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HUGH GREEN GROUP

Park Estate Road Development

For Hugh Green Group Limited

Site Specific Coastal Erosion Assessment

July 2018

REPORT INFORMATION AND QUALITY CONTROL

Prepared for:	Pat Gavaghan Property and Development Hugh Green Limited

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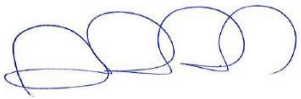
Approved for Release:	Aaron Andrew Managing Director	

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1 INTRODUCTION

Hugh Green Group recently engaged 4Sight Consulting Ltd (4Sight), to undertake a detailed coastal hazard assessment for approximately 3.1km of coast along the eastern shore of Drury Creek. Hugh Green Group are investigating the development potential of approximately 97Ha of coastal land at the site situated in the south-eastern corner of the Manukau Harbour (**Figure 1**). Parts of the site are identified within the AUP as being subject to a coastal erosion hazard through the definitions section. However, it is recognised that the definitions are reasonably generic and based on assumptions around broad coastal classifications of the Auckland coastline. Consequently, it is recommended by Auckland Council that site-specific coastal erosion assessments are undertaken to better understand the risk.

This assessment is intended to inform the design and consent process associated with future development at the site. Further, this report is also expected to form the basis of discussion with Auckland Council around the granting of land for Esplanade Reserve.

Figure 1: Location of the subject site. The yellow line shows the extent of the subject coastline, the blue line is the approximate landward extent of proposed development and the red box illustrates the location (Source: Auckland Council Geomaps)

1.1 Site Description

As noted above, the subject coastline is situated along the eastern shoreline of Drury Creek approximately 5km upstream of Pahurehure Inlet and 10km from the wider Manukau Harbour. The site is currently used for pastoral farming and is largely undeveloped with only a few dwellings and structures present. The subject coastline is void of any structures with only informal access available at a few locations.

2 GEOMORPHIC SETTING

The site is typical of an upper tidal arm of the Manukau Harbour. Drury Creek itself feeds in to Pahurehure Inlet via the main tidal channel which meanders in the upper reaches before straightening along the lower 2km. The system is dominated by the main tidal channel which is fed by numerous small tributaries, that in combination with apparent outcrops of Waitemata Series rock, dictate the direction and meanders of the channel. No detailed bathymetric data for the site is available, but in general the main tidal channel is thought to be approximately 1-1.5m deep at low tide.

Sub-inlets of the creek are typically inhabited by mangroves which migrate into salt marsh and salt meadow habitats where the topography allows. Mangroves also line sections of bank along straighter portions of the main channel or in small depositional nodes made available by the underlying geologic structure.

Geomorphology of the site varies from estuarine coastal cliffs and coastal embankments to low lying sub-inlets. The northern portion of the subject coastline (refer **Figure 1**) is dominated by coastal cliffs transitioning to the landward topography above situated at about RL10m. The cliff height reduces toward the south as the coast moves toward a sub-inlet of approximately 20Ha, which is characterised by mangrove and mudflat habitats on the outer limits and migrating toward salt marsh and meadow habitats further inward. The southern portion site is characterised by tidal banks on the outer bend of the main channel. These banks are at approximately RL4m and in places have mature mangrove trees along their seaward margin. The banks themselves are vegetated with a mix of salt marsh species and exotic grasses.

2.1 Geology

Information from the geological maps available on Auckland Council Geomaps indicates the area is dominated by Puketoka formation material, with some minor outcropping of East Coast Bays Formation sandstones (**Figure 2**). Coffey Ltd. undertook geotechnical investigations of the site in 2015 as a part of the feasibility investigations for development of the site. Hand auger samples from sites close to the coastal margin indicate relatively shallow (2-3m below the surface) occurrence of East Coast Bays Formation material in the northern section of the site. This is supported by observations from the site visit which indicates the cliff material along the northern section is comprised of East Coast Bays Formation material (**Figure 3**).

