AECOM

Option Appraisal Report

Hunstanton Coastal Management Plan

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Borough Council of
King's Lynn & West Norfolk
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Table of Contents

Appendices

1. Introduction

1.1 Project background

AECOM Infrastructure and Environment UK Limited has been appointed by the Borough Council of King's Lynn and West Norfolk (BCKLWN) to develop a Coastal Management Plan (CMP) to implement the 2010 Shoreline Management Plan's (SMP2) preferred management policy for the Hunstanton frontage.

1.2 Purpose of report

This report presents the options appraisal which has been undertaken to establish the preferred options for the Coastal Management Plan to deliver the preferred management policy for the Hunstanton frontage.

The option appraisal process has been undertaken by the project team and has been informed by various meetings between the project team and the BCKLWN. In addition, the evidence collected during site visits, the defence condition assessment and the coastal processes analysis (presented in the interim report) has also fed into the appraisal.

1.3 The site

Hunstanton is a seaside town along the west facing coast of the Wash in Norfolk, approximately 21km north east of the town of King's Lynn (Figure 1-1). The study area comprises approximately 1.3km of undefended cliffs (Unit A) and approximately 1.5km of defended coastline (Unit B) that consists of seawalls, promenade, rear wave wall and beach management groynes. The entire coastline is fronted by a sandy/shingle beach of varying levels.

Hunstanton is a popular tourist area, particularly in the summer months. The promenade is a prominent amenity area with an array of attractions which are well trafficked by the public. There are numerous seasonal kiosks located along the promenade with an amusement park, leisure centre, aquarium and caravan park located just behind the rear wave wall.

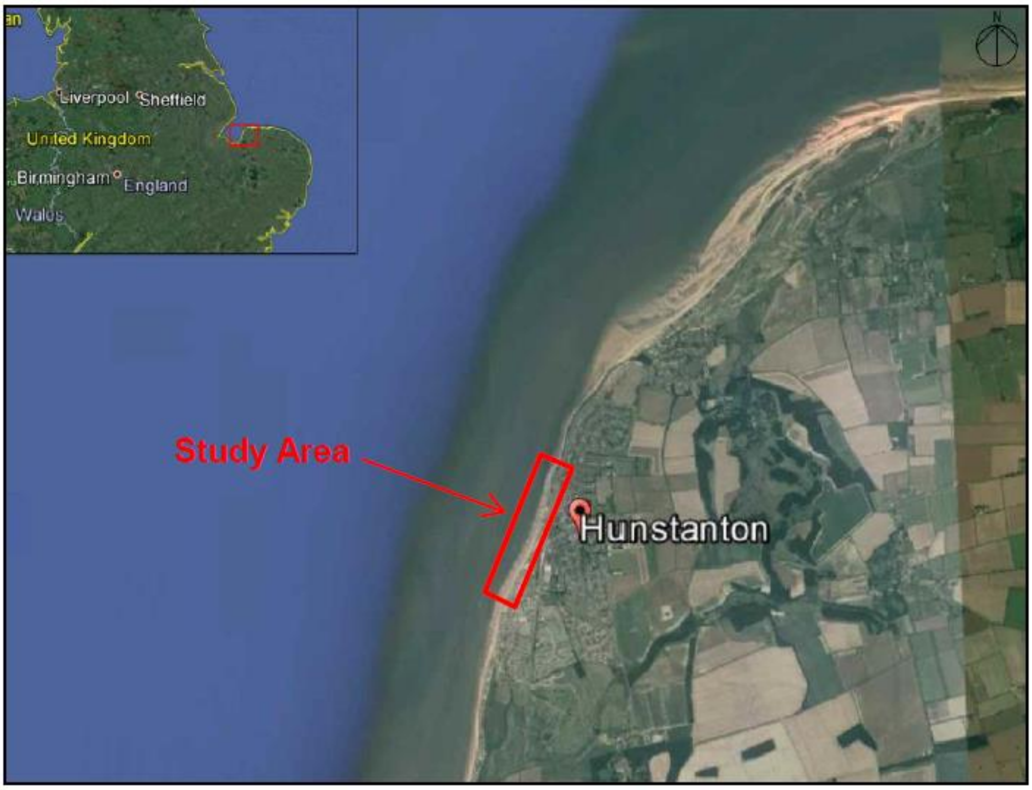

Figure 1-1: Location of study area (imagery ©2017 Google)

2. Appraisal Approach

2.1 Stages of the appraisal

This chapter provides an overview of the approach used to develop the preferred options for the Coastal Management Plan. A breakdown of the option appraisal process is provided below:

1. Develop and characterise the baseline (including flood and erosion risk, economic, environmental, asset condition, coastal processes) for the different management units across the study site (Units A and B), to underpin and facilitate the option appraisal process.
2. Identify a long list of measures which could be used to implement management options in the different units.
3. Screen out the unfeasible and 'non-starter' long list measures for each management unit that do not warrant more detailed appraisal.
4. Identify how the long list measures can be utilised, or combined through time, to implement the management options. The management options represent the short list and comprise:
    i. Do Nothing
    ii. Do Minimum
    iii. Maintain
    iv. Sustain
    v. Improve
5. Appraise the short list options with input from environmental and economic assessments and stakeholder feedback, to determine the preferred option(s).
6. Carry out sensitivity tests of the preferred option(s) to check that it is robust against a range of uncertainties.
7. Carry out partnership funding assessments for initial schemes to ascertain the potential Grant in Aid eligibility and likely funding shortfalls.

2.2 Key terminology

The following descriptions have been used in this report to describe the different levels of options within the appraisal process:

- Policy – the overarching management policy for the frontage recommended by the Shoreline Management Plan. For example Hold the Line or Managed Retreat.
- Option – the approach used to implement the management policy. Includes Do Nothing, Do Minimum, Maintain, Sustain or Improve.
- Measure – the on-the ground intervention to implement the management option, for example construction of a seawall, use of rock armour or gabions. Often a number of measures are combined through time in order to implement an option in the long term.

