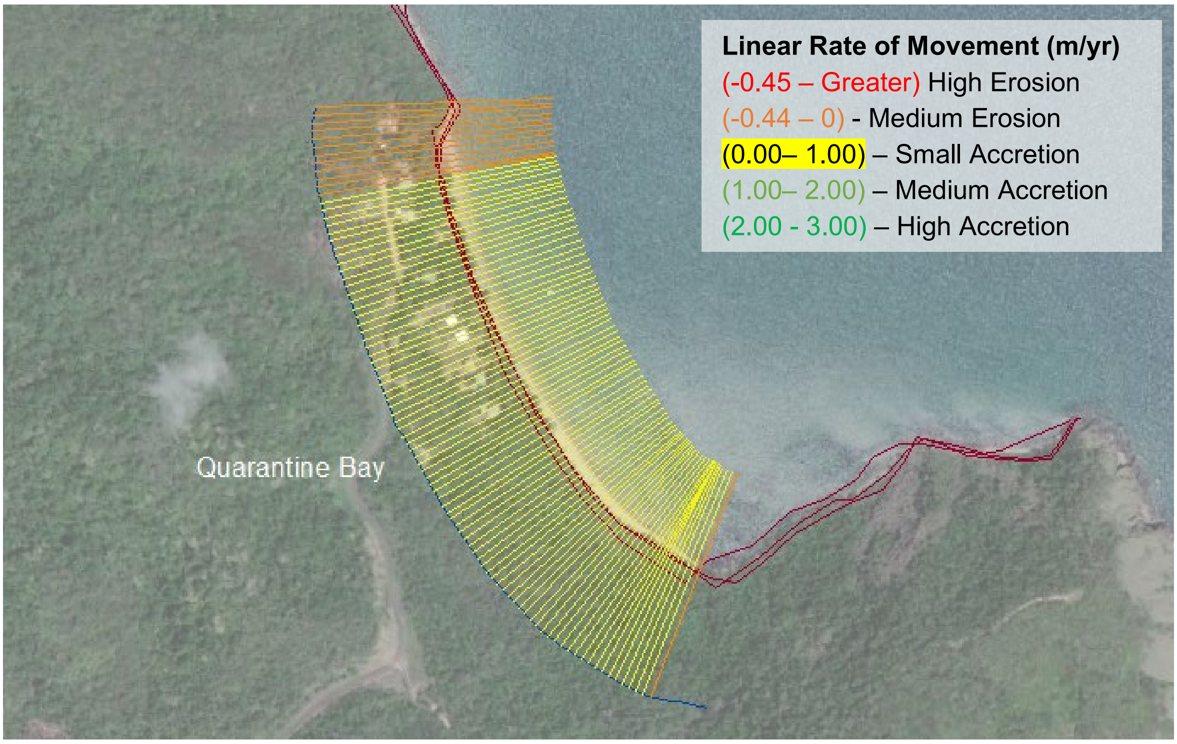


Figure 1-4 Quarantine Bay Long Term Assessment (Base Map 2015 ESRI)

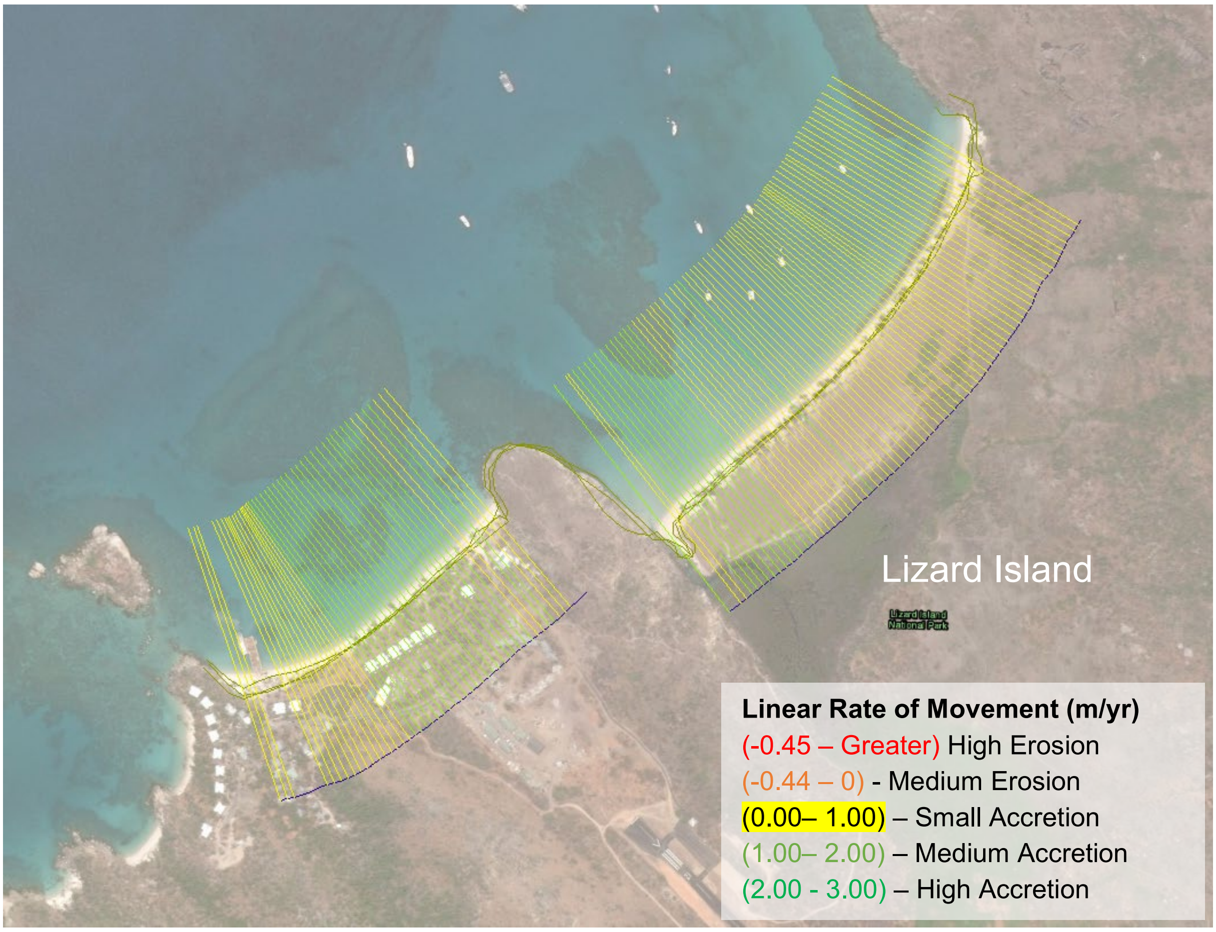


Figure 1-5 Lizard Island Long Term Assessment (Base Map 2015 ESRI)