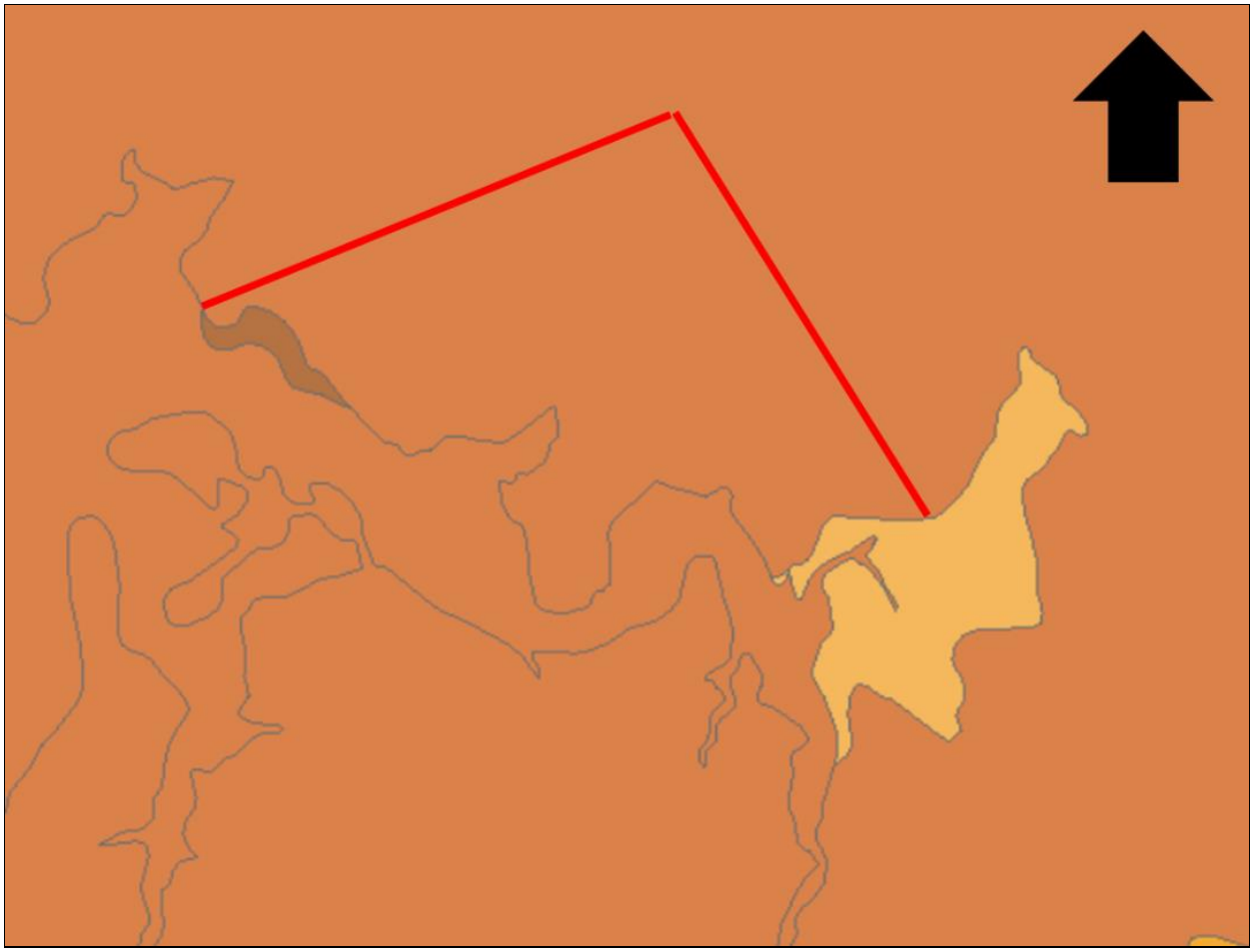

Figure 2: Underlying geology of the subject area. The landward extent of the site is indicated the red lines. The light brown is modern marine/alluvium deposits. The mid tone brown colour indicates Puketoka Formation (Tauranga Group) material. The darker brown indicates out crop of East Coast Bay Formation (Waitemata Series). (*Source: Geomaps*)

The depth of East Coast Bays Formation material across the remainder of the site appears to be variable with topography, with higher elevations characterised by shallow occurrences of East Coast Bays Formation material and the lower elevations across the site characterised by thicker deposits of Puketoka Formation material.

2.2 Historic Coastal Change

Detailed GIS analysis of the available historic aerial photos from the Auckland Council Geomaps website was undertaken as a part of this investigation. This involved manipulation of the aerial images to correct and align the imagery, noting there were some minor discrepancies due to the large-scale rectification process undertaken for Geomaps. Images from the northern section dated back to 1959, while examination of the southern section were limited to 1996. To provide greater context the comparison to the 1959 air photo was extended approximately 3km downstream of the site to improve the extent of longer term analysis.

The results presented in **Appendix A** show no change in the shoreline position along the subject coastline (cliff or bank toe used as proxy). Given the scale of the examination minor erosion such as small slope failures may not have been detected. However, it is considered that overall the analysis provides an adequate understanding of historical shoreline position at the site. Brief analysis of the extent of mangrove habitat across the site indicates that there has been some minor seaward encroachment of the existing mangrove communities.

Figure 3: Waitemata Series toe material from the norther section of cliff at the subject site. (*Source: Site visit*)

3 COASTAL PROCESSES ASSESSMENT

In general, the site is considered to be a very sheltered environment due to its upper harbour location and meandering nature of the water body, which mean the fetch distances are restricted to approximately 1km (largest fetch run NNW to SSE) or less. These short fetches, and the relatively shallow water depth, significantly hamper the generation of wind generated waves at the site despite the majority of the subject coastline being exposed to the predominant SW wind. Further, no major vessels are thought to be able to access the upper parts of Drury Creek (due to relatively shallow water and the height of the Hingaia Rd Bridge) which means the site is not subjected to significant boat wakes. Therefore, extreme waves heights at the site are expected to be less than 500mm high and are further restricted by tidal fluctuations.

Table 1 below provides a range of tidal and storm surge variables as an indication of extreme water levels at the site. The majority of this information has been obtained from Modelling Point 66 of Stephens et al., 2016. A value for MHWS was obtained from Modelling Point 1 from Stephens et al., 2011 and the remaining tidal data is based upon information from Port of Onehunga. This shows spring tide range of approximately 3.6m and this range is known to produce significant tidal current in parts of the Manukau Harbour. However, measured and modelled tidal current velocities (undertaken as a part of a wider catchment management study) have shown that current flows in Drury Creek are well below 0.5m/s (**Figure 4**).

Table 1: Predicted water level fluctuations for the subject area

Tidal Variable and Storm Surge	RL(m)
Mean Low Water Springs	-1.64
Mean Sea Level	0.22
Mean High Water Springs	1.96
5yr ARI Storm Surge	3.03
20yr ARI Storm Surge	3.20
50yr ARI Storm Surge	3.37
100yr ARI Storm Surge	3.51

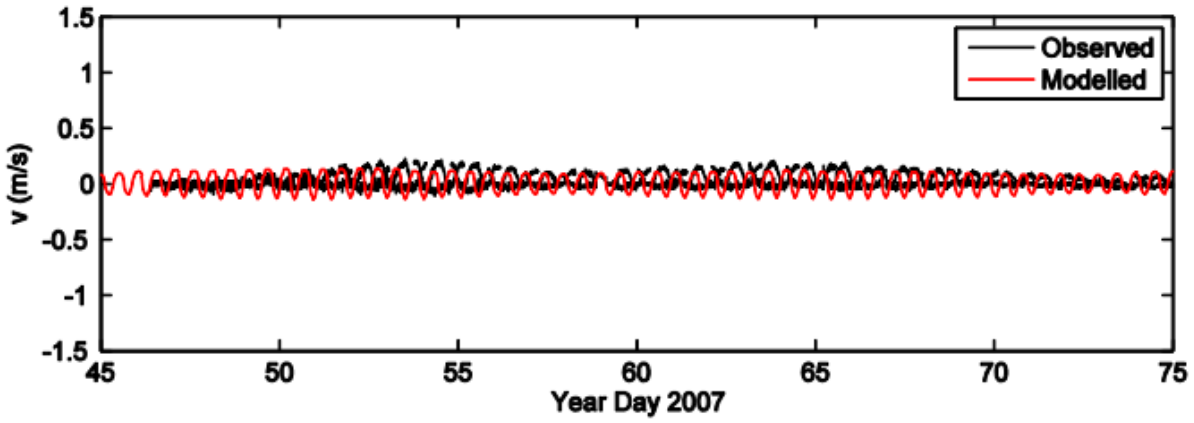

Figure 4: Observed and modelled results of tidal current from within the Drury Creek Site CM4 *(Source: Pritchard et al., 2008)*

4 COASTAL HAZARD ASSESSMENT

In general, the degree of risk from coastal hazards at the site will tend to be restricted by the relatively low energy nature of the site.

An initial high-level assessment of coastal hazards at the site was undertaken to inform the concept design process and to provide focus point for this investigation. This assessment is provided in **Appendix B** for context. The high-level assessment identified four potential areas of risk from coastal erosion which are highlighted in **Figure 5** below. These areas form the basis for further investigation of coastal erosion potential at the site discussed below.

Areas of risk from coastal inundation were also assessed and these are discussed in **Section 4.1** below. Tsunami risk is also considered in **Section 4.2**.