3. Management units

The study site is comprised of two management units as defined in the Wash East Coastal Management Strategy (2015), herein referred to as 'the Strategy'. These units comprise Unit A – Hunstanton Cliffs and Unit B – Hunstanton Town. The boundaries of these units are shown in Figure 3-1.

The agreed intent of the Wash Shoreline Management Plan Review (Environment Agency, 2010) is to continue to allow the cliffs in Unit A to erode naturally and provide sediment to help maintain the beaches to the south, until erosion starts to threaten cliff top properties and the cliff road. This is expected to occur in approximately 50 years. From that time on, the SMP's intent is to prevent further cliff erosion to sustain the properties and the road in Unit A.

The Strategy concluded that the preferred approach to managing erosion in Unit A in the future should be trialled with a pilot study focussing on a range of low cost measures to reduce erosion caused by wave action at specific locations. The trial of the measures would determine their effectiveness in slowing erosion. Measures identified in the Strategy were base netting, sand bags, gabions and a rock sill (rock revetment). The Strategy identified from the key stakeholder group that there was a clear consensus that it is not realistic or desirable to stop erosion, but measures such as these to slow the rate of erosion should be pursued.

In Unit B the preferred management policy of both the SMP2 and the Strategy is to 'Hold the Line'. The preferred option to do this is to maintain the existing promenade, seawall and groyne defences and replace the structures when required.

It should be noted that Unit C to the south of the study area (Wolferton Creek to South Hunstanton) is managed by the Environment Agency with partnership funding contributions from a Community Interest Company, the BCKLWN, Anglian Water and other private individuals. Work is currently being undertaken in this area and opportunities for an integrated approach with this unit are being considered.

A summary of the management units is provided in Table 3-1.

Table 3-1: Summary of management units

Management Unit	**Unit A**	**Unit B**
Location	Hunstanton Cliffs	Hunstanton Town
Geographic extent	North side of Golf course to Lincoln Square N Road	Lincoln Square N Road to the Boathouse Slipway adjacent to S Beach Road
SMP Policy Unit	PDZ4	PDZ3
SMP Policy	Allow cliffs to erode for the next two epochs then consider intervention at an appropriate time to prevent the loss of road and properties	Hold the Line
Characteristics	- Undefended - Exposed open coastline - Nationally designated cliffs actively eroding and providing a source of sediment for Unit B and further downdrift - Cliffs of geological interest and landscape feature - Recognised that works to counter erosion are unlikely to attract significant FCERM GiA funding - Part of the environmental designations including SAC, SPA and SSSIs	- Exposed open coastline - Defended from coastal erosion since 1885. Currently protected by seawall and promenade - Flood and erosion risk. Floodgates incorporated into the defence which are closed during times of high flood risk. - Beach levels maintained by groynes - Significant recreation and amenity value and local commercial centre - Part of the environmental designations including SAC, SPA and SSSIs
Recommended approach in SMP / Strategy	Pilot study to determine an acceptable option to reduce, but not stop, erosion	Sustain the promenade, seawall and groynes, and replace them when needed to Hold the Line.

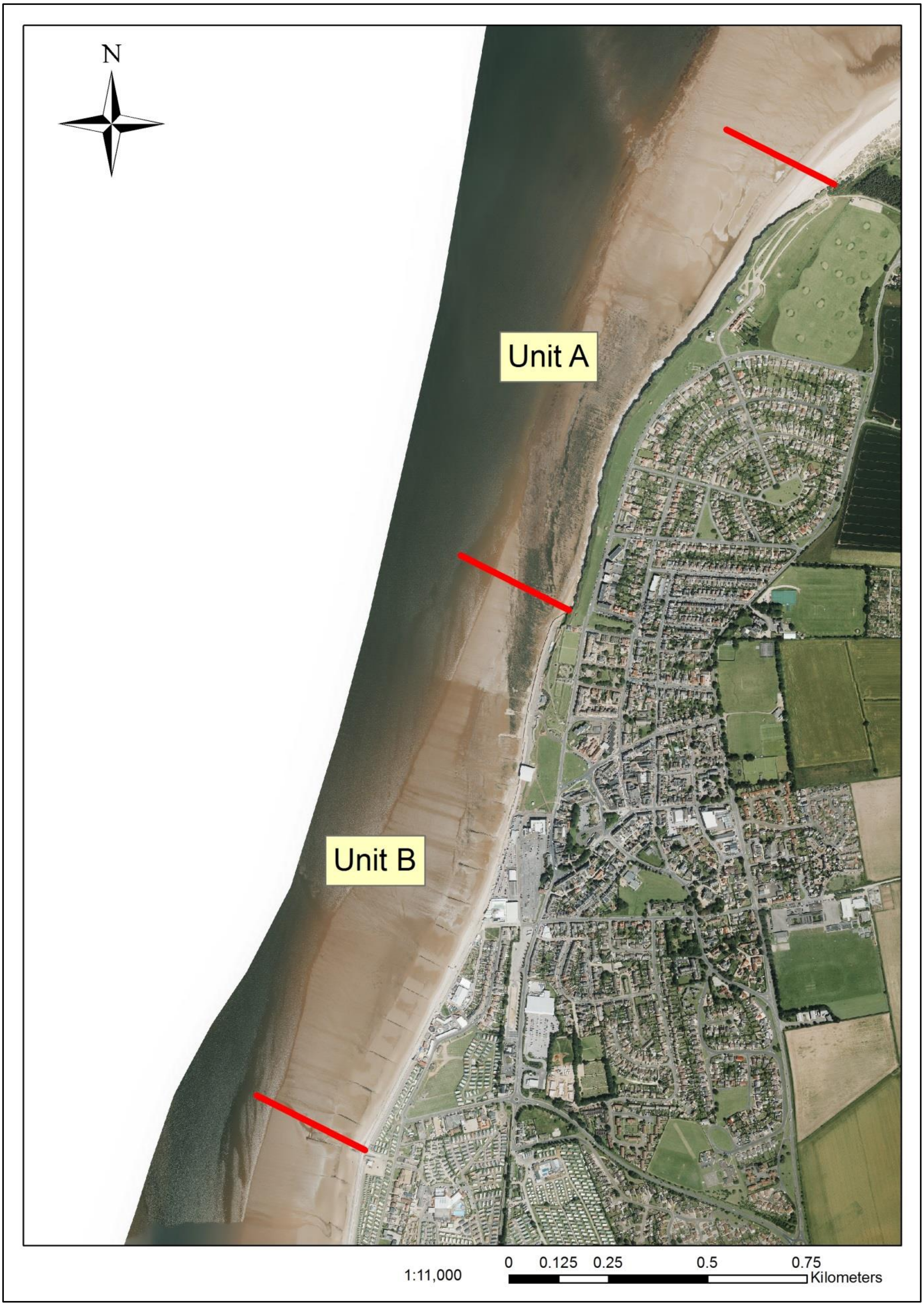

Figure 3-1: Map showing Unit A and B boundaries (imagery © CCO, 2017)