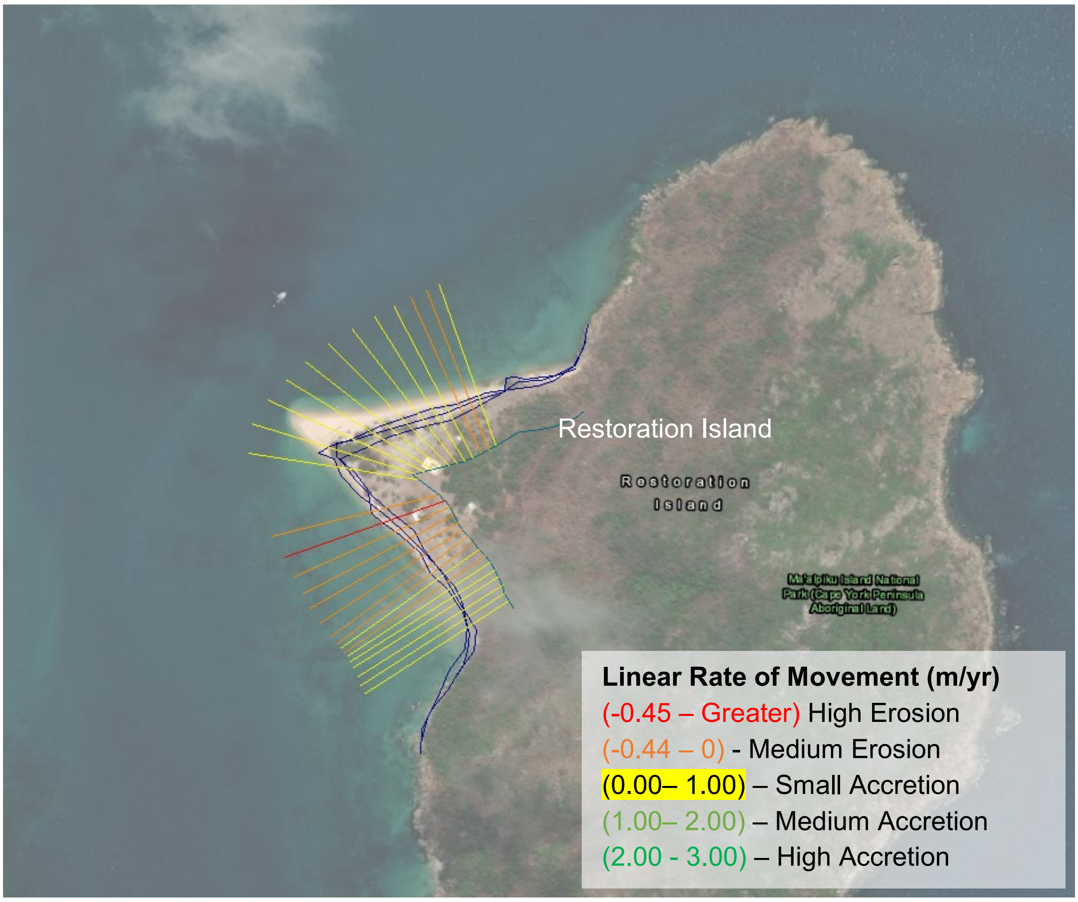


Figure 1-6 Restoration Island Long Term Assessment (Base Map 2015 ESRI)

Figure 1-7 Port Stewart Long Term Assessment (Base Map 2015 ESRI)

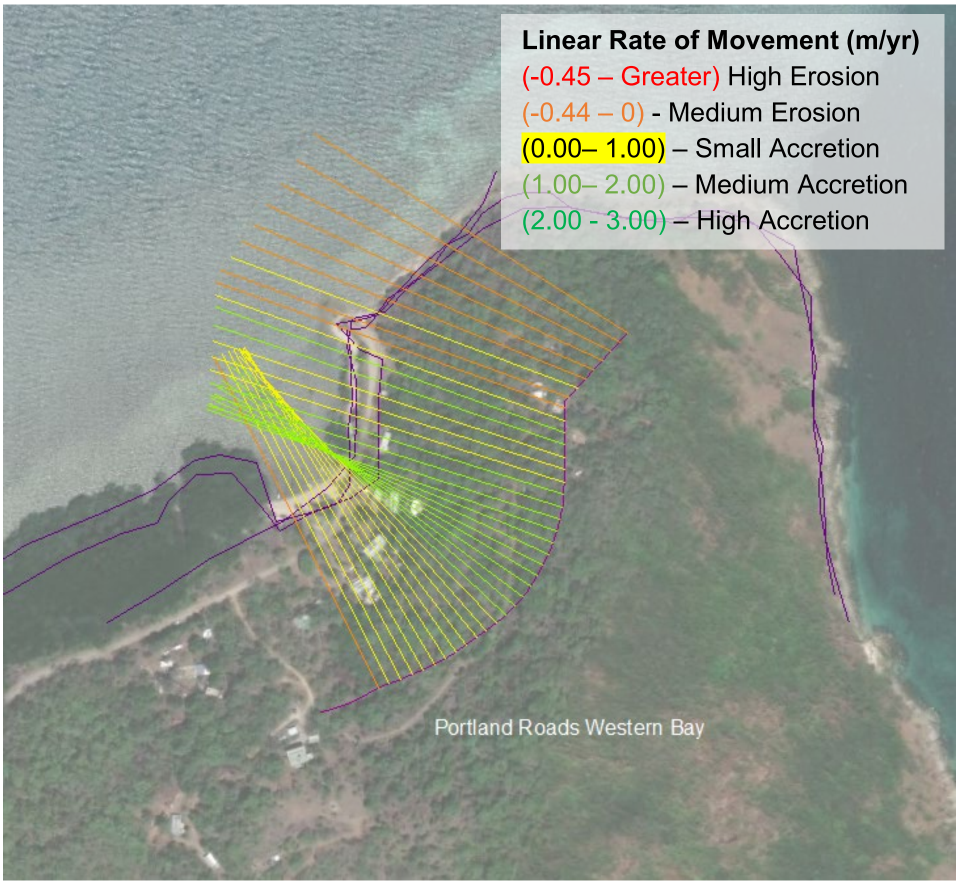


Figure 1-8 Portland Roades Western Bay Long Term Assessment (Base Map 2015 ESRI)