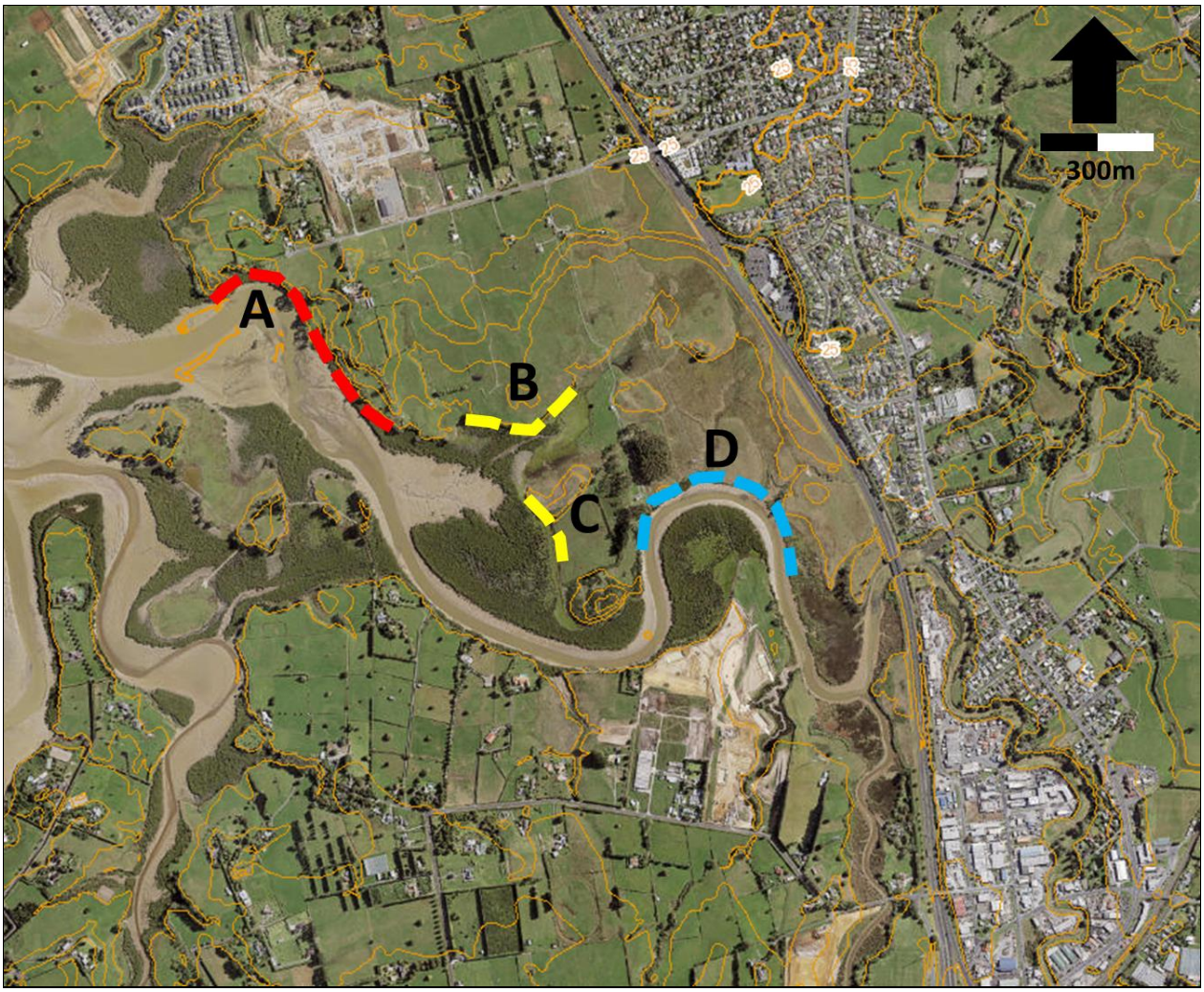

Figure 5: High level assessment of areas possible subject to coastal erosion based upon geomorphology and topography. The areas indicated by the red dashed line indicate a higher risk zone, the blue dashed line represents a moderate erosion risk and the yellow dashed lines indicated a low risk zone. Letters refer to specific areas of interest for future investigation (Source: Auckland Council Geomaps).

4.1 Coastal Inundation

Parts of the site are subject to current and potential future coastal inundation during storm events as highlighted in **Figure 6** below. **Table 1** above provides a summary of current inundation levels from a nearby modelled location.

Low lying areas of the site are expected to be currently susceptible to inundation events and the frequency of inundation is expected to increase with predicted sea-level rise. As an analogy of future frequency of inundation, the event of 4 January 2018 was considered to be between a 10 and 20yr event in terms of inundation on the Manukau Harbour. An event of this magnitude can be expected to be closer to a MHWS tidal event, based upon an allowance of 1m sea-level rise prescribed by the Auckland Unitary Plan.

Figure 6: Areas susceptible to coastal inundation with the solid red line demarcating the approximate landward boundary of the subject site (Source: Auckland Council Geomaps)

4.2 Tsunami

Auckland Civil Defence have produced maps highlighting tsunami risk across the Auckland region. For the subject coast the areas below MHWS are highlighted as exclusion zones (**Figure 7**). Above this point, the risk to the site from tsunami is assumed to be similar to that presented by storm inundation plus predicted sea-level rise.

Figure 7: Tsunami risk for the subject coastline with the red area representing an exclusion zone.

4.3 Coastal Erosion

In general, the potential for coastal erosion is considered to be low due to the sheltered nature of the site. The Auckland Unitary Plan identifies that the coastal erosion hazard area as land which is:

a) *within a horizontal distance of 20m landward from the top of any coastal cliff with a slope angle steeper than 1 in 3 (18 degrees); or*

b) *at an elevation less than 7m above mean high water springs if the activity is within:*

   i. *Inner Harbours and Inner Hauraki Gulf: 40m of mean high-water springs; or*

   ii. *Open west, outer and Mid Hauraki Gulf: 50m of mean high-water springs; or*

c) *within a lesser distance from the top of any coastal cliff, or mean high water springs, than that stated in (a) and (b), where identified in a site-specific coastal hazard assessment technical report prepared by a suitably qualified and experienced professional to establish the extent of land which may be subject to coastal erosion over at least a 100 year time frame.*

Under this broad definition the subject site would be considered to at risk from coastal erosion, and a site-specific erosion assessment should be undertaken to understand the true erosion risk at the site as per part *(c)* of the definition.

Note: the subject site appears not to have been examined in the Auckland Regional Coastal Erosion Hazard Assessment undertaken in 2006 (Reinen-Hamill et al., 2006). This presumably due to the scale of the investigation undertaken.