4. Long list measures

In order to deliver a range of potential management options (i.e. maintain, sustain, improve etc.) a number of measures and interventions may be required, either separately or in conjunction with one another. These may also need to be phased or sequenced in time to deliver the different management options.

To ensure that the appraisal of options was thorough and that no potential options had been left out it was important to cast the net as wide as possible at this initial stage of the appraisal to capture and consider all potential suitable measures for the site. The measures considered are described in the following sections.

4.1 Potential measures (Unit A)

Cliff bolting (stabilisation)

This measure involves using cliff bolting at regular intervals to stabilise the cliff and help reduce rates of cliff top recession. With this measure there is no guarantee that a cliff erosion event would not occur, but the stabilisation would help reduce weathering and slope process related erosion. It would not prevent marine induced erosion (i.e. wave attack at the cliff toe).

Advantages	Disadvantages
- Would support the tensile strength of the cliff material	- Would need to be combined with other measures to protect the cliff toe from wave action
- Would help to reduce quantity of material lost from cliff due to weathering of cliff slope	- Impact on the designated cliff face (i.e. aesthetic), which is of geological interest and is environmentally important
- Would not have a footprint on the beach	- Potential for high costs - Technically challenging

Netting at base of cliff (stabilisation)

This measure involves attaching netting to the face and base of the cliff to trap falling cliff material. This will improve the health and safety to members of the public on the beach from falling objects and will also generate an accumulation of loose material at the base of the cliff which could help to reduce wave interaction with the cliff toe and potentially reduce erosion rates. However, the netting is unlikely to be durable enough to withstand significant wave action and would require regular maintenance / replacement. In addition, if large amounts of rock are suspended above the beach by the netting there could be safety issues that arise.

Advantages	Disadvantages
- Improve health and safety from falling rocks	- Not likely to form a robust cliff toe defence and significantly reduce erosion rates
- Low cost measure	- Netting would need to be replaced frequently and not likely to be durable enough to withstand significant wave action
	- Not likely to work well with major rockfalls / large erosion events

Rock revetment / Sill

This measure involves placing rock armour protection on the foreshore in front of the cliff along the length of the frontage protecting the cliff from wave action. The rocks will be sized to be stable under extreme wave conditions and this structure will be effective at dissipating wave energy and therefore would reduce the amount of energy impacting the cliff.

Advantages	Disadvantages
- Prioritises areas most in need of additional robust protection	- Large amount of rock required (potentially large rocks), so potentially high cost
- Will have only a limited impact on the main area of frontage used by the public	- Slowing cliff erosion will reduce sediment input into the environment and reduce sediment supply to the beach and other sites down-drift

- Rock is relatively easy to move around, can be repositioned if displaced or required elsewhere	- Does not help to maintain beach levels and would need to be implemented in conjunction with some form of beach management option
- Requires little maintenance	- Currently the use of rock armour in the wider area is limited, so this measure would lead to a change in aesthetics.
- Very long design life	- Rock works will potentially have a large defence footprint onto the beach
- Can be designed to offer a continuous level of protection in line with climate change predictions	

Timber revetment

This measure involves constructing a new tropical hardwood timber revetment at the base of the cliff. The existing foreshore has a very limited beach and the underlying material is understood to be rock, therefore the installation of timber piles at this location would be expected to be challenging and expensive as a result.

Advantages	Disadvantages
- This type of protection already exists on the North Norfolk coastline and is very effective at breaking waves and protecting the cliffs	- Potentially difficult to drive timber piles into a rocky foreshore (construction issues)
- Tropical hardwood is comparatively more effective in marine environments (than local alternatives)	- Although better than oak, tropical timber still has a relatively short residual life and is expensive to maintain
- Known method of construction (from similar projects elsewhere in North Norfolk)	- Environmental implications of importing tropical timber (and added cost of ensuring sustainable source)
- Works will avoid impacting on the designated cliff face	- Still a relatively large defence footprint on the beach (although less than other measures)
- Revetment would create a smaller defence footprint compared to other measures	- Aesthetically very different to the existing frontage with potentially detrimental impacts on visual landscape

Geotube / Sandbag revetment

This measure involves placing Tencate Geotube units (or similar) in front of the cliff toe. The two geotubes will be stacked to provide the required protection. The existing foreshore profile will be prepared and where necessary infilled with suitable rock to provide an appropriate bed. The geotube units will be hydraulically filled in situ with local sand to provide a mass-gravity structure that is erosion resistant.

Advantages	Disadvantages
- Relatively easy to install	- Can be easily damaged during installation and the service period, potentially requiring a comprehensive maintenance regime
- Easy to transport due to light weight material	- Vulnerable to vandalism
- Does not involve the importation of significant quantities of rock, timber or concrete	- Comparatively short residual life
- Effective at dissipating wave energy therefore reducing the amount of wave energy impacting the cliff	- Construction assumes there is a large local source of beach material available for infill
- Will have only a limited impact on the main area of the frontage used by the public	- Measure will not assist in maintaining beach levels
	- Use of geotubes in the wider area is limited so this would lead to a change in visual aesthetics
	- Geotubes will have a defence footprint on the foreshore

Gabions

This measure involves protecting the cliff toe from wave action by constructing a gabion revetment / wall at the toe of the cliff. Gabions are rocks placed in steel wire cages which are effective at absorbing wave energy but could deform under extreme conditions and no longer be effective.

