

THE STATES OF DELIBERATION
of the
ISLAND OF GUERNSEY

COMMITTEE *FOR THE* ENVIRONMENT & INFRASTRUCTURE

PROPOSALS FOR THE PARTIAL REMOVAL OF THE ANTI-TANK WALL IN THE EASTERN
PART OF PEMBROKE BAY (L'ANCRESSE EAST) AND THE MANAGED RE-ALIGNMENT OF
THE COASTLINE IN THIS AREA

Whether, after consideration of the attached Policy Letter dated 1st August 2017 they are of the opinion:-

1. To endorse the proposal to implement the managed re-alignment ("Option 7b") of the coastline at L'Ancrese East as set out in Section 7 of this Policy Letter and described in Section 6, Volume 1 of the report "Guernsey Coastal Defences" prepared by Royal Haskoning Dhv.
2. To note that the Committee *for the* Environment & Infrastructure does not have a mandate for the provision of facilities.
3. To agree that the preferred option for the provision of facilities at L'Ancrese East, including the approval of extra funds if necessary, is as detailed in Section 9 of this Policy Letter:

(i) Option (a) – Remove the toilets and kiosk and do not replace.

OR, only if Proposition 3(i) shall have been defeated,

(ii) Option (e) – Remove the toilets and kiosk and replace by a public/private partnership.

OR, only if Proposition 3(ii) shall have been defeated,

(iii) Option (d) – Remove the toilets and kiosk and replace by the States of Guernsey

OR, only if Proposition 3(iii) shall have been defeated,

(iv) Option (b) – Protect by design, using a larger revetment structure and extension of the rock revetment to protect the toilets and kiosk.

OR, only if Proposition 3(iv) shall have been defeated,

- (v) Option (c) – Protect by design (extension of the rock revetment to protect the kiosk), using an extension of the rock revetment to protect the toilets and kiosk.

The above Propositions have been submitted to Her Majesty's Procureur for advice on any legal or constitutional implications in accordance with Rule 4(1) of the Rules of Procedure of the States of Deliberation and their Committees.

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**PROPOSALS FOR THE PARTIAL REMOVAL OF THE ANTI-TANK WALL IN THE EASTERN
PART OF L'ANCRESSE BAY AND THE MANAGED RE-ALIGNMENT OF THE COASTLINE IN
THIS AREA**

The Presiding Officer
States of Guernsey
Royal Court House
St Peter Port

18th August, 2017

Dear Sir

1 Executive Summary

- 1.1 The aim of this Policy Letter is to enable States Members to make an informed decision regarding the damaged 200-metre stretch of anti-tank wall at L'Ancrese East.
- 1.2 The Committee is mandated by the States to protect and enhance the natural and physical environment and develop infrastructure in ways which are balanced and sustainable. The Committee has the responsibility for the majority of the existing coastal infrastructure management, including coastal and flood defence.
- 1.3 A Requête has been lodged that, if laid and successful, could result in delays to the commencement of work and further deterioration of the integrity of the wall. The Committee therefore decided that the most expedient method of ensuring a suitable resolution was to bring forward this Policy Letter at the earliest opportunity.
- 1.4 Prior to WWII, the 1km wide bay at Pembroke was backed by shingle and sand dunes. Around 1942, the German occupying forces built a concrete anti-tank wall along 925 metres of the southern boundary of the beach, founded on sand and shingle, to protect against an amphibious landing by Allied forces.

- 1.5 Because a man-made structure that is not sympathetic to the existing processes has been introduced into the natural environment, there are a number of issues (covered in detail in section 5 of this Policy Letter), including:
- Lack of foundations;
 - Location in front of the high water line;
 - Angle of the eastern end of the wall;
 - Scouring of the wall;
 - Rotation of the wall;
 - Cracking of the wall;
 - Overtopping;
 - Reflection of wave and tide (rather than dissipation);
 - Loss of beach height.
- 1.6 A number of options (as detailed in section 6) have been presented by independent consultants, Royal Haskoning Dhv, which have been considered, on a number of occasions since 2014, by the existing Committee and the previous Environment Board. The options can be summarised as:
- Removal of Defences;
 - Maintain and Improve;
 - Do Nothing;
 - Advancing the Defence;
 - Managed Realignment.
- 1.7 The Committee reaffirmed the decision of its predecessor, the Environment Board, that of all the options considered, the best value and most sustainable in the long-term is **Option 7b – Managed Realignment**. This option addresses the problems inherent in and caused by the existing anti-tank wall. It removes the existing damaged wall between two controlling structures to manage the formation of a dune-backed embayment. It offers a reduction in the long-term management costs of the area and increased amenity. This option has a significant up front cost, but low ongoing management costs.
- 1.8 The proposed realignment would increase the beach amenity at the eastern end of Pembroke Bay and allow a long term solution to flood management. There would not be any direct impact on the golf course, nor is the loophole (pre-Martello) tower at risk.
- 1.9 The Committee is aware that the kiosk at the eastern end of Pembroke Bay is at risk under Option 7b (Managed Realignment). The toilets and kiosk fall outside of the Committee's mandate. A number of solutions for the kiosk at L'Ancrese East have been presented in section 9, and are summarised as:

- Remove and Do Not Replace;
- Protect by Design - larger revetment structure and extension of the rock revetment to protect the toilets and kiosk;
- Protect by Design - extension of the rock revetment to protect the toilets and kiosk;
- Remove and Replace by the States of Guernsey;
- Remove and Replace by Public/Private Partnership.

1.10 The Committee is recommending that the States endorse the decision to proceed with managed realignment. The Committee is also recommending that the States make a separate decision (between five options that are set out and explained) regarding to the provision of toilet and kiosk facilities, which are outside the Committee's mandate.

2 Introduction

2.1 The Committee is mandated by the States to protect and enhance the natural and physical environment and develop infrastructure in ways which are balanced and sustainable, so that present and future generations can live in a community which is clean, vibrant and prosperous.

2.2 The Committee has the responsibility for the majority of the existing coastal infrastructure management, including coastal and flood defence:

- Routine Maintenance;
- Capital (Routine or Reserve) Projects for Major Repairs; and
- Flood Risk Mitigation Structures Associated with Climate Change.

2.3 The States Resolutions, following debate of the Policy and Resource Plan – Phase 2 in June 2017, included:

- Resolution 6 – the coastal repair schemes as one of the 'Small' projects in the 'Maintain' category;
- Resolution 7 – the approval process for capital projects;
- Resolution 8 – the delegation of authority to the Policy and Resources Committee to approve opening capital votes for any project with a capital value not exceeding £2,000,000;
- Resolution 17 – the policy plan of the Committee *for the* Environment & Infrastructure.

2.4 It is clear from the States' Resolutions and the Committee's mandate that the proposed coastal repair scheme at L'Ancrese East is within the Committee's remit, subject to the agreed financial scrutiny by the Policy and Resources Committee and to obtaining the required statutory permissions and approvals.

- 2.5 A Requête has been lodged that, if laid and successful, could result in delays to the scheme. The Committee therefore decided the most expedient method of ensuring a suitable resolution was to bring forward this Policy Letter at the earliest opportunity.

3 Background

- 3.1 Detailed independent analysis of Guernsey's coastal defences to establish flood risk and identify mitigating measures has been published in a series of studies since 1999. These studies have included Pembroke Bay¹.
- 3.2 Appendix 1 provides a chronology of the independent advice provided to the Committee's predecessors. Appendix 2 contains an analysis of the final set of options which were considered by the Committee.
- 3.3 In 2012 the Environment Department created a Coastal Defence Project Group which submitted a policy letter² to the States based on Royal Haskoning's 2007 and 2012 reports. It sought and secured the States' approval of the framework and methodology for prioritising coastal defence work. Using that methodology resulted in work at L'Ancrese East and Fermain Bay being given the lowest priorities, primarily because they do not protect vital infrastructure as the other coastal structures do. The walls at Pembroke Bay and Fermain Bay were constructed as military defences rather than as coastal defences, so their original purpose – to guard against invasion – is now redundant.
- 3.4 Royal Haskoning's 2012 report considered the section of anti-tank wall at L'Ancrese East as a discrete problem for the first time because its condition was distinctly worse than the remainder of the wall. Two options specific to L'Ancrese East, Options 7a and 7b, were included in the report.
- 3.5 In light of the extensive information and expert advice available to them, the Environment Board agreed the preferred management solution at L'Ancrese East should include the removal of the failing sections of the anti-tank wall rather than further attempts to repair them. In August 2015 the Board members selected Royal Haskoning's Option 7b – the managed realignment of L'Ancrese East's natural defences – as their preference.
- 3.6 This issue was further considered in January 2016 when the Environment Board approved plans to investigate the costs and the technical considerations of the project. The investigation was to present board members with a clearer understanding of the works which would be required.

¹ In this policy letter 'Pembroke Bay' refers to the whole bay and 'L'Ancrese East' to the area of the proposed works.

² [Billet XV 2013](#)

- 3.7 Further work by Royal Haskoning to refine Option 7b was completed in early 2017 and resulted in a revised cost estimate.
- 3.8 In 2017, the Committee was briefed on all the main options which had been under consideration and decided to endorse the Environment Board's preference for Option 7b.

4 Pembroke Bay and the World War II anti-tank wall

- 4.1 Prior to WWII, the 1km wide bay at Pembroke was backed by shingle and sand dunes. As can be seen in contemporary photographs (see Appendix 5), these were similar to today's sand dunes at Les Amarreurs, Port Soif and Grande Rocques.
- 4.2 The German occupying forces built a concrete anti-tank wall along 925 metres of the southern boundary of the beach, founded on sand and shingle, to protect against an amphibious landing by Allied forces.
- 4.3 The anti-tank wall was cast in sections, also known as panels. At the eastern end each section, or panel, is 12m wide and the full length of the section of wall covered by the proposed works comprises 23 panels in total.

5 Issues at L'Ancrese East

- 5.1 Because the wall was built without firm foundations on rock or clay, and because the wall at the eastern end is in front of the natural high water line, the foot of the eastern 200m of wall has been scoured: the material beneath the wall has been washed out through wave and tidal action, leaving large voids. This is exacerbated by the angle of the wall along the beach at the eastern end of Pembroke Bay. The reflection of the tide and waves by this man-made structure removes sand from the base of the wall, particularly in storm conditions.
- 5.2 The scouring at the foot of the wall has led to undermining of the structure, which in turn has caused parts of the wall to rotate on their horizontal axis, tipping forward towards the beach. The top of some panels are being held in place by adjacent panels, causing the wall to crack and further compromising its structural integrity (see Appendix 6). The eastern 200m of the wall has, due to a combination of factors, deteriorated to a greater extent than the remainder of the wall (see Appendix 2, page 29 – *Eastern section of DU3*). This deterioration is ongoing.
- 5.3 L'Ancrese East (more so than the wall at the west of the Pembroke Bay) experiences overtopping of wind-driven sea water at high tide. This is because the wall is in front of the natural high water line – in other words, the line the

tide would run to were it not obstructed – and so energy is not dissipated as it would be naturally.