4.3.1 Quantitative Erosion Assessment

Quantitative analysis of the erosion potential across the site has been undertaken based upon the hard cliff equations provided in the Auckland Council Coastal Hazard Guidance Memo (Carpenter, 2016). The adoption of the hard cliff equations is considered appropriate due to the nature of the site ascertained from the initial high-level assessment, GIS analysis and underlying geology. Eight different cross-sections across the site were analysed, which were selected based upon the risks identified in the earlier high-level assessment. The position of the cross sections across the site was determined from the high-level assessment and the identification of higher risk areas (**Figure 5**).

A summary of the quantitative analysis results is provided in **Table 2** below. Details including the assumptions, calculation sheets and respective cross-sections are provided in **Appendix C**. Results indicate that the erosion potential (including the impact of sea-level rise) across the site range between 18-26m inland from the existing toe position. These are marked up on the cross-sections presented in **Appendix C**.

The results from the quantitative analysis form part of the qualitative analysis discussed below and need to be considered in that context.

Table 2: Summarised results from a quantitative analysis of erosion risk at the subject site.

Profile and Section	Natural slope settlement	Erosion potential allowing for 1m sea-level rise (100yrs)
CS1 (Section A)	13	20
CS2 (Section A)	11	18
CS3	10	18
CS4 (Section B)	12	20
CS5 (Section C)	11	19
CS6	18	26
CS7 (Section D)	8	22
CS8 (Section D)	9	25

4.3.2 Qualitative Erosion Assessment

In general, the site is considered to be depositional in nature as indicated by the presence and gradual expansion of mangrove and saltmarsh communities. Additionally, due to the sheltered nature of the site and the general depositional nature of the system the erosion hazard at the site is minimal. These habitats are typically associated with depositional environments and will often increase rates of deposition due their ability to dampen coastal processes and thus encouraging further sediment deposition.

The areas afforded protection from either mangrove or saltmarsh habitat are mapped in **Figure 8** below. This illustrates that only one small area in the north western part of the subject coastline is not afforded protection by coastal vegetation. During the site visit this was attributed to the exposure of East Coast Bays Formation rock material and the proximity to the main tidal channel not allowing for the settlement of soft sediment and mangrove seedlings required to establish the habitat (refer **Figure 3**).

Due to the sheltered nature of the site (and wider fluvial system) and the size of the catchment (~165km^2) supplying sediment, the depositional nature of the site is not expected to change with sea-level rise. The rationale for this is that the rate of sea-level rise will be matched by the additional delivery of sediment due to the increased rainfall predicted with climate change. A contemporary example of this rationale can be seen in the Elkhorn Slough in Central California. Studies from this estuary highlighted that despite an effective 1m sea-level rise the central and upper portions of the estuary were still demonstrating sediment deposition and expansion of saltmarsh communities (Caffrey et al., 2003).

The risk of erosion from tidal and fluvial flows is considered to minimal due to the low current flows, cohesive nature of bed material and protection afforded from existing vegetation. Further the nature of tidal movements means that one portion of bank is impacted for a limited amount of time.

Figure 8: Areas of the subject coastline afforded protection by either mangrove or saltmarsh habitat. The green line represents mangrove habitat, the yellow line is a mix of mangrove and saltmarsh habitat.

For those areas highlighted to be depositional across the site, the risk of erosion is considered to be restricted to the settlement of the existing slopes back to a natural angle of repose. These settlement figures are provided in Column 2 of **Table 2** above and are generally between 8-18m, and once settled these slopes should remain relatively stable. The exception to this, is the area noted as not having protection afforded to the cliff toe from either mangrove or saltmarsh habitat. This area is represented by profiles CS1 and CS2 which show potential future retreat of between 18-20m over the next 100 years (**Figure 9**).

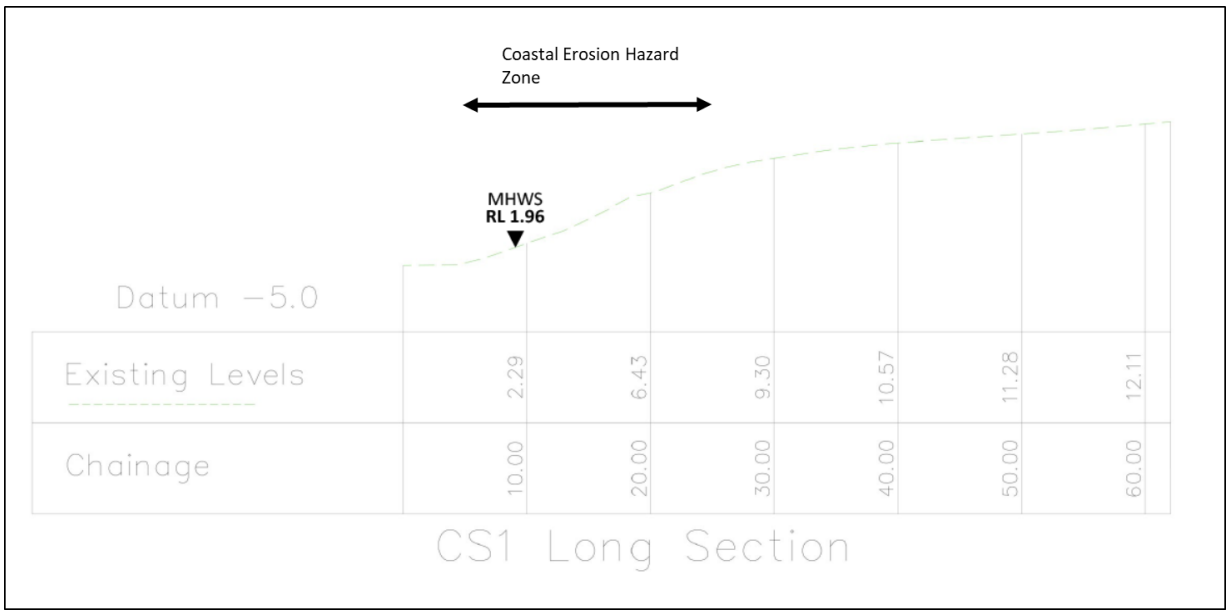

Figure 9: Coastal Erosion Hazard Zone over the next 100 years for Cross Section CS1 Section A.

5 CONCLUSIONS

A description of the site's geomorphology, coastal processes and coastal hazards are provided above. The site can be considered to be a low energy wave environment, and the associated risk from coastal hazards reflect this. In general, these risks are:

- There is a recognised coastal inundation and tsunami risk in low lying southern portion of the site (refer **Figure 6 and 7**).
- The majority of the coastal margin along the site is considered to be depositional with sediment and vegetation accreting, which makes erosion of the coastal cliff toes from wave action to be considered unlikely. Natural slope settlement is still expected in these areas.
- A ~180m section at the northern portion of the site has the potential for coastal erosion now, and in the future increased erosion. This retreat has been estimated to be between 18-20m over 100 years based upon the guidance provided from Auckland Council.