Advantages	Disadvantages
- Help to absorb wave action at the cliff toe	- Service life is typically short, and dependent on wave climate of the area
- Relatively inexpensive (compared to other measures)	- Potentially large maintenance costs

- Less intrusive than other hard defences, can be removed and relocated if required	- No beach management benefits
- Simple to construct	- Failure of gabions can lead to health and safety risks, i.e. split wire mesh. Potential for vandalism
	- Obtrusive / visually prominent structures may have a negative visual impact

Cliff drainage

This measure involves using cliff drainage measures (such as drilling drainage holes and placing filters) to help stabilise the cliff and reduce rates of cliff top recession. With this measure there is no guarantee that a cliff erosion event would not occur, but the drainage would help reduce groundwater induced erosion, weathering and slope processes related erosion. It would not prevent marine induced erosion (i.e. wave attack at the cliff toe).

Advantages	Disadvantages
- Would help to reduce quantity of material lost from cliff due to weathering of cliff slope	- Would need to be combined with other measures to protect the cliff toe from wave action
- Limited footprint on the beach	- Impact on the designated cliff face, which could be of geological interest and is environmentally important
	- Potential for high cost

Seawall

Construction of a continuous impermeable seawall in front of the cliffs would protect the cliffs from erosion. A seawall is likely to be very costly relative to the other measures.

Advantages	Disadvantages
- Protect cliff toe from waves	- Likely to have a high capital cost
- Would require little maintenance	- Will limit entry of cliff material to the beach, potentially affecting supply of sediment downdrift
- Potential to also create a promenade on the new seawall which would increase amenity value of the frontage	- Impact to visual aesthetics of the area, although in-keeping with defences to the south within Unit B
	- Groundwater induced erosion would continue
	- Would need to be paired with another option to remove the risk of falling debris from the cliff (due to weathering)

Offshore breakwater

This measure involves reducing wave action along the frontage by constructing a single (or multiple) offshore breakwater(s), likely to be constructed of rock or pre-cast concrete units. The presence of a breakwater(s) could potentially benefit the beach levels behind the structure, helping to protect the cliffs from wave attack. An offshore breakwater(s) is an extremely costly measure and could disrupt the natural sediment movement and hydrodynamics both locally and in adjacent areas, especially downdrift. The measure would also bring about fundamental environmental impacts offshore.

Advantages	Disadvantages
- Help to absorb wave energy and reduce erosion	- Likely to be very costly
- Potential to increase beach levels	- Will impact offshore environment and coastal processes
- Potentially create a new offshore habitat	- Environmentally intrusive
- Potential benefit for recreation / tourism in the area	- Will not completely eliminate potential erosion; still relies on beach to provide protection
- Would not have a footprint on the beach	- Likely that it would need to be combined with other beach management measures to prolong effectiveness, for example, beach recycling which would add additional cost

Beach nourishment

The beach nourishment measure involves the addition of imported new material to the beach to increase the level of the beach. Each recharge / nourishment would supply material via spraying from an offshore vessel onto the beach; the material would match the existing beach material (on neighbouring frontages). The increase in level of the beach would cause waves to break ‘earlier’ and therefore the amount of wave energy reaching the cliff would be reduced. Periodic beach recharge or ‘top-ups’ would be required to maintain the new beach levels and to maximise the effectiveness of the measure it will require the addition of beach control structures (e.g. groynes) to help to hold the sediment in place.

Advantages	Disadvantages
- Raising beach levels will reduce the wave climates at the toe of the cliffs and therefore reduce the potential erosion	- Very expensive measure and will create significant disruption to the beach and access during construction
- This measure is perceived to be a more 'natural' approach to coastal defence, when compared to introducing hard structures	- Beach is likely to return to its natural level over time, therefore continued management and 'top-ups' will be required
- Likely to have a positive impact on the local landscape	- Will need to be delivered in conjunction with enhancements to the existing groynes resulting in additional costs
- Likely to be beneficial for recreation / beach amenity use and could potentially enhance local tourism	- Potential negative impact on local environment by changing habitats and also the existing coastal processes
- Introducing additional sediment to this frontage will be a benefit to down drift locations	- Further modelling studies would be required to determine long term effectiveness
- Popular approach with the general public	- Due to the dynamic nature of beaches, even with modelling there will be an element of uncertainty with the potential for one large storm event to return the beach to original levels.
- Aesthetically pleasing	- Renourishment of only one section (i.e. 250m) to protect key assets is unlikely to be effective as material would be dispersed

Groynes (rock or timber)

This measure involves the construction of groynes (rock or timber) which are long narrow structures built perpendicular to the cliff which would improve the retention of sediment on the beach. To optimise the arrangement of new groynes a detailed numerical modelling study would be required to determine the preferred configuration.

Advantages	Disadvantages
- Would help to retain sediment on the beach for this part of the coastline	- Likely to be very costly
- Potential to improve amenity of the beach area and would not change the aesthetics of the cliff which is of geological interest	- Would disturb the natural movement of beach sediment and potentially lead to lowering of the beach downdrift at Hunstanton town
- Construction could be staggered	- Potential health and safety issues associated with large step changes in beach levels over the groynes
	- Potential environmental impacts associated with new groynes extending into intertidal or designated zones
	- Would not completely eliminate erosion risk which would depend on beach levels (still potential for a large storm to remove lots of beach material and expose the cliff)

Cliff stabilisation through regrading

This measure involves re-profiling of the cliff face to reduce its slope angle and help prevent further cliff erosion in the future. In order to be a successful long term solution, this approach would need to be combined with another measure which controls the rate of erosion of the cliff toe (such as a hard defence).