- 5.4 Beach records since 2001 show that there is seasonal scouring from the wall, and the movement data indicate that sediment is being lost from the intertidal range to the subtidal – in other words, sand is being lost from the beach to the offshore region. Historical information shows that the average beach height has dropped 1.5m since the wall's construction. However, there is also evidence that there is a reservoir in the subtidal range (offshore region) as under certain conditions there is aggregation on the beach. This suggests that should the wall be removed, there is sediment in the system that would re-accrete onto the beach.
- 5.5 Although not part of the island's coastal defences, the anti-tank wall at Pembroke Bay – and the section at L'Ancrese East in particular – has been the subject of numerous extensive repairs over a number of decades.
- 5.6 A series of concrete aprons were constructed at the base of the wall around the toe in the 1960s and a series of repairs were made over subsequent decades. However, these have not been successful at the eastern end. The wall's rotation forward has pushed the apron sections away from the base and has caused them to crack longitudinally (see Appendix 7).
- 5.7 In some sections, the undermining of the wall and cracks in the wall extend its entire thickness, allowing material from behind the wall to be washed out. Emergency repairs to the affected sections of wall have been carried out as needed to reduce the imminent likelihood further failure and a potential large scale breach.
- 5.8 In addition to coastal defence, the Committee's mandate includes managing climate change. Climate change-derived sea level rise has the potential to impact on sea defences around Guernsey's coastline. At L'Ancrese East, management of sea level rise through soft defences, such as a dune backed system, would be more cost-effective than hard defences such as a vertical sea wall. Dunes would be easier to adapt to changes in conditions through additional landscaping. If hard defences were ever deemed necessary, the anti-tank wall would have to be removed and a new structure constructed, as the anti-tank wall is not founded and so cannot be enhanced directly.

6 Consideration of the Options at L'Ancrese East

- 6.1 On a number of occasions since January 2014, the Environment Board and subsequently the Committee *for the* Environment & Infrastructure have considered the options for the management of the bay at L'Ancrese East, following updated reports from Royal Haskoning (see Appendices 1&2).

6.2 The Committee reconsidered all the main options that were considered in 2012.

6.3 Cost Estimates for each of the main options

Option	2017 Estimated Development Cost £million	Estimated Ongoing Management costs
1 – Removal of Defences See Appendix 3, p36 Design life: 50+ years	0.665	* Dune management – c. £1,000-£3,000 per decade. * Replacement cost at end of design life – N/A
2 – Maintain & Improve See Appendix 3, p36 Design life: 25 years max	0.450	* Replacement panels as required – c. £80,000 each. * Rock armour management – c. £5,000-£15,000 per decade. * Replacement cost at end of design life – £665,000-£2,700,000 (plus inflation).
3 – Do Nothing See Appendix 3, p38 Design life: 50+ years	0.400 spread over a period of years	* Dune management – c. £1,000-£3,000 per decade. * Replacement cost at end of design life – N/A
7a – Advancing the Defence See Appendix 3, p42 Design life: 50+ years	2.700	* Rock armour management – c. £5,000-£15,000 per decade. * Replacement panels as required – c. £80,000 each. * Replacement cost at end of design life – N/A
7b – Managed realignment (including removal of defences) See Appendix 3, p43 Design life: 50+ years	1.015	* Dune management – c. £1,000-£3,000 per decade. * Rock armour management – c. £5,000-£15,000 per decade. * Replacement cost at end of design life – N/A
Full length rock revetment over the full frontage of L'Ancrese East³ Design life: 50+ years	1.800	* Rock armour management – c. £5,000-£15,000 per decade. * Replacement panels as required – c. £80,000 each. * Replacement cost at end of design life – N/A

³ Note that this option was presented as a more significant (larger) structure to protect to the top of the wall that would offer better long term protection, but was not in the initial 2012 report.

- 6.4 The 2017 costs as outlined in the table above are uplifted from the costs in the 2012 Royal Haskoning report, taking account of Guernsey-specific costs (on-island supplies and contractors from recent projects) and allowing for some inflation in the intervening period.
- 6.5 The cost for Option 3 (Do Nothing) is based on concrete disposal rates of £20,000 per 12m panel, and the cost would only be incurred as and when concrete separated from the wall.
- 6.6 The estimated ongoing management costs for rock armour have been calculated based on records of the previous decades' work across all rock armour, but quantified based on improvements in design of rock armour in modern installations. Bulwer Avenue had interlocking rock armour installed in 2014 and has had no work required. It would be expected that, due to the engineered nature of the structures and the significantly large rock, the movement of rock at L'Ancrese would be even less than that at Bulwer Avenue. However, it is also noted that, due to the importance of an interlocking structure, any movement of the rocks would require placement back into the interlocking structure.
- 6.7 The estimated ongoing management costs for dune management are based on records over the past decade (which included storm events in 2008 and in the winter of 2013/14). There was no requirement for dune work following storm events within this period. The main costs were associated with fencing at Port Soif to stabilise the sand and work on boulder facing of the dune at Grande Rocques.
- 6.8 **Option 1 – Removal of Defences.** This would involve the proactive deconstruction and disposal of the anti-tank wall at L'Ancrese East. The beach would be allowed to realign without further management, and the dune-backed beach would be able to be managed as such thereafter. An issue with this is that the remaining anti-tank wall to the west would be at risk and would therefore require either protection, to prevent water ingress behind to cause the remaining wall to “unravel”, or removal of the remaining wall. This option would be better suited to a whole bay solution.
- 6.9 **Option 2 – Maintain and Improve.** This would involve repairing and replacing failing panels and protecting the existing wall with a 20m deep rock armour revetment (extending approximately the length of the slipway). Over time there would be a need for greater investment even along these lengths of defence, and the overall trend for management would be to encase the whole frontage with rock revetment. The gradually falling beach levels combined with sea level rise and less drying in the upper beach area would reduce the amenity of the beach. This option would require further expenditure within 25 years to address the problems inherent in the anti-tank wall.

- 6.10 **Option 3 – Do Nothing.** This option would allow the wall to fail over time. Work would only be undertaken to address safety issues (for example, removing failed sections of wall from the beach and cordoning off areas behind the wall). This is a low cost solution. As with Option 1, a dune-backed beach would form over time; however other sections of the wall would be at risk. Failed and partially failed sections of wall could cause loss of beach amenity for a time.
- 6.11 **Option 7a – Advancing the Defence.** This option would aim to provide a naturalised defence alignment through use of groynes as control structures. The groynes would be positioned out into the bay from the wall to allow sediment to aggregate in front of the wall, creating a faux dune to protect the existing structure. This is a high cost option.
- 6.12 **Option 7b – Managed Realignment (including removal of defences).** This option removes the existing wall between two groynes as control structures to manage the embayment forming behind the location of the existing anti-tank wall. This offers a reduction in the long-term management costs of the area and increased amenity. This option has a significant up front cost, but low ongoing management costs.
- 6.13 Options 7a (Advancing the Defence) and 7b (Managed Realignment), as well as the “improve” section of Option 2 (Maintain and Improve), have an additional advantage: large stone used as part of the structures will retain its inherent value and structural integrity. That means that, for options 7a and 7b, should the structures be removed in the future, there would be a potential realisation of this value.
- 6.14 Option 2 (Maintain and Improve) is the only option that does not offer a long-term solution at L’Ancresse East, with a maximum expected life of 25 years. This means that there would be a need to spend significant further funds within this timeframe.
- 6.15 Option 2 (Maintain and Improve) is the only option considered that does not provide a potential solution to long-term sea level rise.
- 6.16 Option 1 (Removal of Defences) and Option 3 (Do Nothing) offer permanent solutions, although both risk potential issues with the wall remaining to the west.
- 6.17 Options 7a (Advancing the Defence) and 7b (Managed Realignment) offer solutions with a design life of 50 years. However with careful maintenance of the structures it would be expected that these would survive well beyond this time. 7b also offers the opportunity for further adaptation in the future.

- 6.18 The highlighted cost of Option 7b (Managed Realignment) does not include likely savings that could be achieved by incorporating the existing wall structure, in the form of broken concrete, into the core of the groynes. A significant proportion of the concrete could be expected to be incorporated into the core of the groyne structures, thus reducing the costs of removal and disposal of concrete, and reducing the amount of stone required to be purchased.
- 6.19 The cost of managing sand dunes year round is minimal compared with a concrete or masonry wall. Dunes offer an effective form of defence and can be managed, and adapted, at minimal cost. At Grandes Rocques and Port Soif (which are both backed by dunes with some rock armour) there is minimal risk of coastal flooding to the roads, utility services and the properties adjacent. Neither beach required remedial work to the dunes following storms in 2008 and 2013/14.
- 6.20 The additional costs of the protection, removal or relocation of the toilets and kiosk and managing the beach re-alignment process have been excluded within the estimated costs for all options. This is covered in detail in Section 9.
- 6.21 Planning permission would be required for the development works associated with any proposed permanent or semi-permanent structure on the beach, as well as the removal of any structure, and the normal planning application process would need to be followed. The works may require an Environmental Impact Assessment (EIA) if considered necessary by the Planning Service. Only Option 3 (Do nothing) would not require planning consent.
- 6.22 This eastern 200m of the wall is the only part that would be removed or affected under any of the options considered. Almost 800m of the WWII anti-tank wall would remain, assuming mitigating measures would be taken in Option 1 (Removal of Defences) and Option 3 (Do Nothing) to protect it from water ingress behind.
- 6.23 It should be noted that the Committee prioritises coastal defence work based on a number of factors, as set out in the 2013 Environment Department Policy Letter⁴, with the recommendations (p1217) approved by the States. Because of this, the wall at L'Ancrese is of low priority and it will be difficult to justify ongoing maintenance spend at this site when other, higher priority sites, require it. Therefore if Option 2 (Maintain and Improve) were chosen, the States would need to revisit the policy on coastal defence to ensure effective ongoing maintenance of the wall.

⁴ Billet XV Volume 2, 2013, pp 1187 - 1251

7 The Proposal

- 7.1 In the light of the extensive information and expert advice available to them, Environment Department Board Members acknowledged that the preferred management would include removal of the failed sections of the anti-tank wall. In August 2015 the Environment Department agreed Option 7b – the managed realignment of the L’Ancresse East defence.
- 7.2 This issue was further considered in January 2016 when the Environment Board approved plans to investigate the cost of repair and the technical considerations regarding how repairs would be undertaken to the L’Ancresse East anti-tank wall. The aim was to present the Board with a clearer understanding of the final works that would be required.
- 7.3 The further work by Royal Haskoning to refine Option 7b (Managed realignment) was completed in early 2017 and resulted in a revised cost estimate. All options with revised costs as appropriate were brought to the Committee *for the* Environment & Infrastructure for consideration.
- 7.4 The Committee agreed Option 7b – Managed Realignment of part of the Eastern Section of the Pembroke Bay anti-tank wall. This decision reaffirmed the decision of the previous Environment Board. The favoured option is also in line with the policy as agreed by the States in 2013. The Committee is confident that Option 7b provides:
- the most cost-effective solution with a long-term strategy for the protection of the sea defences;
 - acceptable flood defences for the area; and
 - an improved amenity with semi-natural beach development in the area.
- 7.5 The proposal seeks to address the problems inherent in and created by the anti-tank wall and further seeks to restore a section of the eastern part of the bay to a dune-backed beach. This proposal allows for a more natural beach environment with a sand dune and shingle ridge, similar to that east of the slipway.
- 7.6 The proposal comprises a managed realignment of the beach with a protective boundary of sand dunes and shingle which would allow the sea to run to its full extent: the natural high water mark. Sand dunes would therefore dissipate the energy of the tide and waves. This is currently what happens at L’Ancresse to the east of the slipway where there is shingle and a low rock armour bank to the edge of the grassland. The Common here does not flood at high tide and there is no dramatic erosion in the absence of a concrete wall. There is also a

section to the east where there is a break in the wall: here a natural dune area has formed, which was unaffected by the storms in 2013 and 2014.

- 7.7 Subject to States' approval, planning consent and funding being secured, a 130m length of the anti-tank wall will be removed. The area will be flanked by two protective rock armour groynes, one close to the kiosk and one 130m to the west, near the rock outcrop. These are essential to allow the controlled formation of a dune-backed beach to the west of the slipway.
- 7.8 The cost of removing the 130m eastern section of damaged wall, construction of rock armour groynes and creating a managed realignment of the natural beach head in this area is estimated at approximately £1m, and would be put out to tender.