6 RECOMMENDATIONS

Given the low level of risk posed from coastal hazards at the site the following recommendations are given:

- Land identified as being susceptible to coastal inundation and tsunami risk should be raised above the predicted 100yr storm surge levels (**Table 1**) prior to site development plus an additional allowance of 1m for sea-level rise and a 500mm freeboard.
- A 20m setback from MHWS be provided with respect to the positioning of any private property boundaries and significant infrastructure.
- Suitable planting be undertaken along the reserve area to ensure that the risk of erosion is minimised.

REFERENCES

Caffrey, J.M., M.T. Brown, W.B. Tyler, and M. Silberstein, eds. 2003. Changes in a California Estuary: A Profile of Elkhorn Slough. Moss Landing, CA: Elkhorn Slough Foundation.

Carpenter, N. (2016). Coastal Hazard Assessment Guidance Memo. Dated 14th November 2016.

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Appendix A:

GIS Analysis

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PROJECT

TITLE 1959 and 1996 (adjusted) aerial imagery

Legend

Current Coastline

Date Created: 2/07/2018
Status: DRAFT
Drawnr: FP
Checked: SM
Approved: SM

Document Path: F:\FELIX_DATA\4SIGHT\AA3722_Hinpaia\CoastalAssessment\Coastline_Changes.mxd

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PROJECT

TITLE Latest aerial imagery

Legend

Current Coastline

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1:2,000 @A3

0 0.05 0.1 km

PROJECT

TITLE Shift applied to 1996 aerial image

Legend

Current Coastline

Shift Apllied to 1996 imagery

Date Created: 2/07/2018
Status: DRAFT
Drawnr: FP
Checked: SM
Approved: SM

Appendix B:

High-Level Coastal Hazard Assessment

Memorandum

To: Nick Rae- Director, Transurban

From: Sam Morgan - Senior Coastal Consultant, 4Sight Consulting Ltd.

Date: 10 July 2018

Subject: Park Estate Hingaia- Baseline Coastal Hazard Risk Assessment

Introduction

Hugh Green Group are investigating the development potential of approximately 88Ha of coastal land along the eastern shore of Drury Creek, situated in the south-eastern corner of the Manukau Harbour (**Figure 1**). Parts of the site have been highlighted within a coastal erosion hazard zone as per the Auckland Unitary Plan definitions section.

The scope of this initial assessment is to define the high level coastal hazards at this site. This will allow for a focused site-specific investigation of coastal hazards at the site to help inform future discussions around the appropriate vesting of esplanade reserve land along the subject coastline.

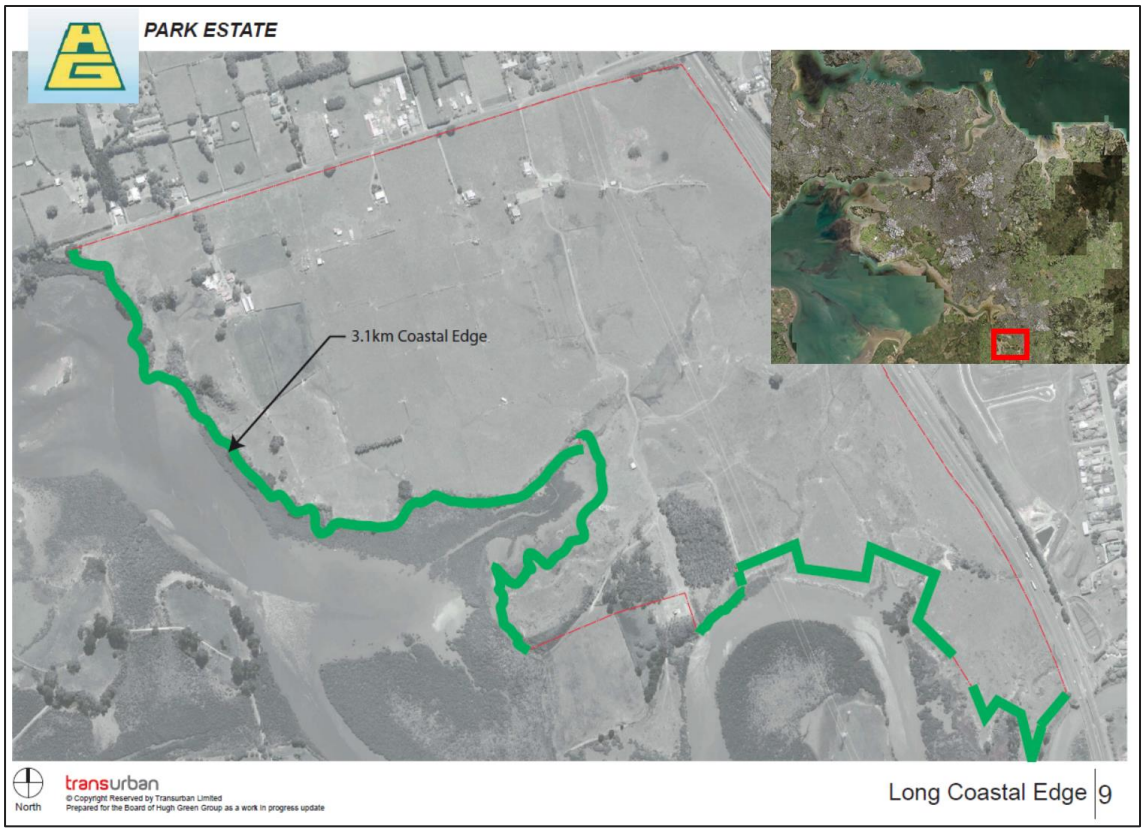

Figure 1 - Location of the subject site. The green line shows the extent of the subject coastline and the red box illustrates the approximate location (Source: Auckland Council Geomaps)

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Background

The site borders approximately 3.1km of coastline along the eastern shore of Drury Creek in the south eastern corner of the Manukau Harbour. The area can be considered a relatively low energy environment in terms of coastal processes, sheltered from wave activity but subject to tidal movements and stream flows down the Drury Creek and surrounding catchment.