Advantages	Disadvantages
- Would help reduce the quantity of material lost from cliff due to weathering	- Will need to be combined with other measures to protect the cliff toe from wave action
- Limited footprint on the beach	- Impact on the cliff face, which is of geological interest (SSSI) and environmentally important
- Potentially low cost (as a measure on its own)	- Could impact visual aesthetics of the area
	- Initial re-profiling could lead to loss of properties, infrastructure and important land at the cliff top

Relocation of key assets

This measure involves the relocation of the key assets along the Unit A frontage which are at risk of erosion. The most prominent of these are the lighthouse and the ruins of St. Edmunds Chapel, but also the Coastguard Lookout (holiday let) and the Lighthouse Café. Moving the structures 15-20m or more inland is potentially feasible but would not provide a long term solution as continued erosion of the cliff and the presence of properties behind the seafront road ensure that space for additional asset moves in the future is limited.

Advantages	Disadvantages
- Key assets maintained and removed from immediate erosion risk	- Would be technically challenging and difficult to implement this measure
- Would protect the historically significant assets at greatest risk of erosion	- Assumes that new land to move the assets to would be available
- Would be a gradual approach which adapts to change	- Only postpones the erosion issue, and does not solve it long term.
- Would not change the aesthetic of the cliff which is of geological interest	- Potential to lead to cliff stability issues, if removing a significant sized structure from the cliff top
	- Most of the assets are privately owned and would require consent (however, St Edmunds Chapel ruins and the shelters are council owned). - Potential to be unpopular with the community.
	- Potential planning and other stakeholder consenting issues

4.2 Potential measures (Unit B)

Patch and repair of existing defences

This measure involves reactive repair and small-scale maintenance of the existing defences to maintain their integrity and to ensure health and safety compliance. This measure essentially represents what is currently being undertaken and does not include any capital interventions such as large scale refurbishment or replacement of the existing defences.

Advantages	Disadvantages
- Inexpensive low cost measure	- Reactive approach
- Focus resources on at risk areas	- Does not minimise probability of failures from occurring - Gives a poor aesthetic appearance
- Extend the service life of the existing structures in the short term	- Not a suitable long term approach and does not reduce flood risk
	- Greater likelihood of health and safety risks developing

Re-facing of the existing defences

This measure involves a capital re-facing of the seawall, promenade and setback floodwall defences in Unit B. This approach is proactive (compared to patch and repair) and would ensure that the defences retain their erosion and flood defence functionality. There are different approaches available to re-face the existing structures but the most typical methods are concrete spraying or encasement / strengthening. The main advantage of this measure is that it makes best use of the existing structures and therefore costs are significantly reduced compared to construction of a new defence.

Advantages	Disadvantages
- Proactive and will protect the existing structure and extend service life	- Unlikely to have as long a service life as a brand new structure
- Lower cost compared to construction of new structures	- Does not include crest raising to mitigate future flood risk
- Ability to focus resources on at risk areas	- Works will disrupt access to promenade during construction
- Typically, no significant environmental impacts as it involves working with existing defences	- In-situ concrete works present an environmental risk in the marine environment

Eventual replacement of the existing defences

This measure would be implemented after initially re-facing of the existing defences and would be required when it is no longer technically feasible or practical to continue re-facing the structures. It is likely that the existing defences could be re-faced a number of times before they would need to be replaced entirely. The main advantage of re-facing the existing structures and delaying the point at which the structures need to be replaced is that it decreases the whole life present value costs of the option and means that a large up-front investment is not required along the frontage immediately. When replacing the defences, there would be an opportunity to raise the height of defences to respond to increased sea levels.

Advantages	Disadvantages
- Makes best use of the existing defences and residual service life	- Higher maintenance costs associated with working on existing structures before replacement
- Reduced whole life present value cost compared to replacing the defences now	
- Opportunity to raise the height of the defences to respond to increased sea levels	

Repair of groynes

This measure involves proactively repairing the timber and concrete groynes in Unit B to maintain their functionality. For both the timber and concrete groynes the refurbishment may involve replacing timber/concrete planks, piles and joints when the features come towards the end of their service life. In the future it may no longer be feasible to repair individual sections of each groyne and therefore a full replacement may be necessary and more cost effective.

Advantages	Disadvantages
- Proactive and would extend service life of existing structures. Potentially could act to trap more beach material on the frontage.	- Unlikely to have as long a service life as a brand new structure
- Lower cost compared to construction of new structures	- Does not include groyne lengthening or raising to help trap more sediment on the beach
- Ability to focus resources on at risk areas	- Can be technically challenging to replace certain elements, with groynes partially hidden beneath the beach and because of corrosion of fixings it is not always possible to replace single elements
- Typically, no significant environmental impacts as it involves working with existing defences	

Raise existing defences

This measure involves raising the crest level of the existing seawall or setback floodwall (including the floodgates). There are many methods of raising the defences including constructing a new vertical capping beam on top of the existing defences. This measure will lead to a higher standard of protection (SoP) against flooding. Should the setback floodwall be raised it will be necessary to also undertake re-facing / replacement of the frontline seawall.

Advantages	Disadvantages
- Increased SoP against flooding	- Does not increase condition of existing defences and re-facing / replacement of frontline defence would also be required
- Lower cost relative to construction of new structure	- Could impact landscape and views in the area - New floodgates would be required

Rock revetment

This measure involves placing rock armour protection on the foreshore in front of the existing defences along the length of the Unit B frontage. This structure will be designed with rocks large enough to be stable under extreme wave conditions and would be effective at dissipating wave energy and therefore would increase the service life of the existing defences.

Advantages	Disadvantages
- Prioritises areas most in need of additional robust protection	- Large amount of rock required, so potentially high cost
- Requires little maintenance and would reduce the maintenance requirements of the existing defences	- Does not help to maintain beach levels and would need to be implemented in conjunction with some form of beach management option
- Rock is relatively easy to move around, can be repositioned if displaced or required elsewhere	- Currently the use of rock armour in the wider area is limited, so this measure would lead to a change in aesthetics.
- Very long design life - Can be designed to offer a continuous level of protection in line with climate change predictions	- Rock works will have a large defence footprint onto the beach in front of the existing defences - Health & safety implications - Reduction in usable beach area for public

Geotube / Sandbag revetment

This measure involves placing Tencate Geotube units (or similar) in front of the existing defences. The two geotubes will be stacked to provide the required protection. The existing foreshore profile will be prepared and where necessary infilled with suitable rock to provide an appropriate bed. The geotube units will be hydraulically filled in situ with local sand to provide a mass-gravity structure that is erosion resistant.