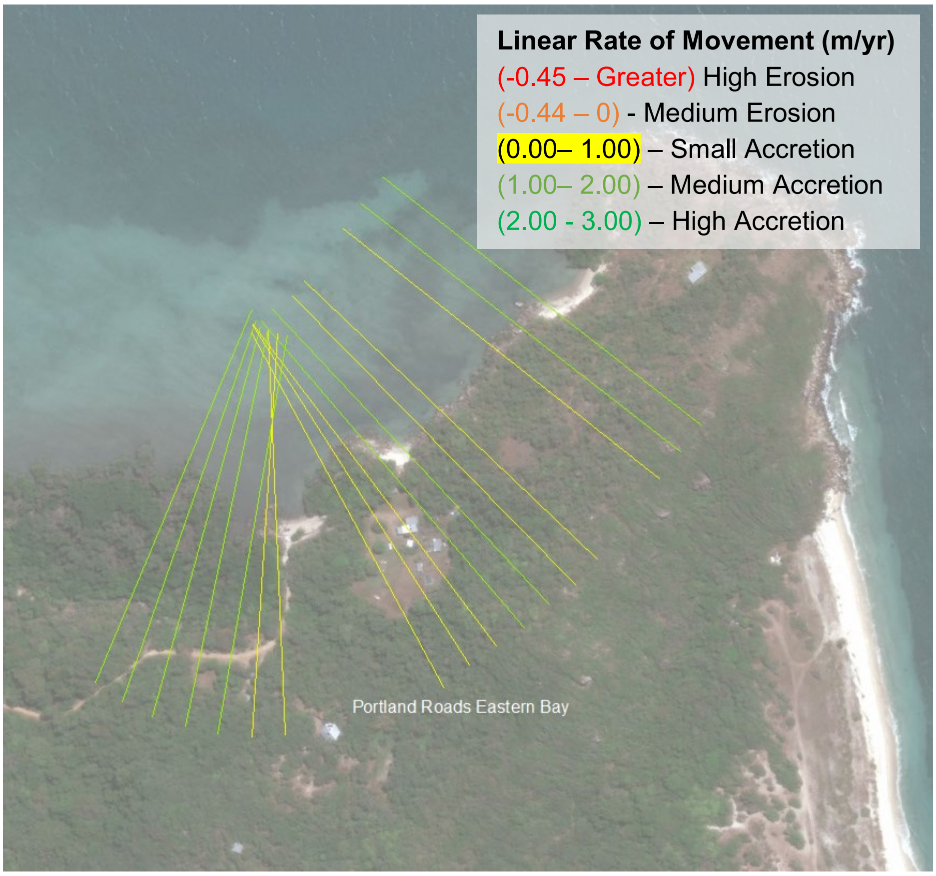


Figure 1-9 Portland Roads Long Term Assessment (Base Map 2015 ESRI)

Appendix C - Short Term Assessment (Beach Profile Locations/Sediment Data/SBEACH Outputs/Mapping Guide)