Geologically the area is characterized by the Puketoka Formation silts, sands and clays overlaying weathered Waitemata Series material. Puketoka Formation material is typically poorly bonded due to the age (less three million years) and highly variable due to the fluctuations in sea level over the Pliestocene period (2,588,000 to 11,700 years ago), resulting phases of erosion and deposition. Detailed geotechnical investigations indicate that the Puketoka Formation material at the site is between 2-15m thick, depending on bore location, and before Waitemata Series (East Coast Bays Formation) material is encountered (Coffey, 2015). Observations from aerial photography indicate that exposures of relic Waitemata Series shore platforms are present within the subject area (**Figure 2**). This was confirmed during a site visit undertaken on 6 July 2018 (**Figure 3**) as indicated by the folding patterns present within the exposed shore platforms and hardness and composition of material observed. Those parts of the intertidal area not highlighted in **Figure 2** as Waitemata series group are presumed overlain by contemporary depositions of estuarine muds and silts.

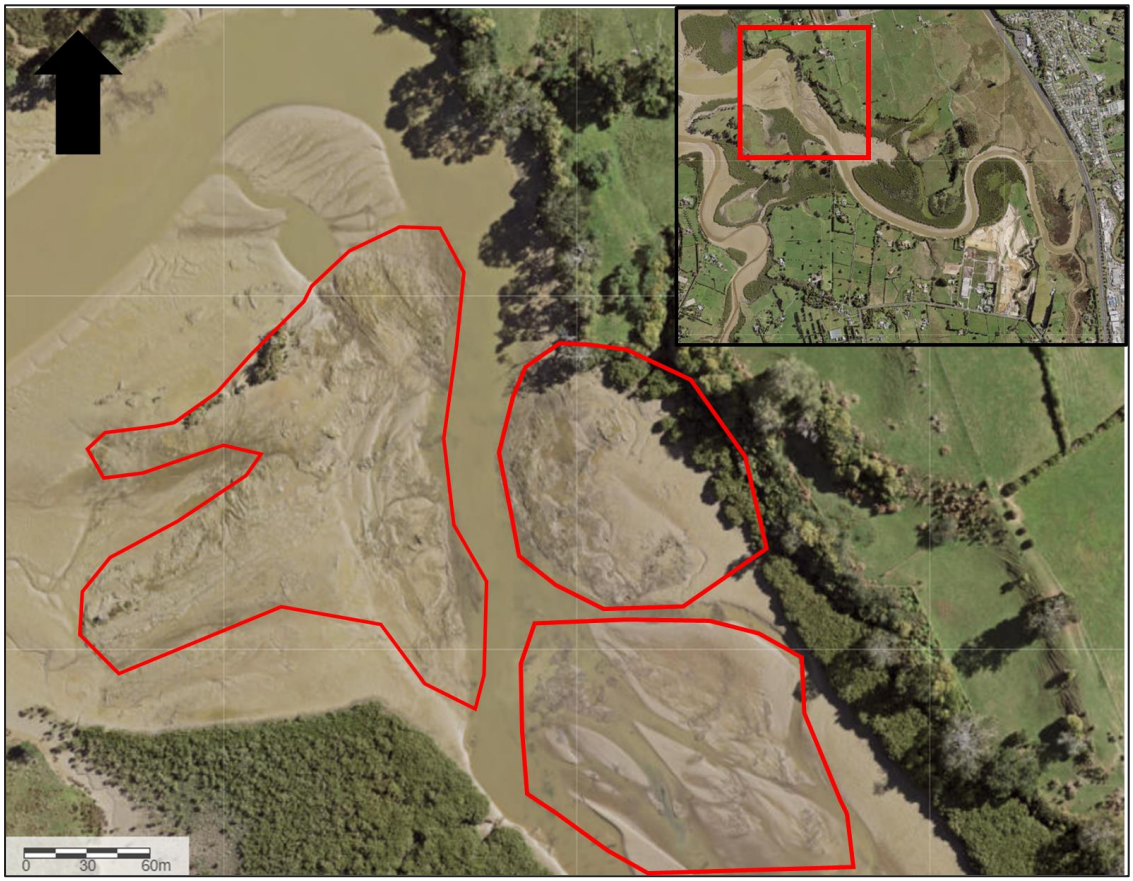

Figure 2 - Exposed Waitemata Series material based upon air photo analysis from the north western portion of the subject coast. Location indicated by the red box in the inset (Source: Auckland Council Geomaps)

Figure 3 - Waitemata Series material forming a narrow shore platform along the northern shoreline of the subject area (Source: Site Visit)

Baseline Coastal Hazard Assessment

Coastal Inundation

Figure 4 illustrates those areas of the proposed development site subject to present coastal inundation and, that with projected sea-level rise, will potentially be subject to additional inundation in the future. Typically, these areas are associated with low lying sub arms of the Drury Creek. It is expected that inundation of these areas would have occurred during the storm in early January 2018, which could be used as a proxy for future conditions at the site. It is noted that increased inundation (expected with predicted sea-level rise) can be managed via elevation of the proposed development area, due to the sheltered nature of the site.

Figure 4 -Areas susceptible to coastal inundation with the solid red line demarcating the approximate landward boundary of the subject area (Source: Auckland Council Geomaps)

Coastal Erosion

It is noted that the coastal erosion hazard zone defined within the Auckland Unitary Plan is a generic value applied to broad coastal types across the Auckland region. Site specific erosion rates are recommended, and these are dependent upon local conditions and geomorphology. In this case it is considered appropriate to apply the estimations based upon the hard cliff erosion equations of projected shoreline retreat. This is due to the toe material of the subject cliffs are presumed to be Waitemata Series group material based upon site information provided in the geotechnical investigations, aerial photography analysis and site observations (**Figure 2**). This potentially allows for analysis of future erosion to be based upon the hard cliff erosion equations provided from the Auckland Council Coastal Hazard Guidelines, subject to GIS analysis of coastal erosion rates at the site.

A high-level area assessment of the coastal erosion risk to the site is provided in **Figure 4**. This assessment is based the geomorphology and topography of this site. Typically, those areas on the outward bend of a stream indicate an area of potential erosion and these are indicated by the red (**A**) and blue (**D**) dashed lines. The distinction between the two is made by the topography and type of vegetation present along section **D**. The areas highlighted by the yellow (B and C) dashed line are considered to be of low risk from coastal erosion due despite their relatively steep topography. This is due to the sheltered nature of the sites and protection afforded by significant mangrove habitat.