8 Impacts of the Proposal on the Recreational Amenity of the Area

- 8.1 **Beach amenity.** The new beach and coastal dune area created as a result of implementing these proposals will offer a larger area of dry sand between tides, improving the recreational value of the beach. This will result partly because of the increase in beach height and sand extent and partly because of the reduction in shade on the beach with the removal of this section of vertical concrete wall.
- 8.2 **The loophole tower.** The 18th century loophole (or pre-Martello) tower immediately to the south will not be affected by the removal of the 20th century anti-tank wall and subsequent realignment of the beach. The public footpath, currently running along the back of the wall, will in future be closer to the tower, where there is already a well-trodden 'desire line' path running from the centre of the bay and behind the kiosk towards the slipway.
- 8.3 **The golf course.** The managers of the golf course have voiced a concern that the proposals heighten the risk of flooding and therefore threaten the continuation of their recreational activities in this area. The reports and expert advice show with certainty that this is not the case. The topography of the area behind L'Ancrese East is such that there is no additional risk of flooding arising from these proposals. Indeed, the opportunity to manage future flood risk is better with natural defences. It should be noted that when there was flooding on the golf course in following storm inundation after the 2013/14 storms, the water drained in a relatively short time.
- 8.4 **The 15th hole.** The managers of the golf club have raised a further specific concern regarding risk to the 15th hole. This is based on a perception that there is a real risk of erosion of the land to the south of the loophole tower. None of the studies' conclusions suggest that is at all likely. The worst case scenario (i.e. the greatest extent of erosion, which is the least likely outcome) stops several

metres to the north of the tower and touches the track that passes there. There is ongoing dialogue between the Committee and the golf club.

- 8.5 **Flood risk.** The flood risk to the land from the sea at L'Ancrese East is minimal. Royal Haskoning's report on Pembroke/L'Ancrese of 2012 concluded that . . .

"The land behind the bay is at such a level that it is only into the third epoch (50 to 100 years in the future) that there is likely to be any substantial risk affecting the land to the south of L'Ancrese Common. In addressing this in the future, it is seen as more sustainable to landscape the narrow valleys in such a manner as to achieve a retired level of protection that will not impact on and force the need for works at the sea front."

- 8.6 **The western end.** There is no risk of loss of the Beach House Café at the western end of the bay or of any of the car park areas in the vicinity.

9 **The Future of the Toilets and Kiosk at L'Ancrese East**

- 9.1 The Committee is aware that the kiosk at the eastern end of Pembroke Bay is at risk under Option 7b (Managed realignment including removal of defences). The toilets and kiosk fall outside of the Committee's mandate and as such, none of the options include costs for the protection, removal or relocation of the kiosk if needed.

- 9.2 As a result of the Committee's dialogue with the Vale Commons Council, Vale Douzaine and other interested parties, the Committee has given consideration as to what options are available for either securing the current facilities or replacing them.

- 9.3 As highlighted in the earlier independent studies, there is little economic value in protecting the assets immediately at risk. The simplest and cheapest option would be to remove the kiosk and the toilets as there are other facilities towards the western end of Pembroke Bay around 500 metres away.

- 9.4 However the Committee is aware of a desire by some to protect the toilets and kiosk which appears to demonstrate a willingness to pay, from at least part of the island community, to preserve or replace these assets.

- 9.5 The States have a number of options regarding the future of the current toilets and kiosk and these options are set out below.

- (a) **Remove and do not Replace.** This is the simplest and cheapest option. It would comprise the termination of the existing license agreement with the tenant and removal of the existing facilities during the managed

realignment. The estimated cost of the removal of the facilities is in the region of £30,000. There has been a campaign to keep these facilities and the local community may well wish to preserve them.

- (b) **Protect by Design – larger revetment structure and extension of the rock revetment to protect the toilets and kiosk.** This option involves amending the design for the managed realignment to protect the existing facilities. Royal Haskoning have modelled this option and have estimated it would cost an additional £236,000 to amend the proposals for the project. It would involve increasing the revetment structure height by 2m to a crest of +6m AOD in order to secure panels 4 and 5 and offer protection to the wall and kiosk from wave action. In addition, this involves extending the revetment structure behind the wall to offer protection to the exposed western extent of the kiosk. Further modelling work will be required to understand the potential impact of an additional structure on the outcome of the realignment.
- (c) **Protect by Design – extension of the rock revetment to protect the kiosk.** This option involves amending the design for the managed realignment to offer some protection the existing facilities. At the request of Property Services, Royal Haskoning have modelled this option and have estimated it would cost an additional £103,000 to amend the proposals for the project and offer protection to the kiosk, but with higher risk associated with the design. This involves increasing the length of the seaward extent of the revetment. In addition, this involves extending the revetment structure behind the wall to offer protection to the exposed western extent of the kiosk.. Further modelling work will be required to understand the potential impact of an additional structure on the outcome of the realignment.
- (d) **Remove and Replace by the States of Guernsey.** This option involves working with the States' Trading and Supervisory Board to replace the facilities with a new kiosk and toilets in a different location at the Eastern end of L'Ancrese. The Committee has been advised by Property Services that the removal and replacement with equivalent facilities would cost £617,000. This is based on design fees of c. £80,000 and building costs calculated at c. £525,000 (assuming granite construction with pitched roof and toilets integrated) and costs for the removal and disposal of existing structure of c. £12,000. Note that these costs are rates as applied for fire insurance purposes. A lower cost could be reached if a render built block construction were to be permitted (estimated lower range of £350,000).

The actual land ownership of the Vale Common is not clearly defined so legal arrangements would be complicated. There would also be a need

to obtain planning permission for the replacement development, if an alternative site could be agreed which complied with planning policies.

L'Ancrese Common is designated as a Site of Special Significance in the Island Development Plan. The Land Planning & Development (Guernsey) Law, 2005 extends the definition of development within a Site of Special Significance. Particular planning policy requirements also apply to ensure that, wherever possible, development will not damage the special interest of a Site of Special Significance.

- (e) **Remove and Replace by Public/Private Partnership.** This option involves working with local stakeholders to form a Public Private Partnership in order to provide new toilet and kiosk facilities. In this instance, in order to reduce the States' investment the replacement facilities could be jointly funded. The States' contribution to any funding would require a robust business case to be made for new facilities in this location, with alternatives already servicing this bay within 500m.

- 9.6 Property Services have advised that it is unlikely that a commercial business case could be made for facilities as currently exist at this location. The Committee has been advised that these facilities are considered a public service rather than a full commercial asset. Property Services consider that this is not a cost benefit question which can be evaluated in financial terms alone.

10 Resource and Implementation of the Proposal

- 10.1 If the States support the Proposition for the Managed Realignment of L'Ancrese East, the Committee will proceed with the completion of the Business Justification Case and commence a competitive tendering process in order to award a contract for the completion of the managed realignment of part of the coastline. It is important that the work is undertaken during favourable seasonal weather conditions and so the timing of the tender award is critically important.
- 10.2 If this Proposition is supported, the Committee anticipates a contract could be awarded with the work commencing in time for summer 2018. The contracted work on the managed realignment is anticipated to take 18 weeks.
- 10.3 Royal Haskoning have advised that it would take between 18 months and two years for the proposed realisation of the managed realignment to naturally form. During this initial period the sediments within the forming bay would be quite mobile and might not necessary reflect the longer term dune scape that will naturally occur.

10.4 During the work to deploy the groynes and remove the eastern section of the anti-tank wall there would be areas of the beach and behind the wall that would be inaccessible. However, once the work is completed it is not expected that there will be any areas that are to be “closed” or inaccessible, even following storms.

10.5 The work required to remove, relocate or protect the toilets and kiosk will be carried out appropriately as per the direction of the States.

11 Consultation and Engagement

11.1 In 1999 the “Coastal Defence and Beach Management Strategy Report” was produced, which assessed the entirety of Guernsey’s coastal region. This report was publically accessible.

11.2 in 2007 Royal Haskoning Dhv undertook a review and update of the 1999 work. Following this report there was a public consultation undertaken by the Environment Department, as summarised in the 2008 Policy Letter (Billet II 2008).

11.3 Further engagement and consultation, specific to the long-term management of Pembroke Bay, began in 2012 following the publication of “Coastal Flood Risk Studies” by Royal Haskoning. The Environment Board chose Option 7b (Managed Realignment) in 2015 and in 2017 that decision was reaffirmed by the Committee.

11.4 More recently there have been meetings with Vale Commons Council, Vale Douzaine, Deputies, and the L’Ancresse golf course managers to inform them about the proposals.

11.5 It is understood that the Committee *for* Education Sport, and Culture will form a view in relation to the golf course, under their mandate around sport, when they meet later this month. Given the deadline for the submission of this Policy Letter, the view of the Committee *for* Education, Sport & Culture is therefore unknown to the Committee and unavailable for inclusion at the time of writing.

11.6 The Committee held two open public meetings in June 2017 when the preferred option and the background studies that led to its development and selection were explained. Further open meetings and briefings will be held in the lead up to the States Debate of this Policy Letter along with ongoing engagement with stakeholders.

11.7 Full information has been made available to the public through a succession of media releases and comments and by the posting of information on the States website.

12 Conclusions

- 12.1 The Committee agrees that Option 7b offers a value for money, cost effective and adaptable long-term solution to coastal defence at L'Ancrese East. Additionally it gives the Island the opportunity to reclaim part of its coastal legacy at L'Ancrese East that was significantly affected by a man-made structure constructed during the Occupation.
- 12.2 Despite its physical size, the wall was built in such a way that its positioning, well in front of the natural high water line, has caused ongoing structural problems, with the power of the wave scouring the sand from this area beach and undermining the wall itself. Indeed, the absence of attention to suitable foundations is also suggestive that the anti-tank wall was seen as a temporary structure even at the time it was constructed.
- 12.3 The Committee considers that the best balance is struck between heritage considerations, recreational amenity and the future financial risk for the Island if weakest and most damaged parts of the wall are removed and the process of managed re-alignment is implemented. This will restore a small but significant part of this beach to an environment closer to its pre-war state, improving the beach area without increasing the risk of flooding to the land beyond.
- 12.4 Should the States decide that the Committee should not pursue Option 7b and instead implement a shorter-term maintenance-based approach, the States would be required to change the coastal management policy that the Committee currently works to, as approved by the States in 2013⁵. In the absence of this alteration of policy, it is unlikely there would be any significant change to the existing low ranking L'Ancrese East receives when funds for coastal infrastructure are prioritised.
- 12.5 The question of the future provision of the toilet and kiosk facilities at L'Ancrese East is clearly outside the Committee's mandate for coastal infrastructure. Recognising that a number of views exist on this subject, Members are unanimously of the view that it is for the Assembly to decide the preferred option. As such the Committee has included a list of options for consideration.

13 Propositions

The States are asked to decide whether, after consideration of the attached policy letter, dated 18th August 2017 they are of the opinion:

⁵ Billet XV Volume 2, 2013, pp 1187 - 1251

1. To endorse the proposal to implement the managed re-alignment (“Option 7b”) of the coastline at L’Ancresse East as set out in Section 7 of this Policy Letter and described in Section 6, Volume 1 of the report “Guernsey Coastal Defences” prepared by Royal Haskoning Dhv.
2. To note that the Committee *for the* Environment & Infrastructure does not have a mandate for the provision of facilities.
3. To agree that the preferred option for the provision of facilities at L’Ancresse East, including the approval of extra funds if necessary, is as detailed in Section 9 of this Policy Letter:
 - (i) Option (a) – Remove the toilets and kiosk and do not replace.