1. Beach Profile Locations

Figure 1-1 Ayton/Bloomfield Beach Profiles

Figure 1-2 Cooktown Country Golf Club Beach Profile

Figure 1-3 Quarantine Bay Beach Profiles

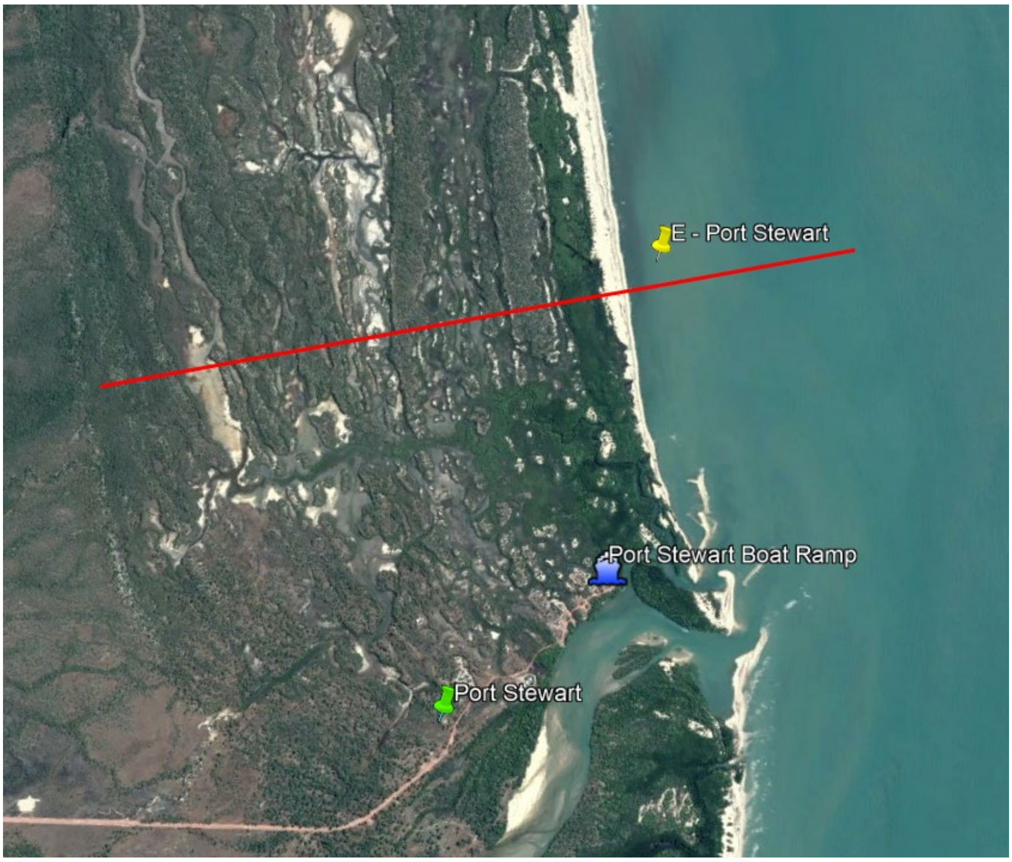


Figure 1-4 Port Stewart Beach Profile

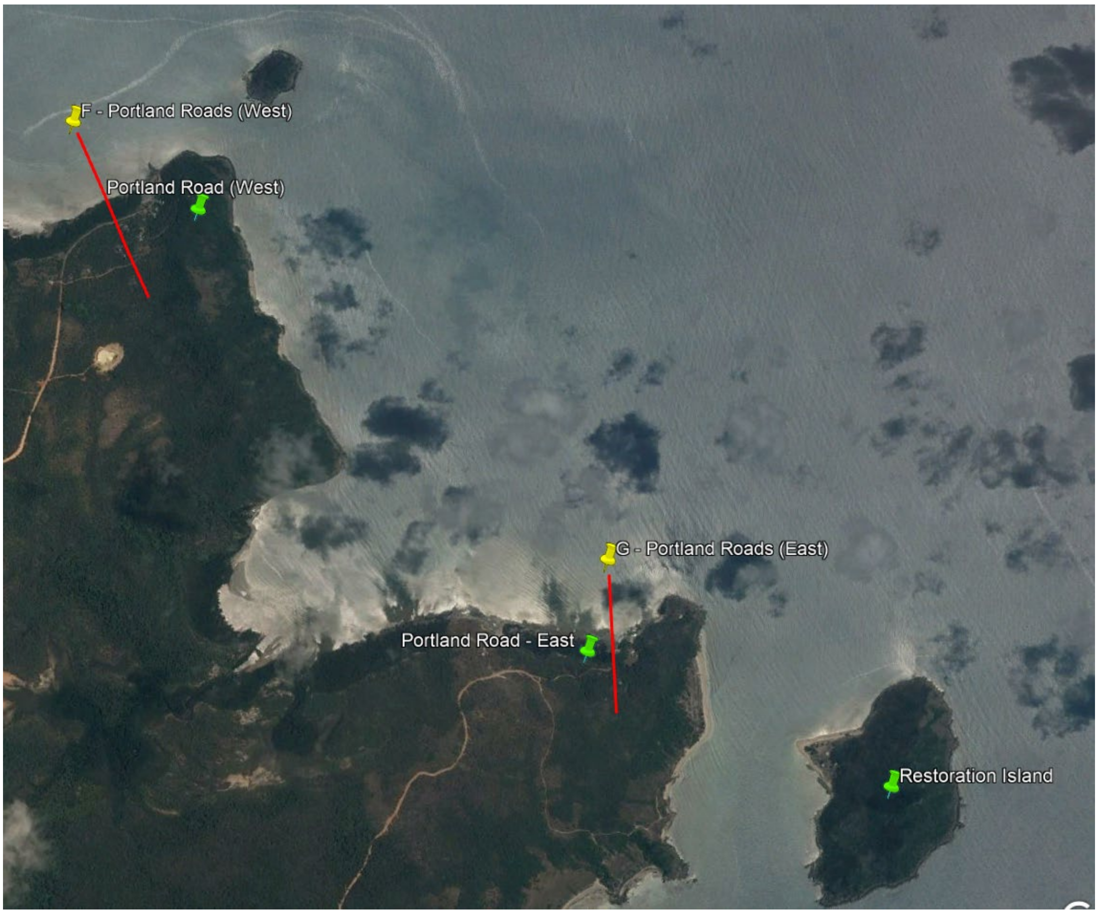


Figure 1-5 Portland Roads Beach Profiles

Figure 1-6 Lizard Island Beach Profiles

2. Sediment Data

Sediment was taken from Portland Roads, Quarantine Bay and Port Stewart.

Table A Sediment Sample Collection Locations

Sample #	Location	GPS - Lat	GPS - Long
1	Portland Road	-12.59428	143.41169
2	Quarantine Bay	-15.49181	145.27509
3	Port Stewart	Exact Co-ordinates unknown as sediment sourced from Client.	

Figure 2-1 Portland Roads Sediment Sample Location

Figure 2-2 Quarantine Bay Sediment Sample Location

3. PSD Graphs

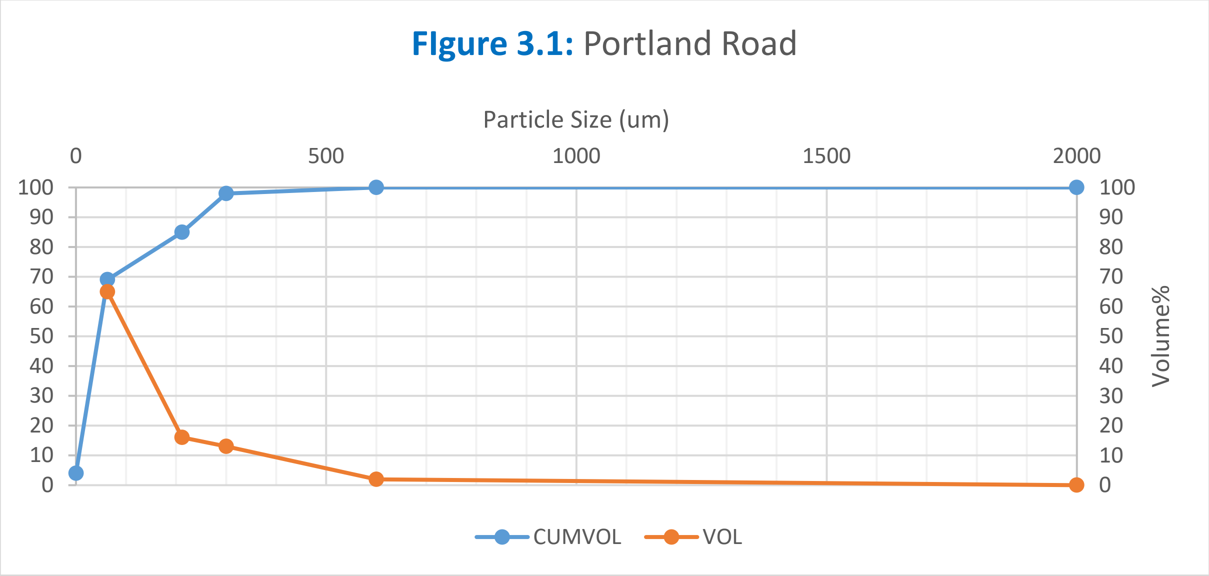


FIgure 3.1: Portland Road
Particle Size (um)
0
500
1000
1500
2000
100
90
80
70
60
50
40
30
20
10
0
Volume%
CUMVOL
VOL