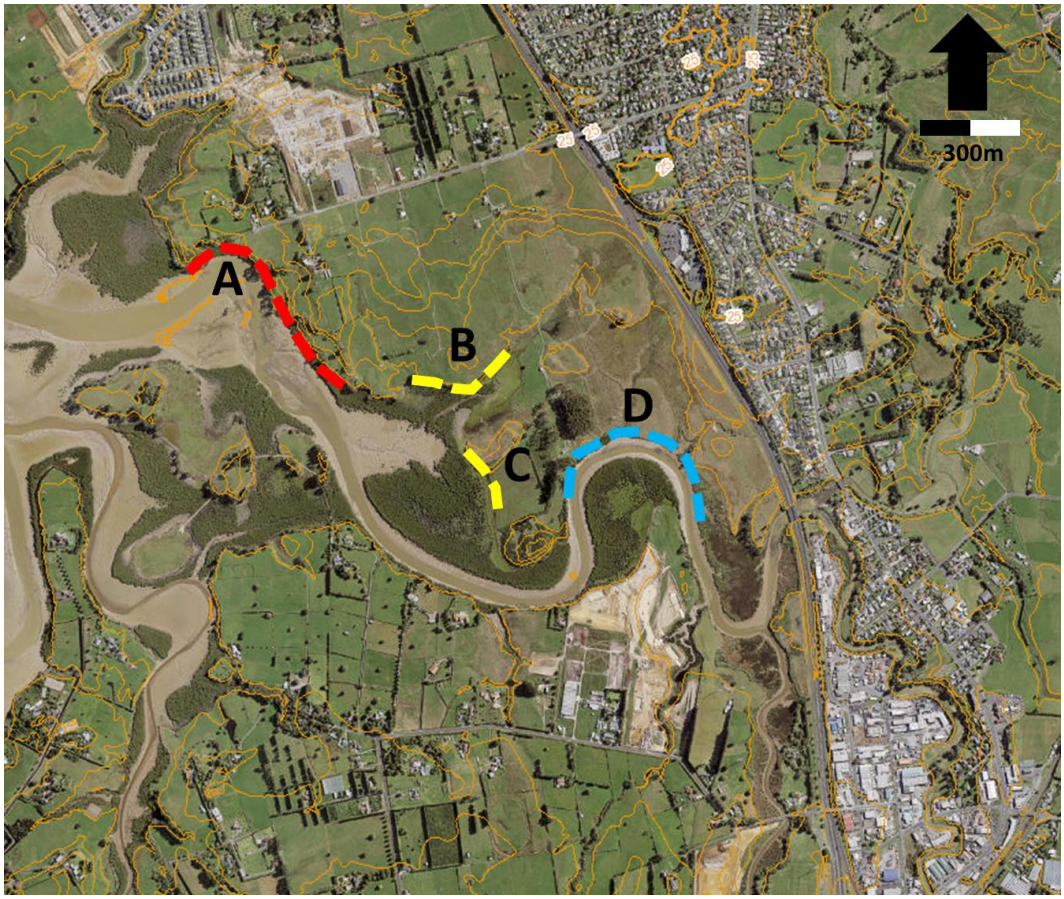

Figure 5 - High level assessment of areas possible subject to coastal erosion. The areas indicated by the red dashed line indicate a higher risk zone, the blue dashed line represents a moderate erosion risk and the yellow dashed lines indicated a low risk zone.

Recommendations

It is recommended that a detailed investigation into the coastal erosion potential across the site is undertaken to help inform the risk at this site and provide the basis for discussions on the suitability of esplanade reserves in the area. The areas noted in **Figure 4** above are intended to provide the focus for these investigations.

References

Carpenter, N., 2016. Coastal Hazard Assessment Guidance Memo. Dated 14th November 2016.

Coffey Geotechnics, 2015. Hugh Green Limited. Residential Subdivision at 144 to 252 Park Estate Road, Hingaia South. Preliminary Geotechnical Investigation Report. GENZAUCK16435AA. Dated 23 July 2015

Appendix C:

Quantitative Coastal Erosion Equations

CS1
CS2
CS3
CS4
CS5
CS6
CS7
CS8

Aerial imagery sourced from Auckland Council GeoMaps

N

Scale 1:6,000 @ A3

0 120 240m

AA3722

Cross Section Location Plan

Figure prepared by 4Sight Consulting.

Date: 11/07/2018
Version: 1.0
Drawn: Sam Hendrikse
Checked: Sam Morgan
Approved: Sam Morgan

4SIGHT CONSULTING

Profile	Natural retreat	Erosion Potential
CS1	13	20
CS2	11	18
CS3	10	18
CS4	12	20
CS5	11	19
CS6	18	26
CS7	8	22
CS8	9	25

$$ASE_{Hcliffs} = \left[(LTR_H \times T) \times F_1 + \left(\frac{H_t + F_2}{tan\alpha}\right)\right]$$

Equation 2

Where:

$ASE_{Hcliffs}$ = **Area of cliff susceptible to erosion**

LTR_H = **Historic Long Term Rate of Retreat (m/yr)**
This factor should take into account the historic regression rate of the cliff based on data (historic aerial photography, past surveys, existing studies) or expert judgement.

T = **Timeframe**
As previously noted, in alignment with the New Zealand Coastal Policy Statement, Auckland Council requires the assessment of at least a 100 year timeframe.

F_1 = **Uncertainty Factor**
Allowance for potential uncertainty in the historic long term rate of retreat (LTR_H).

H_t = **Height of Cliff (m)**
As obtained from survey data associated with the application or Auckland Councils online geodatabase.

F_2 = **Error Factor (m)**
To account for any potential error associated with the height of the cliff. For example, 2.5 for LINZ topomap data.

α = **Cliff Slope Angle**
The characteristic slope angle of the cliff surface measured from the horizontal (typically controlled by the cliffs lithology and structure). This angle varies according to the likelihood of failure considered.