OR, only if Proposition 3(i) shall have been defeated,
 - (ii) Option (e) – Remove the toilets and kiosk and replace by a public/private partnership.

OR, only if Proposition 3(ii) shall have been defeated,
 - (iii) Option (d) – Remove the toilets and kiosk and replace by the States of Guernsey

OR, only if Proposition 3(iii) shall have been defeated,
 - (iv) Option (b) – Protect by design, using a larger revetment structure and extension of the rock revetment to protect the toilets and kiosk.

OR, only if Proposition 3(iv) shall have been defeated,
 - (v) Option (c) – Protect by design (extension of the rock revetment to protect the kiosk), using an extension of the rock revetment to protect the toilets and kiosk.

The above Propositions have been submitted to Her Majesty's Procureur for advice on any legal or constitutional implications in accordance with Rule 4(1) of the Rules of Procedure of the States of Deliberation and their Committees.

14 Committee Support for Propositions

- 14.1 In accordance with Rule 4(4) of the Rules of the Procedure of the States of Deliberation and their Committees, it is confirmed that the propositions above have the unanimous support of the Committee.

Yours faithfully,

B L Brehaut
President

M H Dorey
Vice President

S L Langlois
H L de Sausmarez
S T Hansmann Rouxel

The options for L'Ancrese have been subject to detailed independent investigation in a number of studies since 1999. This section provides a chronology of the independent advice provided to the Committee's predecessors.

Guernsey Coastal Defence Review 1999

The Guernsey Coastal Defence Review was undertaken by Posford Duvivier in 1999. During this review the condition of the L'Ancrese Anti-tank Wall was assessed and four engineering approaches were considered; these are described below.

Option 1 – Major Repairs and Rebuilding (To Improve)

This option comprised undertaking major repairs to and rebuilding of sections of the anti-tank wall and raising the seawall locally. There would have to be monitoring of toe protection of all defences after storm events and undertaking of repair works as necessary. There would also need to be summer and winter beach surveys and regular monitoring of the remaining lengths of the wall so that works could be planned before the condition of the wall became critical.

Option 2 – Beach Nourishment (To Improve)

The beach nourishment option consisted of minor repairs to the existing walls and beach nourishment with sand. This would then require regular surveys of the newly nourished beach and like the other options an annual inspection of the defences.

Option 3 – Beach Nourishment with Detached Breakwaters (To Improve)

Option 3 was based on the beach nourishment approach in the second option with the addition of detached breakwaters which would prevent the loss of the beach nourishment material offshore during storm events. It was recognised that the placement of detached breakwaters within the bay could have several significant environmental impacts including the visual intrusion into an important and aesthetic coastal landscape and direct loss of inter-tidal subtidal area of potential interest for its maritime flora and fauna.

Option 4 – Abandon Defences (To Retreat)

Option 4 comprised abandoning the defences and clearing the debris from the beach and allowing the natural alignment of the bay to develop. This approach would be complemented by beach nourishment through dune creation. It was recognised that the anti-tank wall follows the natural shape of the bay and it should be possible to abandon the existing defences without causing extensive flooding or erosion of the land. This engineering solution would involve removing the anti-tank wall in sections as they deteriorated.

Posford Duvivier noted that originally a semi-mobile dune ridge would have occurred around much of the back of the bay but this area of dunes was effectively lost through sand extraction during the Occupation in order to construct the anti-tank wall. Although allowing failure of the anti-tank wall and natural realignment to take place appeared to be the simplest retreat technique, it was recognised that this option could have some adverse environmental impacts. Without a healthy beach and dune ridge at the back of the bay, erosion of the low lying hinterland on L'Ancrese Common could occur.

The consultants recognised that these impacts could be significantly reduced by undertaking beach nourishment as part of the option and reinstating the dune ridge at the back of the bay. Sediment would need to be partially stabilised through planting with marram grass and other dune vegetation, possibly in addition to the emplacement of sand traps. Reinstating the dune ridge would reduce the potential rate of erosion of the seaward edge of L'Ancrese Common and, in addition, could reduce the overtopping that currently occurs. *While there would be some loss of land currently occupied by the golf course, the likely impact in comparison with allowing natural realignment would be lessened.*

Posford Duvivier concluded that maintaining the status quo for Pembroke Bay was not viable; and that there were insufficient assets at risk to warrant further investment. It recommended that consideration be given to the process of abandoning the defences to allow a more natural development of the coastline. The States of Guernsey undertook repairs of the damaged toe and wall at L'Ancrese to maintain the wall and the recommended approach was not progressed.

Guernsey Coastal Defence Strategy 2007

In 2007 Royal Haskoning was commissioned by the Environment Department to produce an independent report updating the 1999 Strategy. The purpose of the strategy was to establish a sustainable policy for the management of coastal defences for the island. The principal objectives of the strategy were:

- To provide appropriate coastal defences which were technically sound, economically justified and environmentally acceptable;
- To manage the frontage in sympathy with natural and coastal processes;
- To provide best value for money considering capital, maintenance and emergency expenditure in achieving a sustainable coastal defence and beach management;
- To provide a framework which can ensure consistency of approach to the management of defences within the study area; and
- To formulate a comprehensive management plan.

This Report noted that there had been significant investment in the defences at L'Ancrese East and that there had been further development in support of amenity and tourism since the 1999 strategy. Royal Haskoning maintained that it was still questionable whether major investment in defending the existing line of defences would be justified in terms of the hard assets defended.

Royal Haskoning revisited the original options and developed a revised approach. They concluded that without further major investment the central wall within Pembroke and L'Ancrese Bays is likely to fail in the near future. They further noted that if this failure occurs, then without some overall management plan there will be progressive failure of adjacent structures. Royal Haskoning was of the view that even with major works to support the failing wall it would result in increasing costs to maintain the line in the future. Purely from a coast protection perspective it would be considered that this central wall should be removed in a controlled manner over a length between the two Martello Towers. There would need to be some strengthening of the remaining sections of wall to either side.

Royal Haskoning believed that further detailed examination would be required to assess the impact of this on the golf course, but it was anticipated that the developed area of the course would not be affected. Importantly whilst it was acknowledged that the cost of the proposed realignment would be greater than the immediate cost associated with maintaining the existing structures it would result in far less cost in the future and would create a more sustainable defence to the frontage.

Royal Haskoning's review of the 1999 recommendations are shown in the table below

2007 Royal Haskoning Review of Options from 1999

Option	Technical Appraisal	Environmental Appraisal	Economic Appraisal ⁶
Major Repairs & Rebuilding	Ensures integrity of defences; Long term commitment to toe strengthening.	Historic significance of defences;	Not viable £100,000 initial capital cost with £300,000 every 20 years and annual maintenance of £5,500.
Beach nourishment	Ensures integrity of defences Protects toe of wall	Detrimental impacts on environmental interests Enhances beaches	Not viable £6.86m initial capital cost with £1.383m every 10 years and annual maintenance of

⁶ Costs expressed in 2007 prices.

			£5,500.
Beach nourishment & detached breakwaters	Ensures integrity of defences Protects toe of wall	Detrimental impacts on environmental interests Enhances beaches Visual intrusion	Not viable £9.91m initial capital cost with £0.691m every 10 years and annual maintenance of £18,000.
Managed realignment & dune creation	Unlikely to significantly increase erosion	Loss of historic defences Opportunity for habitat creation	Not viable in the absence of a broader management plan. £200,000 initial capital cost with demolition costs and £800 annual maintenance.
Do nothing	Loss of assets	Loss of historic defences Opportunity for habitat creation	Viable, but significant H&S issues to consider.

In the absence of a broader scale plan for the area, Royal Haskoning's advice was to revise the policy for the frontage to one of no further active intervention in coastal protection. The Do Nothing Option however had significant Health and Safety issues associated with it. However it was recognised that if the abandonment and removal of the current defences was adopted it would provide an opportunity to recreate a bay-fringing dune system and enhance the overall level of the habitat. In addition it was recognised that this option could also provide enhancements with regard to the recreational value of the bay.

These options were then re-assessed and expanded upon in the 2012 Flood Risk Assessment study. The States of Guernsey has continued to make repairs to the anti-tank wall since 2007 as funds have allowed and neither the preferred approach or the managed realignment in the Coastal Defence Strategy Report were progressed.

Guernsey Coastal Defences – Flood Risk Assessment Studies 2012

In 2012 Royal Haskoning was commissioned to complete a study entitled "Coastal Defence – Flood Risk Assessment Studies". The independent consultants reviewed the defences at Baie de Port Grat, Belle Greve Bay, Bordeaux, Cobo, Grande Havre, L'Eree, Pequeries, Rocquaine Bay, Saline Bay and St Sampson Harbour as these areas had been highlighted in the 2007 Strategy Report as most vulnerable to sea level rise associated with predicted climate change.

Pembroke Bay / L'Ancrese was not considered vulnerable to flooding in the 2007 report but the then Environment Department requested that it be included in the Flood Risk Assessment Studies. This was with the intention that there should be improved information on whether the Vale Common would be susceptible to flooding from the sea in the event that managed realignment and dune creation, as recommended in 2007, should be taken forward in the future. The Royal Haskoning review involved a more detailed examination of what consequences would arise from abandoning the existing defence line at L'Ancrese and considering further alternatives.

The objectives of the 2012 Review were to:

- Establish a more robust wave and water level climate, allowing a more detailed analysis of coastal processes and understanding of the critical influences of the Bay's behaviour.
- provide an improved assessment of the coastal processes for the frontage, defining the natural alignment of the bay and considering the potential erosion extent should defences or sections of defences be abandoned.
- Examine how the Bay may be managed in different ways, considering approaches such as groynes, offshore structures, local control structures or partial abandonment of existing defences; in addition to re-examining potential future requirements should the existing defence be maintained.
- examine potential flood risk which might arise from loss of defences or the subsequent roll back of the shoreline.
- provide specific costed outline options, highlighting potential benefits and disadvantages of different approaches for consideration by consultees.

Royal Haskoning identified a range of potential approaches that could be adopted for management of the frontage and in developing these, chose to bracket the options in looking in outline at two baseline approaches that could be developed; namely the total removal of defences and that of continuing to maintain and improve defences as at present.

- Baseline – Option 1 Removal of defences; and
- Baseline – Option 2 Maintain and Improve Existing Defences.

The consultants noted that both the two base line options incurred significant cost. Specifically for Option 1, dependent on any phased approach to removal of defences, this cost would occur early on but notionally reduce to zero in the future. Option 2 would incur substantial costs over the initial 20 years with a commitment to increasing cost placed on future generations.

To reduce costs there is a further option of walking away from further investment. This Do Nothing approach was considered as Option 3.

Other broad scale approaches were considered within the strategy appraisal; these included major beach recharge and recharge controlled by shore detached breakwaters. However these were costed as £8m and £10m respectively and consequently these options were not considered further.

In considering the two baseline options, there is a clear distinction highlighted between management of the eastern section of defence and that to the west. With respect to the former, there is an urgent need to address the failing walls or to address their failure. In the case of the latter, while there is a continuing problem, this has not reached the same critical condition. There is also seen to be a distinction in use of the two areas, with the western frontage providing protection to the western valley and greater amenity value associated with the car parks, the slightly higher beaches and the road. The natural rock outcrops do also provide a degree of separation in terms of coastal processes. This difference and natural separation may be developed in assessing alternative approaches to management. Based on this, the consultants developed a number of further options considered including:

Option 4 - enhanced protection to the western wall and holding the line over the western section of the anti-tank wall.

Option 5 - enhanced protection to the western wall and rock groynes along the western section of the anti-tank wall.

Option 6 - enhanced protection to the western wall and developing shore connected structures to the western section of the anti-tank wall.