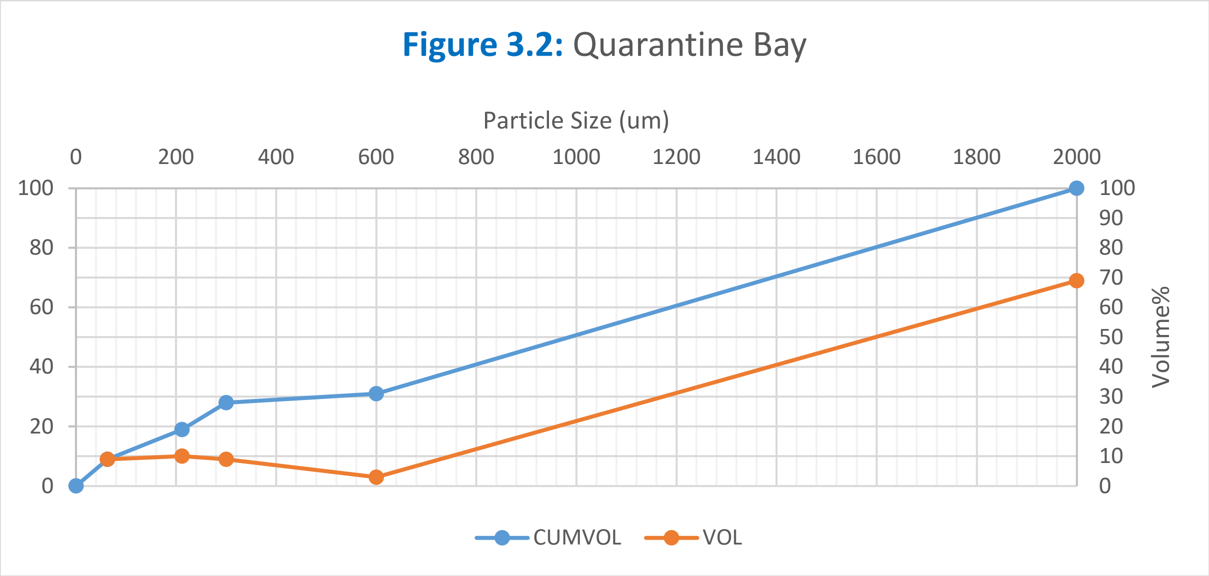


Figure 3.2: Quarantine Bay
Particle Size (um)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
100
80
60
40
20
0
Volume%
CUMVOL
VOL

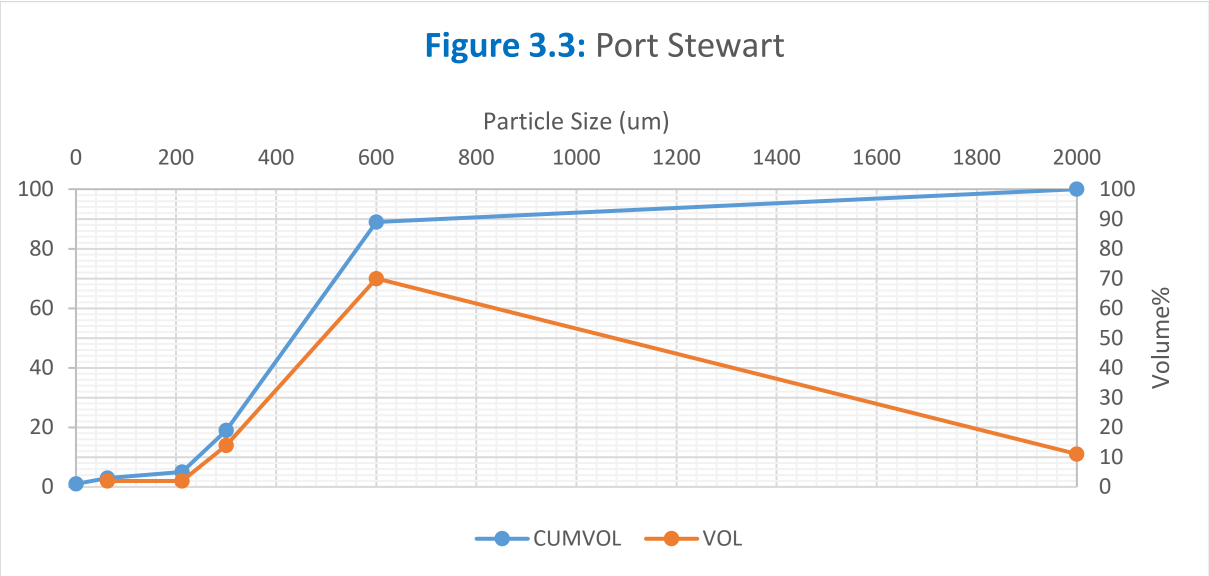


Figure 3.3: Port Stewart
Particle Size (um)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
100
80
60
40
20
0
Volume%
CUMVOL
VOL

4. SBEACH Inputs

Code	Run Name	Reference HAT level	Erosion Depths	Storm Tide Level (1% AEP)	Wave Height (Sig)	Wave Period (Tp)	Fetch Distance (m)	Effective Grain Size (mm)	Time Steps	Step Value (min)	Wave Randomization	Grid Cell	Contours	Max Slope	Sediment Transport
A-2019	Ayton 1 - 2019	1.5	0.01,0.05, 0.1	1.78	1.9	5.9	>10000	0.35	1440	1	Std	Fixed	HAT	18	Std
B-2019	Ayton 2 - 2019	1.5	0.01,0.05, 0.1	1.78	1.9	5.9	>10000	0.35	1440	1	Std	Fixed	HAT	18	Std
C-2019	CCGC - 2019	1.72	0.01,0.05, 0.1	2.11			>10000	0.4	1440	1	Std	Fixed	HAT	18	Std
D-2019	Quarantine Bay - 2019	1.72	0.01,0.05, 0.1	2.11	2.2	6.5	>10000	0.75	1440	1	Std	Fixed	HAT	18	Std

Code	Run Name	Reference HAT level	Erosion Depths	Storm Tide Level (1% AEP)	Wave Height (Sig)	Wave Period (Tp)	Fetch Distance (m)	Effective Grain Size (mm)	Time Steps	Step Value (min)	Wave Randomization	Grid Cell	Contours	Max Slope	Sediment Transport
E-2019	Port Stewart - 2019	1.87	0.01,0.05, 0.1	2.38	2.0	6.0	>10000	0.45	1440	1	Std	Fixed	HAT	18	Std
F-2019	Portland Roads (West) - 2019	1.87	0.01,0.05, 0.1	2.17	1.4	5.0	>10000	0.1	1440	1	Std	Fixed	HAT	18	Std
G-2019	Portland Roads (East) - 2019	1.87	0.01,0.05, 0.1	2.17	1.4	5.0	>10000	0.1	1440	1	Std	Fixed	HAT	18	Std
H-2019	Lizard Island Resort - 2019	1.58	0.01,0.05, 0.1	1.82	2.5	6.9	>10000	0.35	1440	1	Std	Fixed	HAT	18	Std
I-2019	Lizard Island Watsons Bay - 2019	1.58	0.01,0.05, 0.1	1.82	2.5	6.9	>10000	0.35	1440	1	Std	Fixed	HAT	18	Std