$(LTR_H \times T)F$ $\quad \frac{H_t + 2.5}{}$ $\quad tan\ \alpha$

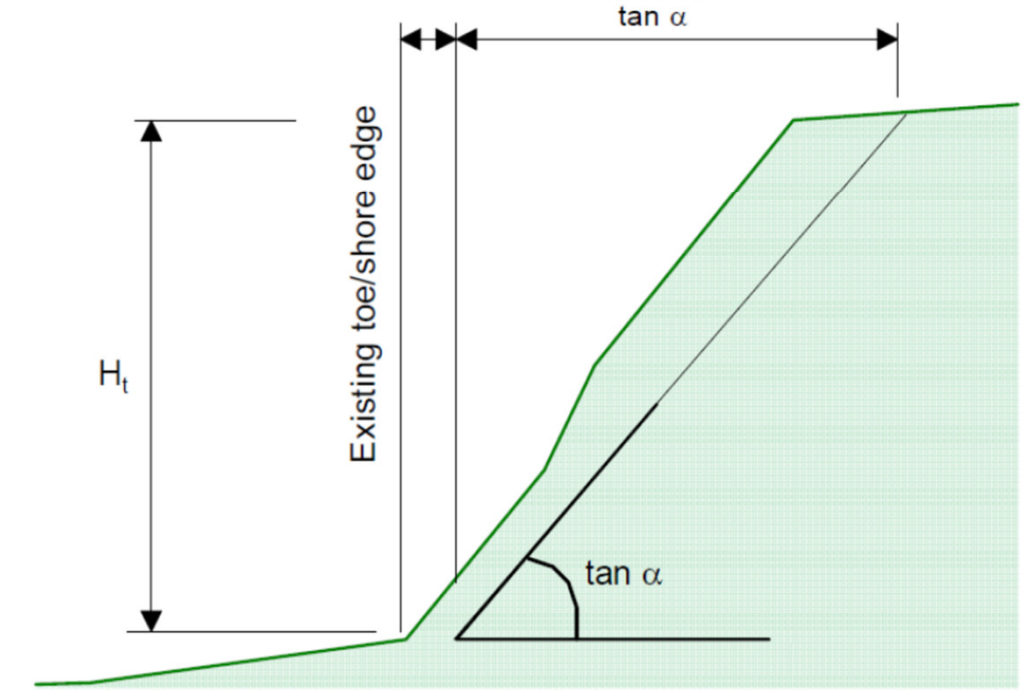

Figure 1: Definition of cliff parameters

Hard Cliff Erosion Emprical Estimate

Site: Hingaia Profile CS1

Date: 13.07.18

Assumed settlement retreat	**13**
ASE- Hard Cliffs=	**20**

Variable	Value		
LTRH*	0.05		
T	100		
F1	1.5		
HT	8.5		
F2	1.5		
α	19.3	0.336849	***Convert to Radians**
tan α	0.350195		

*GIS analysis indicates no change over a 50 yr period. 0.05m/yr over the analysis period would indicate a 2.5m retreat over the 50yr period. If the toe were eroding at this rate it is fair to assume that a change of this order would have been observed at least in part along the subject coast. therefore a 0.05m/yr value is considered appropriate.

1.5 should be fine with LIDAR data

Hard Cliff Erosion Emprical Estimate

Site: Hingaia Profile CS2

Date: 13.07.18

Assumed settlement retreat	**11**
ASE- Hard Cliffs=	**18**

Variable	Value		
LTRH*	0.05		
T	100		
F1	1.5		
HT	5.5		
F2	1.5		
α	16.5	0.287979	***Convert to Radians**
tan α	0.296213		

*GIS analysis indicates no change over a 50 yr period. 0.05m/yr over the analysis period would indicate a 2.5m retreat over the 50yr period. If the toe were eroding at this rate it is fair to assume that a change of this order would have been observed at least in part along the subject coast. therefore a 0.05m/yr value is considered appropriate.

1.5 should be fine with LIDAR data

Hard Cliff Erosion Emprical Estimate

Site: Hingaia Profile CS3

Date: 13.07.18

Assumed settlement retreat	**10**
ASE- Hard Cliffs=	**18**

Variable	Value		
LTRH*	0.05		
T	100		
F1	1.5		
HT	8.5		
F2	1.5		
α	40	0.698132	***Convert to Radians**
tan α	0.8391		

*GIS analysis indicates no change over a 20 yr period. 0.05m/yr over the analysis period would indicate a 1m retreat over the 20yr period. The presence of mangroves indicates this is a depositional environment and the toe is not eroding therefore a 0.05m/yr value is considered appropriate.

1.5 should be fine with LIDAR data

Hard Cliff Erosion Emprical Estimate

Site: Hingaia Profile CS4

Date: 13.07.18

Assumed settlement retreat	**12**
ASE- Hard Cliffs=	**20**

Variable	Value		
LTRH*	0.05		
T	100		
F1	1.5		
HT	6		
F2	1.5		
α	14	0.244346	***Convert to Radians**
tan α	0.249328		

*GIS analysis indicates no change over a 20 yr period. 0.05m/yr over the analysis period would indicate a 1m retreat over the 20yr period. The presence of mangroves indicates this is a depositional environment and the toe is not eroding therefore a 0.05m/yr value is considered appropriate.

1.5 should be fine with LIDAR data

Hard Cliff Erosion Emprical Estimate

Site: Hingaia Profile CS5

Date: 13.07.18

Assumed settlement retreat	**11**
ASE- Hard Cliffs=	**19**

Variable	Value		
LTRH	0.05		
T	100		
F1	1.5		
HT	7		
F2	1.5		
α	19.3	0.336849	***Convert to Radians**
tan α	0.350195		

*GIS analysis indicates no change over a 20 yr period. 0.05m/yr over the analysis period would indicate a 1m retreat over the 20yr period. The presence of mangroves indicates this is a depositional environment and the toe is not eroding therefore a 0.05m/yr value is considered appropriate.

1.5 should be fine with LIDAR data

Hard Cliff Erosion Emprical Estimate

Site: Hingaia Profile CS6

Date: 13.07.18

Assumed settlement retreat	**18**
ASE- Hard Cliffs=	**26**

Variable	Value		
LTRH*	0.05		
T	100		
F1	1.5		
HT	14		
F2	1.5		
α	19.3	0.336849	***Convert to Radians**
tan α	0.350195		

*GIS analysis indicates no change over a 20 yr period. 0.05m/yr over the analysis period would indicate a 1m retreat over the 20yr period. The presence of mangroves indicates this is a depositional environment and the toe is not eroding therefore a 0.05m/yr value is considered appropriate.

1.5 should be fine with LIDAR data

Hard Cliff Erosion Emprical Estimate

Site: Hingaia Profile CS7

Date: 13.07.18

Assumed settlement retreat	**8**
ASE- Hard Cliffs=	**22**

Variable	Value		
LTRH*	0.05		
T	100		
F1	1.5		
HT	4		
F2	1.5		
α	20.5	0.357792	***Convert to Radians**
tan α	0.373885		

*GIS analysis indicates no change over a 20 yr period. 0.05m/yr over the analysis period would indicate a 1m retreat over the 20yr period. The presence of mangrove and salt marsh communities indicates this is a depositional environment and the toe is not eroding therefore a 0.05m/yr value is considered appropriate.

1.5 should be fine with LIDAR data

Hard Cliff Erosion Emprical Estimate

Site: Hingaia Profile CS8

Date: 13.07.18

Assumed settlement retreat	**9**
ASE- Hard Cliffs=	**25**

Variable	Value		
LTRH*	0.05		
T	100		
F1	1.5		
HT	2		
F2	1.5		
α	11.5	0.200713	***Convert to Radians**
tan α	0.203452		

*GIS analysis indicates no change over a 20 yr period. 0.05m/yr over the analysis period would indicate a 1m retreat over the 20yr period. The presence of mangrove and salt marsh communities indicates this is a depositional environment and the toe is not eroding therefore a 0.05m/yr value is considered appropriate.

1.5 should be fine with LIDAR data