Option 7 - managed realignment along the eastern section of the anti-tank wall.

A summary of Royal Haskoning's assessment of these options is provided in Appendix 2

The objective of Royal Haskoning's work was to examine and set out potential options for the future management of L'Ancrese Bay in such a manner as to allow and inform further discussion with interested groups and users of the area. As such they made no recommendations, but instead presented a number of conclusions.

Of particular relevance was the fact that at the eastern end of the frontage the main problem is the much higher wave exposure from all offshore directions and coupled to this the scouring effect of waves approaching the wall at an angle. In terms of management, these wave conditions have resulted in on-going damage particularly at the eastern end of the Bay.

6.5 Discussion of Coastal Behaviour

A beach monitoring programme, focused on spring and autumn surveys, has been undertaken by the States of Guernsey over the last decade. This current study has updated the analysis of this information from 2007 through to 2010. A summary of the results of this monitoring is shown in Figure 6.7.

The data collected demonstrates relative change in beach levels between consecutive surveys. The initial plot (upper right hand side of the figure) shows the comparison between autumn 2000 and spring 2001 (winter 2001). The plot immediately below gives the change that occurred over the summer of 2001 and this pattern is continued through the sequence of plots.

The broad pattern of change is for erosion to the back of the beach (shown in red) and deposition lower down the beach (shown in blue). During the summer periods the typical behaviour is for sediment deposition against the back of the beach and lowering of the foreshore lower down the beach. In effect, sediment is being driven up the beach during the summer, during periods when wave conditions tend to be lower and when the process is likely to be driven by the regular longer period swell waves driving across the beach. During the winter, when there is a greater frequency of shorter period, higher waves; the waves impact on the back defence, drawing sediment down the beach.

Beach levels in front of the wall at the eastern end of the frontage are recorded to have varied by as much as 2m over the monitoring period.

This general process provides good evidence that there is no significant overall loss of sediment and that the system, in general, can respond to natural change. The main supply of coarse sediment (shingle and rock) is likely to come from the headlands. This will be relatively low. It is uncertain to what degree sand may be able to be imported from the offshore area.

Quite obviously from the various plots, while there is this large scale long term seasonal behaviour, there is also significant variation at a more local scale. It may be seen that during the winter of 2002, there was quite severe erosion in the area of the upper beach at the western end. This area of erosion tended to fill during the following summer but with some accretion along the lower beach to the east. During the subsequent winter (2003) there was erosion to the eastern section of the bay and some accretion within the western area.

During the winter of 2010, there was severe erosion of the lower beach, particularly to the eastern end, with little benefit gained at the back shore.

These variations can be seen to reflect the differences observed in relation to the wave climate. The process of beach building is well explained by the typical net direction of swell waves entering the bay and working up the normal beach contours. The general sensitivity of wave direction within the bay helps understand the changes in different areas of the beach. This understanding is used in examining in a more detailed manner the different sections of the Bay described below.

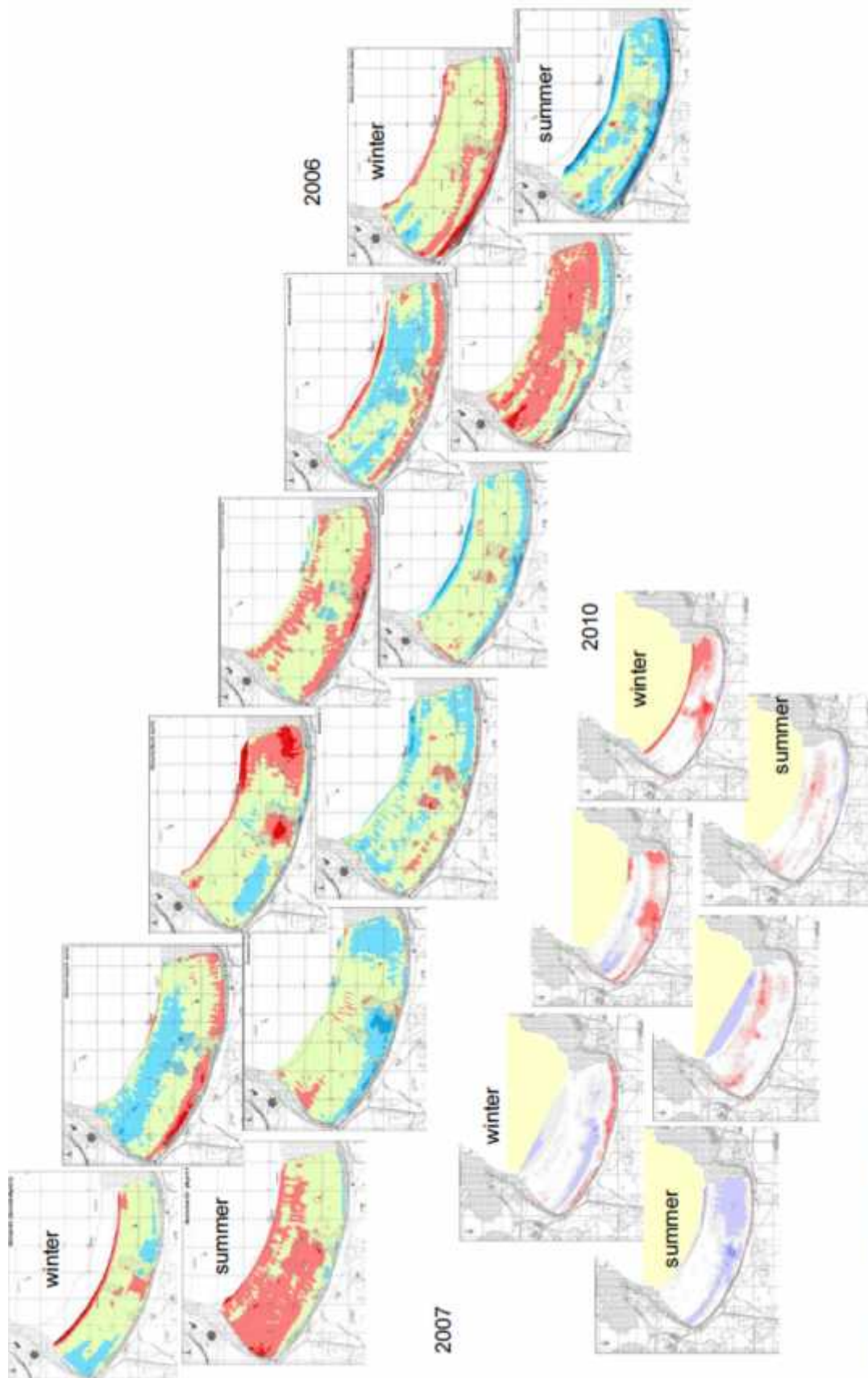


Figure 6.7. Change in beach levels

Western section (DU2) Generally, beach levels in this area are low, with little sand. Under normal conditions this is a low energy area, wave heights are small in the shelter of the headland and there is limited energy transporting sediment into the area; swell waves tend to move sediment further up the beach. During storms from a north north-east direction, the energy increases significantly, with high waves running along the face of the wall, scouring any sediment and gradually removing the coarser stones littering the area in front of the wall. The modelling suggests that waves will be approaching the wall at a critical angle somewhere between 20 degrees and 40 degrees. The interaction between the incoming wave and the wave being reflected off the wall would generate an edge wave which could be twice the height of the incoming wave. This would be mitigated to some degree where the wave spills onto the lower concrete berm. Even so this action would increase the risk of overtopping and would also pile water up into the corner by the western slipway. The old photograph covering this area (Plate 6.4b) in this area strongly indicates that before the wall was constructed, there was sufficient width to allow waves to spill more gradually along the frontage. However, there is still no evidence of any significant back shore dune and this would be explained by the oblique wave action tending to result in significant long shore drift.

Western Slipway (DU2/DU3) The increased wave energy in this corner generated along the western wall tends to deposit stone into the corner and this is seen in the relatively high, very coarse, shingle slope. While there is movement of sand into the area, the generally higher energy wave action tends not to allow this sediment to be retained. The area is, under the more westerly wave conditions, still relatively low energy, but wave heights increase as one progresses to the east.

Plate 6.11. Build up of shingle at the southern end of DU2



Considering the angle of wave approach in this corner, it may be appreciated that waves locally at the slipway are significantly out of line with the curve of the wall. Even further east, towards the western kiosk, waves are shown to be approach the wall slightly from the west of north. This contributes to the trend of erosion causing a slow drift to the east.

Records show that the toe to this section of defence is regularly undermined and requires regular repair. This is consistent with the interaction with waves in the area. It may be concluded that the general alignment of the defence is too far forward and would be subjected to regular periods of erosion and a continuing need for management. With sea level rise this problem will become worse. The area is one of the most vulnerable sections of the frontage and is critical to the longer term flood risk management to the local area behind.

Western Kiosk through to the central rock outcrop The rock to the eastern end of this frontage acts as a groyne. The wave analysis shows how sediment, under all typical westerly storm conditions tend to approach just slightly out of line with the wall and tends, therefore to realign the shingle back beach, exposing the western end of the wall. It would be expected that during storms from the north northeast, waves would be more normal to the wall alignment and would redistribute shingle along the longer length of the wall.

While the rock outcrop maintains control of the drift, the misalignment between the wall and waves is not seen as being too critical. However, there is likely to be a continuing need for repairs as the wall is intermittently exposed. With sea level rise, the pressure on the wall will increase. There would tend to be increased drift to the east and the level of the rock outcrop will be less effective in retaining adequate shingle level in front of the wall.

Central section between the rock outcrops. The rock outcrop to the western end of this frontage is quite narrow and acts as a cross shore barrier, with little ability to act as a breakwater, modifying the way in which the waves approach the frontage. The larger expanse of rock, further to the east, tends to have a more significant influence on the waves approaching the backshore.

The narrow rock outcrop, therefore, tends to stop shingle moving into this central section, but the rock further down the beach does break wave energy such that finer sand can generally be held over the frontage. This breakwater effect is, however, very sensitive to water level. On lower water levels the rock has a more significant impact on waves, tending to encourage sediment deposition. Under higher water levels, waves can pass over the rock outcrop and can tend to erode sediment against the wall. The monitoring plots for summer 2002 and winter 2003 and winters 2009 and 2010 show this variation quite clearly. Sediment movement against the wall can vary with wave direction and the wall remains too far forward to allow the benefit of the rock outcrops to develop a more stable beach behind.

Eastern section of DU3 This section is under the greatest pressure, with the largest fluctuation of beach levels. There is limited long shore sediment supply to the area, and a strong scouring action due to the oblique wave action in relation to the wall. Sediment supply tends to be from lower down the beach, but the forward position of the wall and the angle of waves along the wall prevents the retention of that sediment. The area is clearly seen from the wave analysis to be the most exposed frontage of the Bay. As a result, the low beach levels, coupled with the higher waves, results in significant over topping. This further acts to destabilise the defences.

Western Slipway. The slipway acts principally as a groyne. This acts to retain a good shingle upper beach against the higher ground behind. The short section of rock revetment extends slightly forward of where the natural shingle beach would develop.

Overall it may be concluded that over virtually all sections of the Bay, defences are just slightly forward on the natural beach alignment. This is most obvious in the case of DU2 at the western end, where the main issues arise during waves from a north northeast direction and at the eastern end of DU3, where the alignment and forward position of the defence provides no width for development of a natural form of defence. In other areas the defences are generally just slightly out of kilter with wave action, resulting in long term pressure and intermittent vulnerability.

6.5.1 Analysis of the natural form of Pembroke Bay

As a starting point for looking at future management, it is important to consider how the Bay would develop in the absence of defences.