5. SBEACH Data Output

Code	Run Name	Erosion Dpth (0.01)	Erosion Dpth (0.05)	Erosion Dpth (0.1)	Contour Mvmt (HAT2019)	B (m)	Dune Height (mAHD)	Closure depth (mAHD)	Erosion Due to Sea Level Rise (2019) (+0m)	Erosion Due to Sea Level Rise (2019)(+0.3	Erosion Due to Sea Level Rise (2019)(+0.8
A-2019	Ayton 1 - 2019	21.5	20.5	20.5	0.15	75	4.2	0	0	6	15
B-2019	Ayton 2 - 2019	21.1	21.1	21.1	0	125	4.5	0	0	9	23
C-2019	CCGC - 2019	15.4	9.4	0	0.01	85	2.25	-1	0	8	21
D-2019	Quarantine Bay - 2019	9.3	9.3	8.3	0.03	30	2.75	0.5	0	4	11
E-2019	Port Stewart - 2019	28.8	27.8	26.8	2.9	150	3	0	0	15	40
F-2019	Portland Roads (West) - 2019	21.8	21.8	21.8	9.34	105	2.5	-1	0	9	24
G-2019	Portland Roads (East) - 2019	19.4	14.4	13.4	5.63	125	3	-1	0	10	25
H-2019	Lizard Island Resort - 2019	27.7	27.7	26.7	10.04	120	7	-1	0	5	12
I-2019	Lizard Island Watsons Bay - 2019	35.7	33.7	32.7	14.69	125	4.2	-1	0	8	20

6. SBEACH Outputs

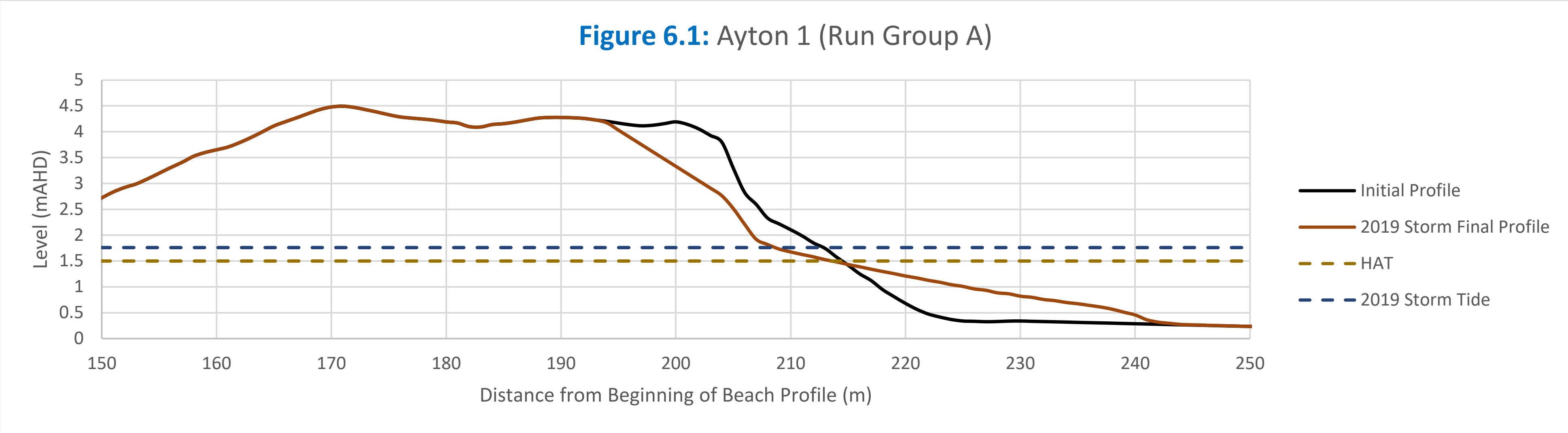


Figure 6.2: Ayton 2 (Run Group B)

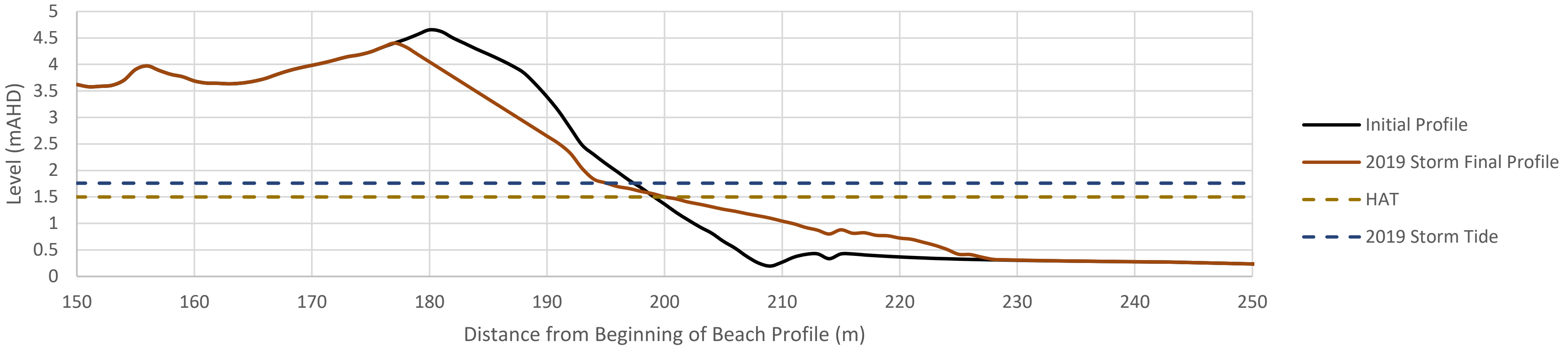


Figure 6.3: Cooktown (Run Group C)

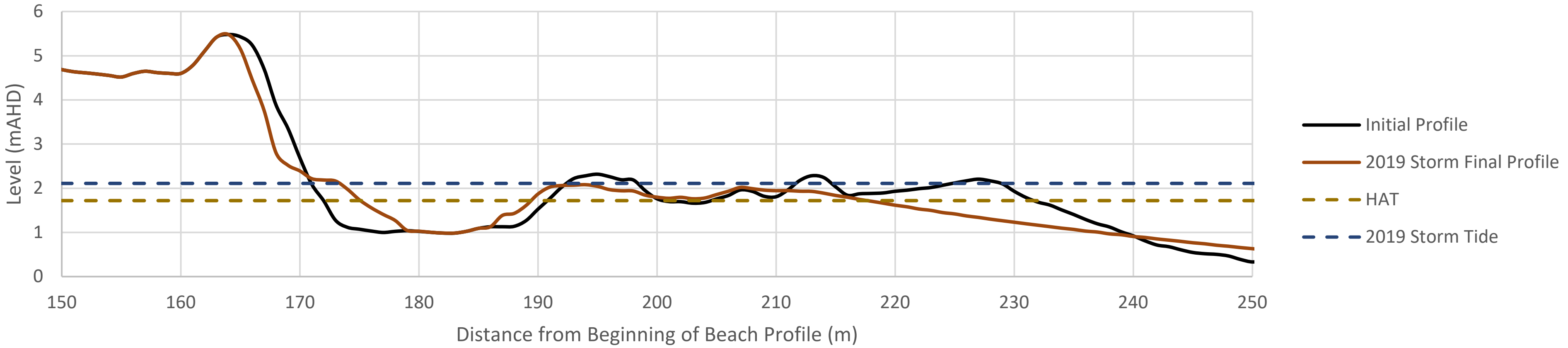


Figure 6.4: Quarantine Bay (Run Group D)