Advantages	Disadvantages
- Relatively easy to install	- Can be easily damaged during installation and the service period, potentially requiring a comprehensive maintenance regime
- Easy to transport due to light weight material	- Vulnerable to vandalism
- Does not involve the importation of significant quantities of rock, timber or concrete	- Comparatively short residual life
- Effective at dissipating wave energy therefore increasing the service life of the existing defences	- Construction assumes there is a large local source of beach material available for infill
	- Measure will not assist in maintaining beach levels

	- Use of geotubes in the wider area is limited so this would lead to a change in visual aesthetics
	- Geotubes will have a defence footprint on the foreshore, reducing the usable beach area for the public

Gabions

This measure involves protecting the existing defences by constructing a gabion revetment / wall in front of the defences. Gabions are rocks placed in steel wire cages which are effective at absorbing wave energy but could deform under extreme conditions and no longer be effective.

Advantages	Disadvantages
- Help to absorb wave action hitting the existing defences and extend their service life	- Service life is typically short, and dependent on wave climate of the area
- Relatively inexpensive (compared to other measures)	- Potentially large maintenance costs
- Less intrusive than other hard defences, can be removed and relocated if required	- No beach management benefits
- Simple to construct	- Failure of gabions can lead to health and safety risks, i.e. split wire mesh
	- Obtrusive / visually prominent structures may have a negative visual impact
	- Potentially large footprint in front of the existing defences, reducing the usable beach area for the public

Initial replacement of the existing defences

This measure would be implemented right away and would involve replacing the existing defences and raise the crest levels. This approach is likely to lead to large up-front construction costs compared to other approaches which make best use of the existing defences.

Advantages	Disadvantages
- Robust new structure with little maintenance requirements. - Long term solution for the frontage.	- High initial capital cost, which is not likely to be feasible in terms of funding
- Can design crest level of defence to account for sea level rise – by raising the crest now or by designing the foundations to be able to accommodate future raising	- Potential for environmental impacts associated with new defences – i.e. larger defence footprint, change to visual aesthetics

Offshore breakwater

This measure involves reducing wave action along the frontage by constructing a single (or multiple) offshore breakwater(s), likely to be constructed of rock or pre-cast concrete units. The presence of a breakwater(s) could potentially benefit the beach levels behind the structure, helping to protect the frontage from wave attack and increasing the service life of the existing defences. An offshore breakwater(s) is an extremely costly measure and could disrupt the natural sediment movement and hydrodynamics both locally and in adjacent areas, especially downdrift. The measure would also bring about fundamental environmental impacts offshore.

Advantages	Disadvantages
- Help to absorb wave energy and increase service life of existing defences	- Likely to be very costly
- Potential to increase beach levels	- Will impact offshore environment and coastal processes
- Potentially create a new offshore habitat	- Environmentally intrusive
- Potential benefit for recreation / tourism in the area	- Likely that it would need to be combined with other beach management measures to prolong effectiveness, for example, beach recycling which would add additional cost

Beach nourishment

The beach nourishment measure involves the addition of new material to the beach to increase the level of the beach. The beach recharge / nourishment would supply material via spraying from an offshore vessel onto the beach; the material would match the existing beach material (on neighbouring frontages). The increase in level of the beach would cause waves to break ‘earlier’ and therefore the amount of wave energy reaching the existing defences would be reduced which would increase their service life. Periodic beach recharge or ‘top-ups’ would be required to maintain the new beach levels and to maximise the effectiveness of the measure it will require the addition of beach control structures (e.g. groynes) to help to hold the sediment in place.

Advantages	Disadvantages
- Raising beach levels will reduce the wave climates at the defences and help to increase their service life	- Very expensive measure and will create significant disruption to the beach and access during construction
- This measure is perceived to be a more 'natural' approach to coastal defence	- Beach is likely to return to its natural level over time, therefore continued management and 'top-ups' will be required
- Likely to have a positive impact on the local landscape	- Will need to be delivered in conjunction with enhancements to the existing groynes resulting in additional costs
- Likely to be beneficial for recreation / beach amenity use and could potentially enhance local tourism	- Potential negative impact on local environment by changing habitats and also the existing coastal processes
- Introducing additional sediment to this frontage will be a benefit to down drift locations	- Further modelling studies would be required to determine long term effectiveness
- Popular approach with the general public	- Due to the dynamic nature of beaches, even with modelling there will be an element of uncertainty with the potential for one large storm event to return the beach to original levels.
- Aesthetically pleasing	- Renourishment of only one section (i.e. 250m) to protect key assets is unlikely to be effective as material would be dispersed

Timber revetment

This measure involves constructing a new tropical hardwood timber revetment in front of the existing defences. The existing foreshore has a very limited beach and the underlying material is understood to be rock, therefore the installation of timber piles at this location would be expected to be challenging and expensive as a result.

Advantages	Disadvantages
- This type of protection already exists on the North Norfolk coastline and is very effective at breaking waves and protecting the cliffs / assets behind	- Potentially difficult to drive timber piles into a rocky foreshore (construction issues)
- Tropical hardwood is comparatively more effective in marine environments (than local alternatives)	- Although better than oak, tropical timber still has a relatively short residual life and is expensive to maintain
- Known method of construction (from similar projects elsewhere in North Norfolk)	- Environmental implications of importing tropical timber (and added cost of ensuring sustainable source)
- Revetment would create a smaller defence footprint compared to other measures but would still encroach out from the existing defences onto the beach	- Aesthetically very different to the existing frontage with potentially detrimental impacts on visual landscape - Reduced usable beach area for the public and potential health and safety risk

Groyne replacement

This measure involves a largescale replacement of the existing groyne structures which would enable the groynes to be redesigned potentially increasing the height and/or length. This could lead to more material being trapped on the beach which would improve the level of protection.