Pembroke Bay is formed as a relative square shape. Although, as discussed above, there are areas where locally long shore sediment drift is an important feature of the backshore, locally, these effects are as a result of the interaction between the dominant wave energy and the defence line. The more natural shape of the Bay would be a shallow sweep in behind the two headlands straightening out over the central section of the bay. This curve would be modified slightly by the natural rock features, and by the relative levels and strength of material backing the bay. The natural bay shape is, therefore going to be very much dictated by the ability of the upper beach to dissipate wave energy approaching quite normal to the general contours of the bay. This can be seen quite graphically in the air photograph from the 1930s, prior to construction of the military defences (Figure 6.8).



Figure 6.8. Pembroke Bay 1930s.

Figure 6.8. Pembroke Bay 1930s. This figure shows a deeper indent to the bay at the eastern end, backed by a solid shingle beach and ridge behind. In the centre of the bay, the influence of the rock outcrop is clearly seen holding the bay slightly forward but with a steeper back cliff behind and by the way in which the rock in the centre of the bay allows the development of a beach and dune ridge over the western side of the bay. Some of the features local to the shore have clearly changed. However based on this photograph together with a historic map from 1938 an approximation can be made of the alignment of the backshore prior to the construction of defences. This is shown in Figure 6.9. The historic map is shown as an insert in the Figure. There appears to have been some form of defence even at this time to the east of the bay in front of a building in this area. This provides a typical baseline for additional analysis of potential erosion that might occur now in the absence of defences in the area.

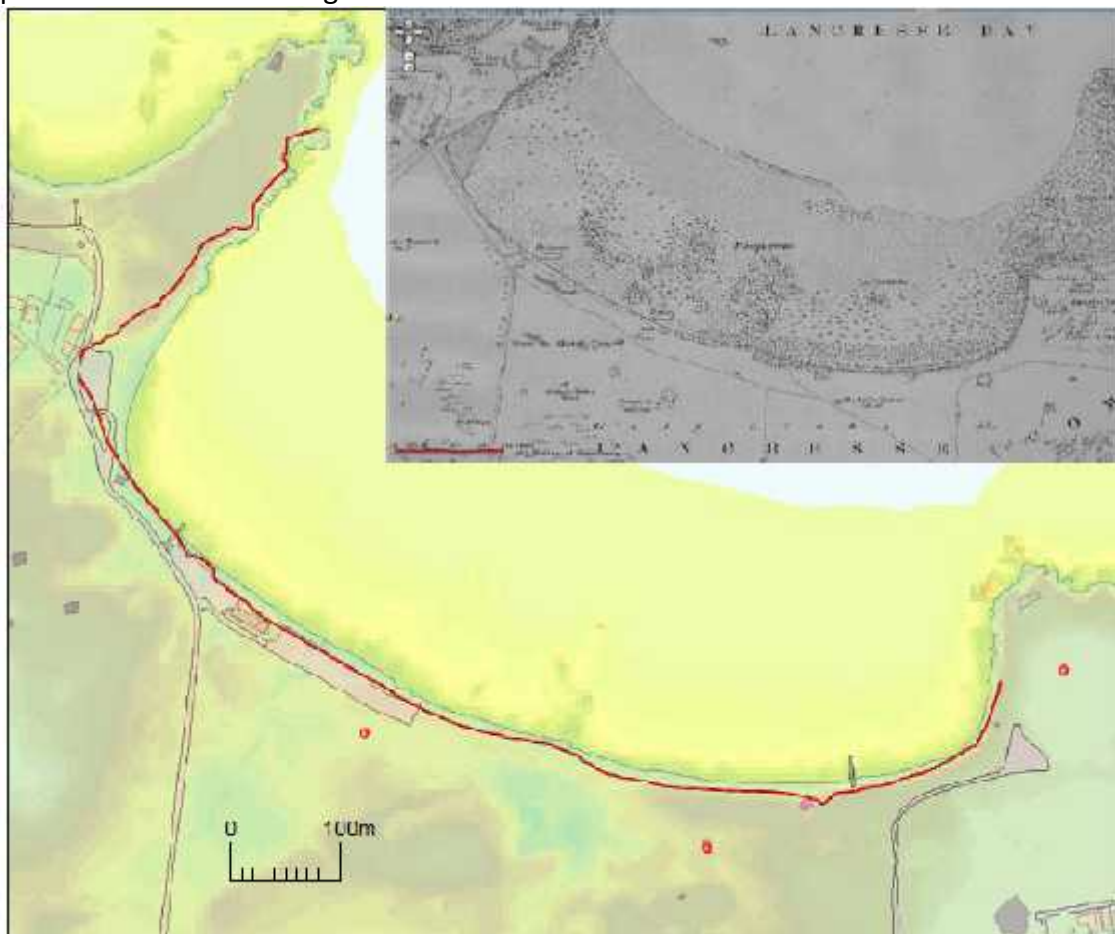


Figure 6.9. Initial Estimate of Erosion based on historic photograph.

Figure 6.9. Initial Estimate of Erosion based on historic photograph. The approach taken is based on the beach profile information. Profiles have been taken at various locations around the coastline. This analysis and positions of the profiles are shown in Figure 6.10 (a-i). Profiles a, b and c cover the western half of the Bay, profiles d and e cover the area of the rock outcrop and profiles f, g, h and i cover the east area. It is immediately apparent that beach levels close to the wall over the western section are generally higher than those to the east. The form of the beach to the western end

adopts a more convex shape, consistent with a more nature profile. Further offshore the profiles adopt a more uniform slope.

Figure 6.10 a) profile positions



Figure 6.10 b) profiles relative to defence line

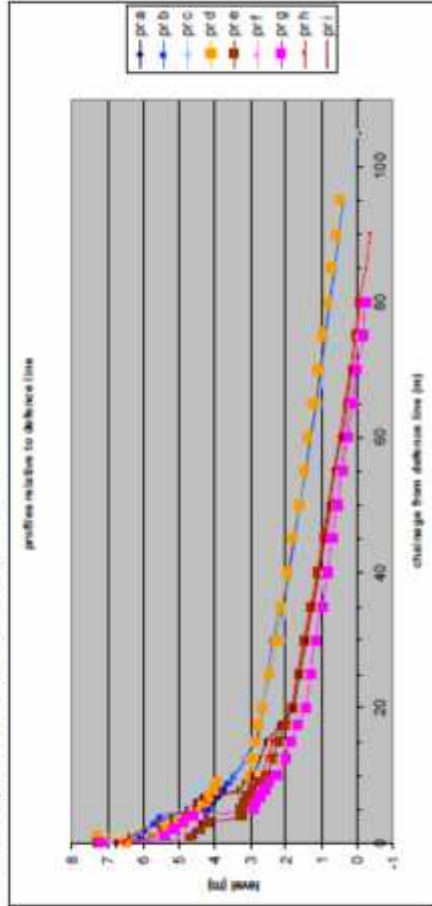


Figure 6.10 c) normalised profiles

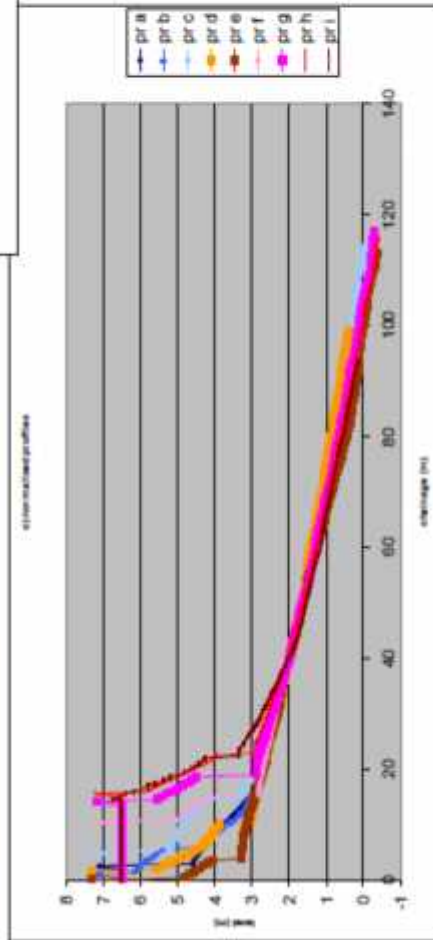
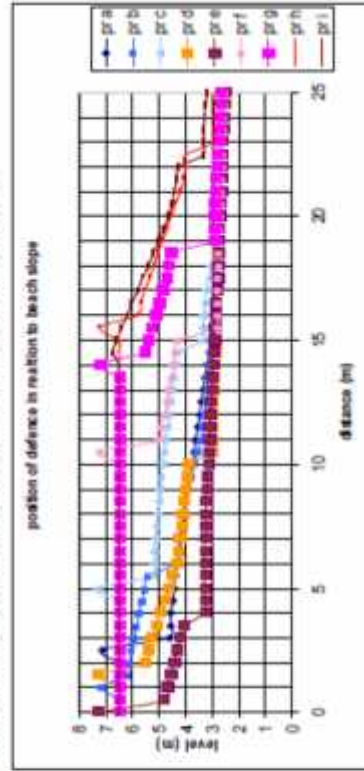


Figure 6.10 Beach profile analysis.

Figure 6.10 d) position of defence in relation to beach slope.



In attempting to assess the degree to which defence may be in advance of the natural line of the beach, it is recognised that the walls themselves would be keeping beach levels artificially low. To correct for this, the profiles have been normalised along their respective chainage at 2mLOD.

This is shown in figure 6.10 c). Profile (e) behind the rock outcrop is taken as the baseline, taking this as a semi natural development of the beach. It can be seen that profiles (d) and (b) are quite closely aligned to this semi-natural position. Profile (c) is held forward, in effect, by the accumulation of sediment at the crest of the beach, held forward by the groyne effect of the rock.

The profiles most clearly forward are along the eastern end as would be expected. This is shown in more detail in Figure 6.10 d). It is noted that profile (i), at the far eastern end of the frontage is also well forward but this may be explained by the steeper beach as the backshore curves around to the beginning of the rock headland. The beach levels at this location are higher over the upper beach reflecting the stability of the shingle bank created by the shelter of the headland.

Typically from this analysis, it may be seen that in relation to the natural beach form based on profile (e), the western defences are some 5m forward and those to the east some 15m forward.

The profiles give a typical foreshore slope of 1:30 and an upper beach slope of around 1:7.

Given that the level of the wall at profile (e) is still held at the sea wall, it might be anticipated that to complete the profile there would need to be a further set back of some 20m to allow natural development of an upper beach.

Based on this approach the anticipated set back of the shoreline over the frontage may be determined. This is set out in Table 6.3.

Table 6.3. Predicted erosion distances.

Location	Adjustment to alignment (m)	Retreat to a stable crest position (m).
Between western kiosk and slipway	5 -10m	15m – 20m
Western kiosk to rock outcrop.	2m	12m
Central rock section	0	20m
Central rock section to eastern kiosk	15m	35m
East of eastern slipway	5m	5m

As sea level rises, the overall profile of the beach will attempt to adapt. If this change is taken as occurring at MHWS, the probable impact would be for the beach profile to adjust inline with the shallower slope of the foreshore area. Based on this approximation, the horizontal movement of the backshore would be the slope x the rise in sea level. The additional erosion distance is shown in Table 6.4.

Table 6.4. Additional erosion with sea level rise.

Epoch	2011 to 2021	2021 to 2051	2051 to 2101
Additional erosion	4m	9m	15m

The results of this analysis are presented in Figure 6.11 in comparison with the baseline estimate from Figure 6.9.

Figure 6.11. Unconstrained erosion lines.