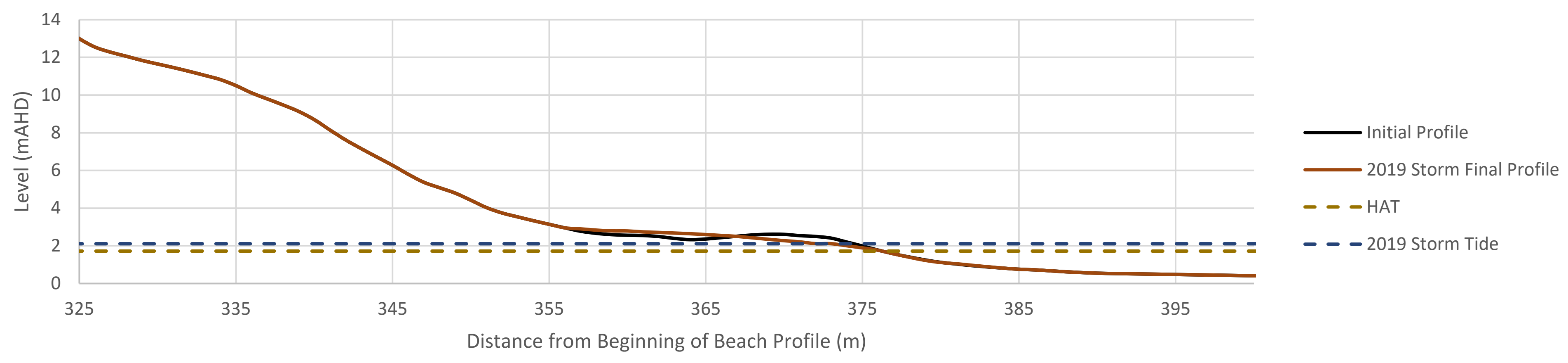


Figure 6.5: Port Stewart (Run Group E)

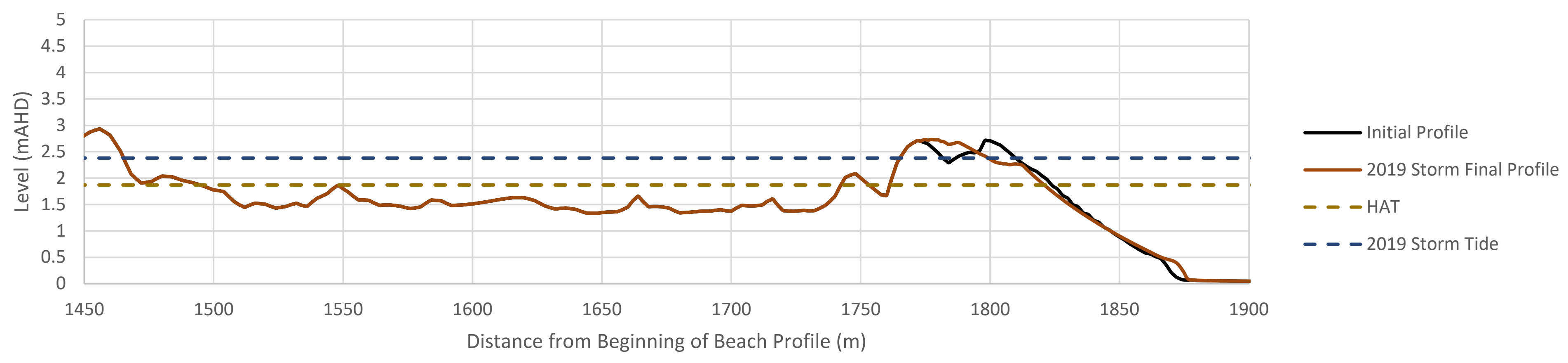


Figure 6.6: Portland Roads West (Run Group F)

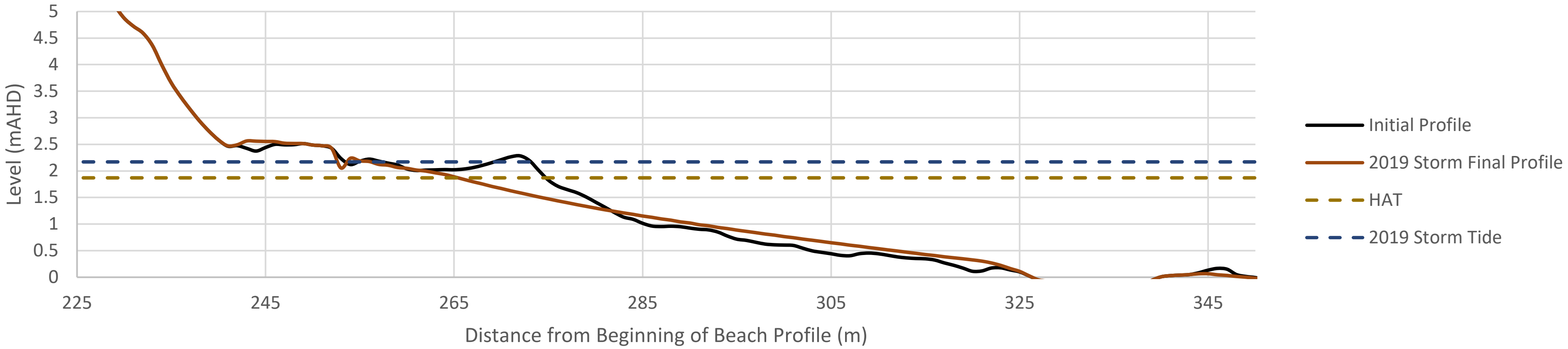


Figure 6.7: Portland Roads West (Run Group G)