Advantages	Disadvantages
- Would enable the groynes to be redesigned, potentially increasing length and height	- Increasing the amount of sediment retained on this frontage will cause less sediment to be available in downdrift locations
- May act to trap more material on the beach	- Performance can be unpredictable due to the dynamic nature of sediment
- Replacement could be staggered and different groynes prioritised	

Rock groynes

This measure involves constructing new rock groynes to potentially improve the retention of sediment on the beach. This measure would be significantly more costly than working with the existing groyne structures.

Advantages	Disadvantages
- Likely to have a longer service life compared to using existing structures	- Likely to be very high cost
- Can undertake modelling to identify optimal groyne placement / arrangement to maximise beach material	- Potential environmental impacts associated with new groyne structures
	- Modelling would be required to optimise design

4.3 Screening of long list measures

A multi-criteria assessment of the long list measures was undertaken to screen the measures and remove those from the appraisal process which are not considered to be feasible solutions. Each of the long list measures was initially assessed against the following nine key parameters:

- Erosion risk
- SMP policy compliance
- Technical feasibility
- Maintenance requirements
- Environmental impacts
- Cost (comparative against other similar measures)
- Health and safety compliance
- Measure design life
- Public acceptance

For each category, the measure was ranked with a colour code of red, amber or green. The following table outlines the classification system used for each category:

Table 4-1: Classification system used for each category

Category	Red	Amber	Green
Erosion risk (and flood risk if relevant – i.e. Unit B)	Increases erosion risk or has no / negligible impact on erosion risk	Potential to address or partially reduce erosion risk	Potential to significantly reduce or remove erosion risk
SMP policy compliance	Does not facilitate SMP policy	Partially supports / general support but localised change	Fully facilitates SMP policy
Technical feasibility	Option is technically very challenging or difficult to implement/construct	Option presents some technical challenges to implement/construct	No significant technical challenges to implement/construct
Maintenance	Requires a significant level of ongoing maintenance	Some scheduled maintenance is required	Maintenance free/minimal maintenance
Environmental impacts	Environmentally detrimental	Environmental benefits, but also drawbacks or no significant change	Potential for environmental enhancement
Cost (in relation to other similar measures)	Significant cost	Moderate cost	Low cost
Health and safety	Fails to address or mitigate risk or makes risks worse including construction risks	Partially mitigates against health and safety risks or results in limited risks including construction risks	Potential to significantly reduce health and safety risks and low construction risks
Measure design life	Short term (<20 years) with further interventions required	Medium term (20-50 years)	Long term (50+ years)
Public acceptance	Potential for major objections or goes against feedback received	Likely public will be for and against or meets some feedback received	Will be supported by majority of public and addresses main concerns

In addition to the classification outlined in Table 4-1, where a measure is prohibitively negative in any one category (e.g. prohibitively expensive, dangerous or ineffective) a **black** classification has been used. If a measure has a black classification against any of the categories it has automatically been screened out of the appraisal process.

4.3.1 Unit A

Table 4-2 below shows the multi-criteria screening assessment of the measures in Unit A.

Table 4-2: Multi-criteria screening assessment for Unit A

Measure	Category								
	Erosion risk	SMP policy compliance	Technical feasibility	Maintenance	Environmental impacts	Comparative Cost	Health and safety	Measure design life	Public acceptance
Cliff bolting									
Netting to base of cliff									
Rock revetment / sill									
Timber revetment									
Geotube / sandbag revetment									
Gabions									
Cliff drainage									
Seawall									
Offshore breakwater(s)									
Beach nourishment									
Groynes									
Cliff stabilisation through regrading									
Relocation of key assets				n/a	n/a			n/a	

Based on the multi-criteria assessment, Table 4-3 below summarises which measures were screened out from further consideration, and which measures were taken forward in Unit A.

Table 4-3: Measure screening for Unit A

Measure	Screening	Reason(s)
Cliff bolting	Out	Multiple red classifications including technical feasibility, health and safety and design life
Netting to base of cliff	Out	Multiple red classifications including technical feasibility, maintenance and design life
Rock revetment / sill	In	Majority amber classifications with some green in erosion risk, maintenance and measure design life.
Timber revetment	In	All amber classifications
Geotube / sandbag revetment	In	Majority amber classifications with the only red classification being the measure design life
Gabions	Out	Black classification on technical feasibility as gabions are unlikely to be suitable for the exposed coastline subject to a vigorous wave climate
Cliff drainage	Out	Multiple red classifications including technical feasibility as it will not address the erosion resulting from wave and tidal action. Other red classifications include health and safety and design life. (Please note: Scoping cliff drainage out of the coastal management plan, does not preclude the Council investigating drainage improvements under a different scheme.)
Seawall	Out	Black classification on cost as a new seawall structure would be very expensive and realistically un-fundable
Offshore breakwater(s)	Out	Black classification on cost as an offshore breakwater(s) would be very expensive and realistically un-fundable
Beach nourishment	In	Multiple red classifications but following initial consultation this measure is understood to have strong support from the public and has therefore been included for further appraisal
Groynes	Out	All amber classifications but could significantly compromise the sediment supply from this area to the south including Units B and C so deemed unfeasible, unless implemented in conjunction with beach renourishment.
Cliff stabilisation through regrading	Out	Multiple black classifications on technical feasibility, environmental impacts and public acceptance (loss of property at cliff top)
Relocation of key assets	In	Mixture of red, amber and green classifications but green classifications for erosion risk and health and safety warrant further appraisal

4.3.2 Unit B

Table 4-4 below shows the multi-criteria screening assessment of the measures in Unit B.