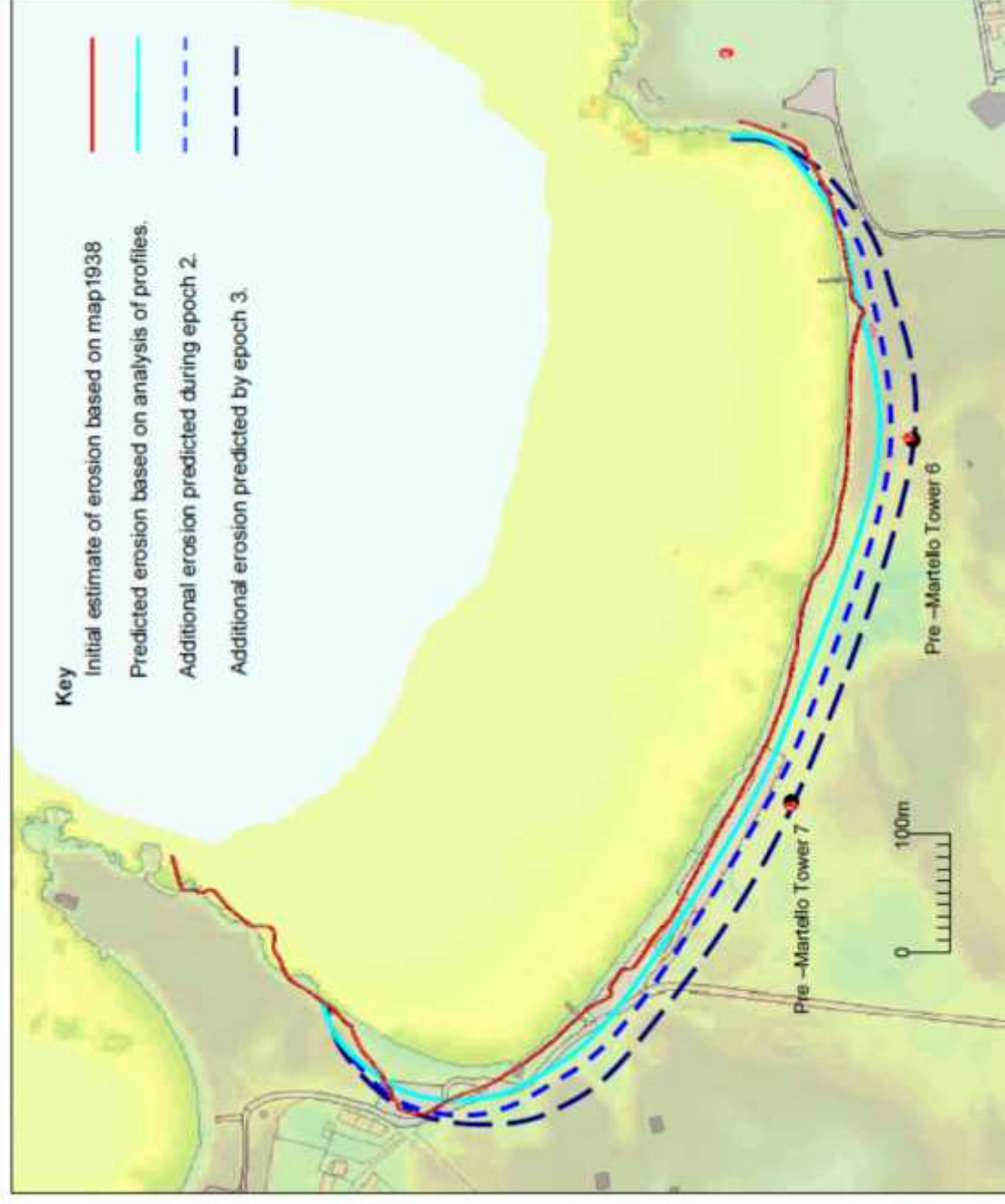
Notes:

Although the erosion lines are based on the beach profiles, it may be seen that the adjustment in alignment brings the shoreline in better alignment with net wave directions.

The erosion lines cut back into higher ground behind the western slipway, in the centre of the bay and at the eastern end. The rate of erosion in these areas may be reduced but would then tend to form a slightly cliffed backshore.

Between these areas of high ground, shingle ridges would tend to form. These ridges would adjust to storm conditions providing a degree of natural flood defence. However, from examination of the old air photograph, there is some indication that shingle has been swept over the ridge at the western end. This would be consistent with the potential sudden change in wave exposure under north northeast storms at this end of the bay.

The road at the western end of the bay could be lost quite rapidly. The two pre-Martello towers could be at risk in the long term depending on the rate of sea level rise.



Baseline Option 1 - Removal of defences.

The first option provided an extreme baseline from which to baseline the other approaches and involved the complete removal of the defences in their entirety. Attempting to cost this option was problematic but based on broad assumptions the total cost for the removal of the entire anti-tank wall defences was estimated to be in the order of £2.75m.

The primary aim of this approach is to restore the bay to a natural condition allowing the bay to function naturally in the future. The main benefits in such an approach would be in restoring access to the shoreline and to improve that natural amenity of the bay. In setting back the line, the natural response at the back shore would be to develop a shingle ridge. This would provide a good level of flood defence across the two main valleys back on to the golf course. This would not provide full protection against extreme water level flooding and further raising of the land may be required to the back of the beach. This could, however, be undertaken through re-landscaping along a line across the common, set well back from the coastal edge. Such works might only be required as sea level rises and as the risk increases in the future.

The obvious and immediate disbenefit would be in the loss of both kiosks and the loss of the main car park areas. There would also be the loss of the amenity area to the western side of the bay and loss of the two slipways. There would also be loss of the heritage value of the military defence.

Associated with the loss of the western sea wall would be the increased risk of flooding to the low lying area to the west. Royal Haskoning did not believe that flooding would impact on the main area of the golf course but in the longer term could affect the Club House. There would be the loss of the main road behind the beach at the western end of the bay. There is, however, alternative access around the main headland for both properties and to Pembroke Fort.

The two pre-Martello Towers set back behind the bay would not be a risk in the short to medium term. Potentially over the next 100 years, erosion may reach these important historic structures. They would, however, be at the back of a far more stable beach line and local management could sustain these structures without significant interruption to the natural processes.

Baseline Option 2 - Maintain and Improve Existing Defences.

Royal Haskoning noted that current practice has been to carry out critical (but reactive) maintenance to sea walls as specific problems have developed. The works undertaken to the sea wall indicate that erosion and undermining around the western slipway and along the eastern section of anti-tank wall has been a long term problem.

This has resulted in various works to strengthen the toe of these sections of wall. These toe buttresses have themselves required continuing maintenance to ensure their survival. The most critical area has been at the east end. At the step in the alignment of the wall, just to the east of the area of rock outcrop, there had been settlement and rotation of the entire wall. This movement was noted as continuing, in their opinion as a result of undermining, most probably exacerbated by the severe overtopping.

At the eastern end of the anti-tank wall, in front of the Kiosk, the concrete toe had rotated forward, exposing the toe of the actual wall to undermining with the scouring nature of the waves running along the frontage. The most recent repairs undertaken along this section of the defence were carried out in 2007, infilling the voids and gap between the wall and the concrete toe. In the 2011 inspection it was noted that the toe apron has again moved forward, leaving a weakness to be exploited by the wave action. Royal Haskoning commented that "The present approach to management can only be considered a stop gap before more major works would be required under this baseline option, to address the underlying problems." The consultants believed that in the short to medium term major works would be required to address emerging problems and to safeguard other structures around the frontage. The anticipated works would include:

- On the western wall a need to reduce scouring and to address the deterioration of the toe piles which would require a rock toe extending up to the concrete apron. This would need to be improved and reinforced with sea level rise, such that the wall would be faced eventually with a larger rock revetment over its full length.
- on-going maintenance at the western slipway but with the toe being replaced eventually over some 150m of the 310m length by a rock toe. In the future with sea level rise it has been taken that a more substantial rock revetment would be required to safeguard the toe and provide protection against over topping.
- Resolving the issues at the eastern section of wall through to the eastern slipway which was considered to be in the process of failing. Minor works merely patch the problem. The wall continues to be undermined and each time this occurs, it is likely to increase the overall instability of the wall. In assessing options prior to the repairs undertaken in 2007, the longer term solution of a substantial rock revetment was proposed. This would need to be reinforced over time with sea level rise.

The primary purpose of this approach is to maintain the existing erosion and flood risk protection provided by the existing defences. This protects the two kiosks and car parks and reduces the flood risk to the local western valley. Over the first epoch (0-25 years) use of the coast would continue much as at present, continuing to provide the current amenity value of the area. The consultants concluded that there was limited

economic benefit derived from this continued defence, as identified by the strategy. The examination of flood risk shows that there is no larger benefit area.

Over time, however, there would be a need for greater investment even along these lengths of defence and the overall trend for management would be to encase the whole frontage with rock revetment. This, together with gradually falling beach levels and with sea level rise, less drying upper beach area, would reduce access to and use of the beaches. This would have a significant impact on the amenity value of the area. In addition there would be greater reliance on the defence line with greater risk of defences being overtopped and potentially failing.

Option 3 – Do Nothing.

Under this approach, rather than positively removing defences, defences would be allowed to fail and the only works undertaken would be to address safety issues. There would be some cost associated with this option but no significant works would be undertaken. With this option the consultants advised that major sections of the eastern wall might be expected to fail over the next five to 10 years. These defences are large mass concrete structures and would typically fail due to undermining and toppling on to the beach. The structures would be monitored and access behind the structures would be fenced off as damage was identified. There would be a need to close the Kiosk and the small car park.

Once they had failed, wave action would tend to get behind the walls, undercutting and outflanking adjacent sections of wall. Failed sections of wall would act as low breakwaters, modifying the pattern of erosion behind, tending to form quite steep areas of erosion in the fill material behind. The whole section of wall might be expected to have failed within the next 15 years. Royal Haskoning suggest that outflanking would tend to be limited to the west due to the rock outcrop. However, as the general shoreline sets back to the east there may be an increased loss from behind the area of rock, slowly reducing the sand levels at the toe to the wall behind.

Potentially the next most vulnerable section of defence would be in the area of the western slipway. In this area failure is more likely to occur quite rapidly during a storm event. Typically this might occur in 10 to 20 years time, with the section of wall becoming increasingly vulnerable to damage as the toe to the wall is lost. There would be continued undermining of the toe and eventual failure of the wall.

Loss of defence in this area could increase the risk of overtopping with wash out and wash over of sediment. As with the eastern section, failure of one section would encourage failure of adjacent sections of wall.

Over the same period of time, there would be continued down cutting of the beach platform in front of the western wall and, as significantly, holes would start to appear in the exposed sheet piling. This would result in voids developing under the concrete

berm and this berm may then start to fail. It is uncertain to what degree the concrete berm acts as a support to the main wall behind but it would be expected that there would be undermining and movement of this high retaining structure.

Over the next 20 to 30 years, failure would have occurred along most of the western frontage, with short sections of wall remaining but only acting locally in terms of defence.

Over much of the frontage, large sections of wall would litter the beach area as the shoreline retreated back. In the longer term this would not necessarily result in a safety risk, although individual sections of failure would need to be assessed with the possible need to remove some sections of failed defence. In particular the western wall is likely to present a problem due to failed and undermined decking and the exposure of the sheet piling.

The cost of managing this is highly uncertain but would give rise to on-going costs in the addressing of specific areas. Typically, one might envisage the need to remove the western wall completely, at a cost of some £700,000 at around years 20 to 30. In other areas, the intent would be only to remove critical sections of failed defence as and when they posed a risk to safety.

Clearly decisions could be made combining this approach to management with that of actively removing sections of defence as in Option 1. This sub-option may then act to spread cost more effectively and may still allow some planned approach into the future.