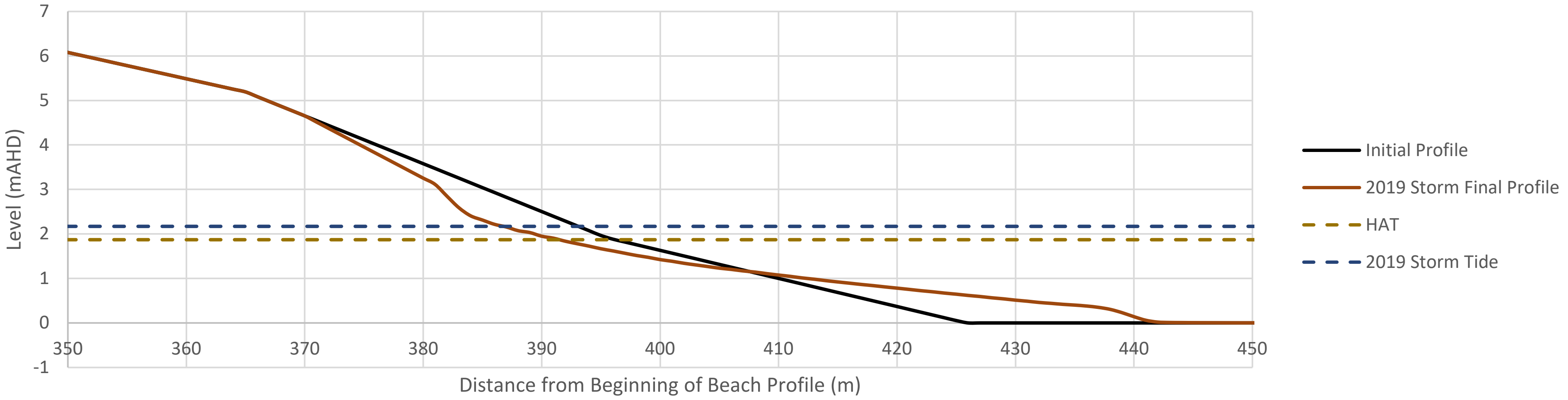


Figure 6.8: Lizard Island Resort (Run Group H)

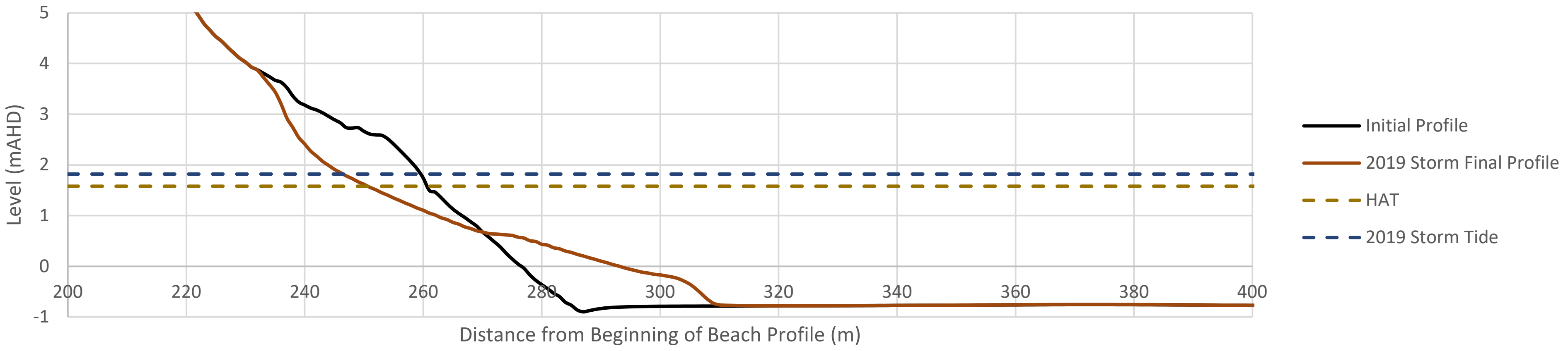
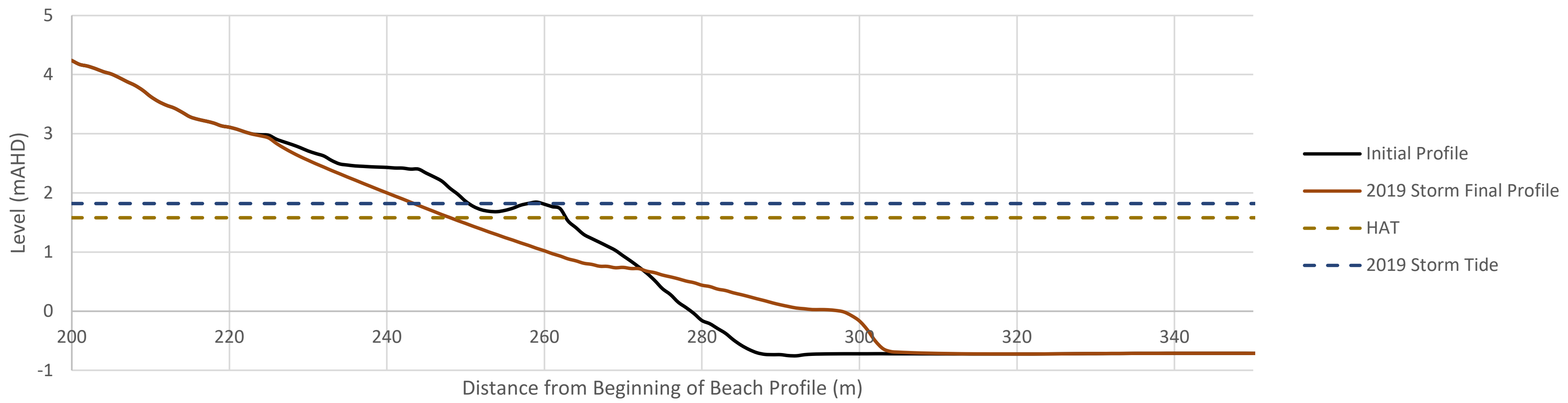


Figure 6.9: Lizard Island Watsons Bay (Run Group I)



GHD

Level 8 Cairns Corporate Tower 15 Lake Street
Level 8
T: 61 7 4044 2222   F: 61 7 4044 2288   E: cnsmail.ghd.com

4221024-89356/https://projects.ghd.com/oc/nqoc1/cscchasphase38/Delivery/Documents/4221024-REP_ CSC CHAS Ph3-4.docx

Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
A - DRAFT	R O'Keeffe M.Mikelat	H O'Keeffe	**HOK			22/11/19
B- DRAFT	R O'Keeffe M.Mikelat	H O'Keeffe	**HOK			16/12/19
0	R O'Keeffe M.Mikelat	P O'Keeffe	**POK			

www.ghd.com