For example, taking forward this in relation to the eastern frontage, the area where movement of the wall is already happening could, as at present be fenced off, the wall allowed to fail and action then taken merely to tidy up specific areas posing a risk to safety. In other areas a more structured approach may be required that actually removes the defence.

The main benefit of this approach would be in reducing costs and spreading the cost of demolition over a longer period of time. Over the longer term there would typically be the same general benefits identified in Option 1. A major disadvantage is there would be no planned programme of change. As such, as defences became more vulnerable there would be the need to evacuate the kiosks in advance of failure and removal of the buildings in a manner determined by the deterioration of the defences.

Over the early years, there would be increased deterioration of the amenity value of the area and areas where visitors to the frontage were excluded from using sections of the sea front and beach. Over the longer term other damages would occur as identified in Option 1.

Option 4 - Enhanced protection to the western wall and holding the line over the western section of Anti-tank wall.

The main immediate issue along the western frontage results largely from the way in which waves, particularly during significant storms from a north northeast direction, interact with the western wall. This gives rise not only to continued deterioration along the wall itself but also causes erosion at the western slipway and the adjacent wall in this area. Placing a rock toe along the base of the western wall would to some degree reduce these problems by reducing the level of reflection and reducing the development of the edge wave effect. The cost associated with this is identified as being of the order of £200,000 initially (Option 2). More effectively, some form of breakwater or groynes could be constructed along the frontage and at the southern end of the western wall. These works would not exclude the need for protection along the face of the sheet piles but would significantly improve the effectiveness of this toe while also reducing reflected waves that run along the face of the wall by the western slipway.

The outline estimated cost of the work would be of the order of £600,000 (this includes the cost of the rock toe allowed for in Option 2).

The approach outlined above aims to address the exposure create by waves, principally from the north northeast, running along the western wall. This reduces pressure on this wall but would also address some of the scour problems along the western section of the anti-tank wall. This would reduce maintenance costs and provide the opportunity for a more stable and higher level of beach in this important amenity area.

If the defences were to be sustained over the full 100 year period, there would still be a need for further work to address the issues of sea level rise. However, the key aspect of moving towards an approach that is addressing the main cause of the problems would be in maintaining the opportunity for adaption in the future.

The approach outlined could be developed further if future defence was deemed sensible. Alternatively, if the initial period of maintaining defences was used to plan an adaptation of use in the area, this approach would still be compatible with any potential future realignment. Future management would be far less driven by the deterioration of existing defences. The main issue would be in addressing the reducing standard of flood defence as sea level rises.

The main disbenefit is in terms of the additional cost. There would be a cost of the order of £400,000 over and above that estimated in Option 2 during the first 20 years.

Option 5 - Enhanced protection to the western wall and rock groynes along the western section of Anti-tank wall.

Option 4 could be developed further in addressing the vulnerability to the western section of the anti-tank wall. There would not be the same quite the same benefit in that waves approach this section of defence more normal to the beach crest. However, by placing short rock groynes they would act to improve the stability of the upper beach retaining sediment against the toe of the wall. There would still be the tendency during more severe storms for sediment to be drawn down the beach but not to the same extent as at present.

In outline, groynes would be constructed typically every 50m along the length and would extend possibly some 30m from the face of the wall. Typical costs would be of the order of £60,000 per structure. With seven potential, structures covering the frontage, this would amount to an overall cost of the order of £420,000.

As with Option 4, the benefit accrues from the additional amenity value provided by a more stable upper beach area and in the longer term from taking a more adaptive approach to management. This option would still require further work over the longer term to address the issues of sea level rise.

There would be a significant cost involved in the work and while there would be a reduction in on-going maintenance to the existing defences, there actual benefit terms of reduced damages to assets would be minimal.

A further risk associated with this approach would be the possible reduction of sediment movement through to the east. This risk appears small given that the rock outcrop in the centre of the Bay already tends to reduce such drift at present.

Option 6 - Enhanced protection to the western wall and developing shore connected structures to the western section of anti-tank wall.

This option further develops on the above options providing significantly greater control of the upper beach. In association with works to the western wall, the intent would be to construct a larger structure in the area of the rock outcrop.

The intent of this approach is, in effect to draw forward the whole shape of the western section of the bay, to create wider beaches and to provide more complete protection to the existing defence line. In doing this there may be the further need to actively recharge the areas between structures so as to avoid material being redistributed as the structures influence the coastal processes. This would need further detailed study and the possible need for physical modelling. With sea level rise there would be the need for further works but as with other options considered for this area, the approach provides a longer term management that could be adapted to either holding the line or to manage realignment in the future.

Without additional detailed design, there is increased uncertainty within the costs. This uncertainty has however been allowed for. The overall costs, over and above the costs estimated for Option 4, which would form part of the scheme, are in the order of £3M.

The option provides a more secure approach to defence over the next 50 years, with the benefit that this approach could be taken forward in a sustainable manner in the future. There would be improved amenity value in terms of wider beaches and areas of beach that would remain dry over normal tides. The approach builds on the natural rock base in the centre of the bay reinforcing natural processes.

There is a significant cost associated with the approach that goes well beyond flood and erosion risk benefits that may be derived from the work. The large structures would have a significant impact on the landscape of the area, with large structures exposed over much of the tide. These structures could have an impact on the eastern frontage tending to draw sediment into the lee of the most easterly structure and further reducing beach levels to the east.

The following discussion focuses on the eastern end of the bay, with two principal options being considered for managed realignment.

Option 7a – Control Structures to Develop the Shoreline in Front of the Existing Defences.

The intent of this option is similar in principle to those considered for the western end of the bay, in that the aim would be to provide a natural defence alignment through use of control structures.

The relatively normal wave approach means that to advance the line of a beach sufficiently to provide continued protection to the toe in this area, structures have to extend a significant distance offshore and provide sufficient shelter to allow waves to spread within the influence of the arms.

Typically, two structures would be used: at the section of wall that is badly undermined as in toppling forward, providing support to this wall, and at the slipway. These structures could be integrated with the various defence approaches taken in managing the western frontage.

The optimum position of the structures would need to be modelled in detail to ensure that a stable beach provides adequate long term protection to the existing defence. There is therefore increased uncertainty in costing this option. There are also significantly greater costs associated with the increased height of the structure in relation to beach levels at the wall. Typical costs are of the order of £1.8M.

There is little economic benefit for this option and the prime reason would be to stabilise the existing defence and provide continued protection to the Kiosk. There would be an improved area of beach with some amenity value and the slipway might be improved during the construction of the eastern structure.

The main disbenefit would be the extremely high cost associated with the work.

Option 7b – Control Realignment of the Existing Defence.

One of the main difficulties in taking forward the line of defence is the size of structures necessary to create the width needed to hold an adequate beach. The alternative to this would be to allow the existing defence to fail, thus creating width for a beach to develop to the rear of this forward line and to control erosion as this occurs.

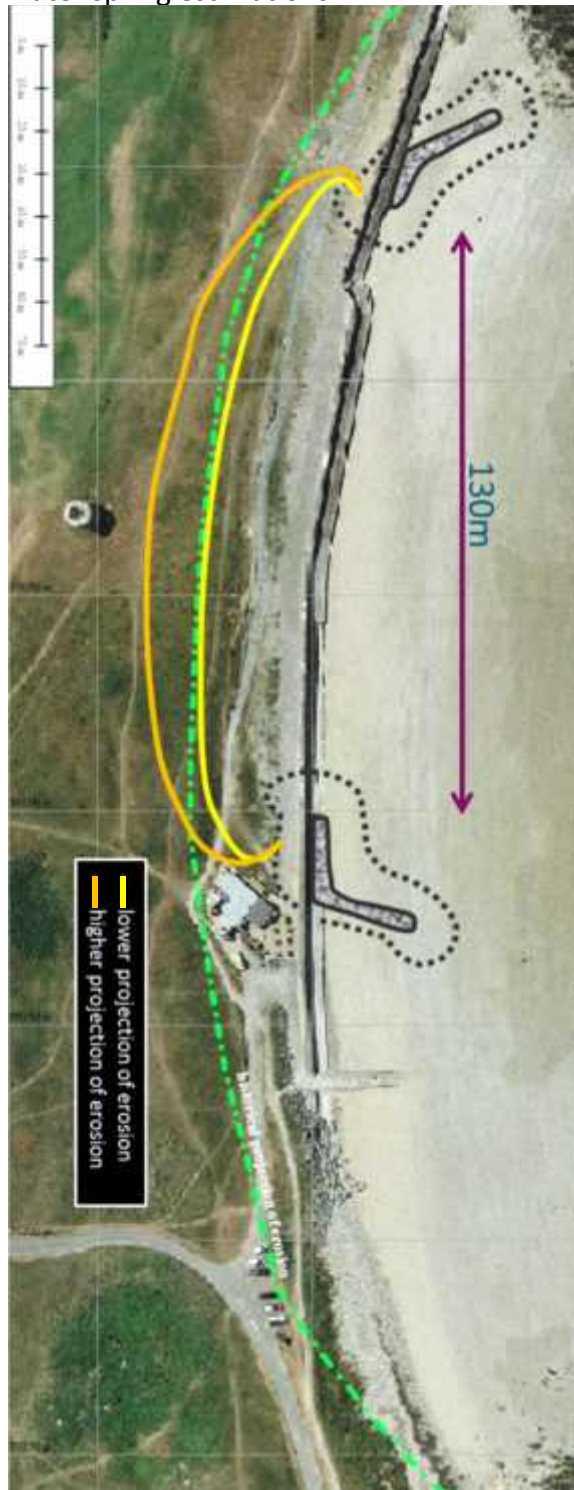
The works would need to be undertaken as part of and as an additional element of works associated with managing the failure or removal of the existing defences. Typically the additional cost would be of the order of £120,000. The aim would be to sustain the defence to the area of the Kiosk and to provide additional protection to the slipway and existing rock revetment. These works might be compatible with works undertaken to the west, allowing controlled adaption of the frontage over the longer term.

The main benefits would be in substantially reducing cost of management, maintaining defence to the Kiosk and addressing the immediate problems associated with the wall. The approach would significantly improve the overall amenity value of the area by allowing development of a semi-natural beach and significantly improving access. The approach would allow sustainable adaptation in the longer term. The main disbenefit would be in some additional cost.

Design and planned realignment (Option 7b)

The groynes will incorporate part of the existing wall structure along one edge, and are of a “fishtail” design so have a second arm positioned out into the bay.

The aim is to control the realignment and formation of the bay. The below image outlines the modelled new bay alignment compared to historical (pre wall) mean high water spring estimations.



Modelled incursion

Appendix 5

History

The following photographs from 1933 highlight the natural state of the beach prior to the wall's construction. These images have been included in public presentations on the proposals.



Appendix 6 – photo timeline of L'Ancrese East Panel 5

The photo timeline series below illustrates how a crack in the wall can develop over time, and does not increase in size in a linear fashion; rather there can be periods of little change followed by a short-term significant change. The cause of these cracks is continued undermining of the wall leading to the large gaps beneath, into which the wall is rotating.



Panel 5, 25 March 2015



Panel 5, 19 January 2016

There was little change between March 2015 and January 2016



Panel 5, 27 April 2016

Between March 2016 and April 2016 there is an obvious increase in the crack in the wall.



Panel 5, 6 February 2017

While less obvious, the crack continued to increase in size between April 2016 and February 2017.



Panel 5, 5 April 2017

A small further increase in the main crack was again evident, but additional separation along the smaller crack along the upper third of the wall was noticeable. It was also at this point obvious that the crack extended throughout the all with material being lost from behind.

Appendix 7 – diagram of toe and apron separation.