Table 4-4: Multi-criteria screening assessment for Unit B

Measure	Category								
	Erosion risk	SMP policy compliance	Technical feasibility	Maintenance	Environmental impacts	Comparative Cost	Health and safety	Measure design life	Public acceptance
Patch and repair maintenance of seawall, promenade and floodwall	Amber	Green	Amber	Red	Amber	Green	Green	Red	Amber
Re-facing of the seawall, promenade and floodwall	Green	Green	Amber	Green	Amber	Amber	Amber	Green	Green
Delayed replacement seawall, promenade and floodwall and promenade	Green	Green	Amber	Green	Amber	Red	Amber	Green	Amber
Repair of groynes	Amber	Green	Amber	Red	Amber	Green	Amber	Red	Amber
Raise existing defences	Green	Green	Amber	Green	Amber	Amber	Amber	Green	Amber
Rock revetment	Amber	Green	Amber	Green	Amber	Red	Amber	Amber	Red
Geotube / sandbag revetment	Amber	Green	Amber	Amber	Amber	Amber	Amber	Red	Red
Gabions	Amber	Green	Black	Red	Amber	Amber	Amber	Red	Red
Initial replacement of seawall, promenade and floodwall (i.e. present day)	Green	Green	Amber	Green	Amber	Black	Amber	Green	Amber
Offshore breakwaters	Amber	Green	Black	Amber	Red	Black	Amber	Amber	Amber
Beach nourishment	Amber	Green	Amber	Red	Amber	Black	Amber	Red	Green
Timber revetment	Amber	Green	Amber	Amber	Amber	Amber	Amber	Amber	Red
Groyne replacement	Amber	Green	Amber	Amber	Amber	Amber	Amber	Amber	Amber
Rock groynes	Amber	Green	Amber	Green	Amber	Amber	Amber	Green	Amber

Based on the multi-criteria assessment, Table 4-5 below summarises which measures were screened out from further consideration, and which measures were taken forward in Unit B.

Table 4-5: Measure screening for Unit B

Measure	Screening	Reason(s)
Patch and repair maintenance of seawall, promenade and floodwall	In	Multiple green classifications including SMP policy compliance, cost and health and safety
Re-facing of the seawall, promenade and floodwall (Maintain)	In	Multiple green classifications including erosion risk, SMP policy compliance, maintenance, design life and public acceptance
Replacement seawall, promenade and floodwall (Improve)	In	Multiple green and amber classifications therefore scoped in for further analysis despite a red classification on cost.
Repair of groynes	In	Mixture of red, amber and green classifications but a comparatively low cost measure and therefore warrants further appraisal
Raise existing defences (Sustain)	In	Mixture of amber and green classifications
Rock revetment	Out	Mixture of red, amber and green classifications but unlikely to be publically acceptable due to loss of beach area with rock armour extending out in front of the existing defences and also comparatively high cost compared to other measures in this unit
Geotube / sandbag revetment	Out	Red classifications including design life and public acceptance with the structure extending out onto the beach in-front of the existing defences
Gabions	Out	Black classification on technical feasibility as gabions are unlikely to be suitable for an exposed coastline subject to an vigorous wave climate
Initial replacement of seawall, promenade and floodwall	Out	Black classification on cost as an initial replacement of the existing defences would be very expensive and realistically un-fundable
Offshore breakwaters	Out	Black classification on cost as an offshore breakwater(s) would be very expensive and realistically un-fundable
Beach nourishment	Out	Black classification on cost and would not eliminate erosion risk / would still be dependent on other structures
Timber revetment	Out	Majority amber classification but unlikely to be publically acceptable due to loss of beach area with timer revetment extending out in front of the existing defences
Groyne replacement	In	All amber classifications except for SMP policy compliance which is green
Rock groynes	In	Mixture of amber and green classifications

4.3.3 Summary of measures taken forward

Table 4-6 provides a summary of the measures taken forward from the long list for further consideration.

Table 4-6: Summary of measures taken forward

Unit	Measures taken forward from long list
A	Rock revetment / sill Timber revetment Geotube / sandbag revetment Beach nourishment Relocation of key assets
B	Patch and repair maintenance Re-facing of existing defences (seawall, promenade and floodwall) Replacement of existing defences (seawall, promenade and floodwall) Raising of existing defences Repair of groynes Groyne replacement (i.e. rock groynes)

5. Short-list options

The short-list options comprise the high level management options which include:

- Do Nothing – hypothetical walk away scenario. No work will be carried out to maintain or repair defences allowing them to deteriorate over time.
- Do Minimum – maintain existing defences with minimal investment (i.e. no large capital investments) until the defences fail and then Do Nothing as above.
- Maintain – defences are maintained as they are but as sea levels rise the flood and erosion risk is expected to increase over time. The Maintain option permits large capital investments to maintain the defences (i.e. a re-facing scheme).
- Sustain – defences are raised and strengthened keeping the levels of flood and erosion risk and standard of protection the same as they are now.
- Improve – construction of defences if not currently present or improvement of existing defences to increase the standard of protection over time, beyond the requirements of sea level rise.

In Unit A, given that the frontage is currently undefended, it is only possible to consider two of the short list options; Do Nothing and Improve. Options such as Do Minimum, Maintain, or Sustain cannot be considered because there are no existing defences. Because of this, a number of different approaches to implementing the Improve option have been included in the short list, based on the different measures taken forward from the long list.

In Unit B the presence of the existing defences means that it is possible to consider the full range of short list options. For each option the most suitable combination of measures from the long list have been identified to deliver the options for the next 100-years.

5.1 Option development – Unit A

5.1.1 Improve 1 – Rock armour revetment / sill

This option involves placing rock armour protection on the foreshore in front of the cliff. The rock armour would be built on a geotextile and rock core 60-300kg. A large size of rock, or 'keystone', will be placed at the seaward extent of the revetment. Some minor excavation may be necessary to provide a robust ground profile.

Figure 5-1: Example photographs of rock revetments in front of steep cliffs

Protection for the full length of the unit (1325m) and for just the pilot study (250m) have been costed based on a unit rate of £2.05k per metre length of defence (rate includes a 30% optimism bias).

Table 5-1 below presents the undiscounted capital costs for construction for each length of defence. The total capital cost for constructing 250m of defence for the pilot study is estimated to be approximately £511k. To protect the entire length of the frontage in this unit (1325m + 50m tie-in) the undiscounted capital costs is estimated to be approximately £2,813k.

Table 5-1: Undiscounted capital construction costs for Improve 1 – rock armour revetment / sill

Description	Price rate (£k/m)*	Pilot study cost (250m frontage)	Full frontage cost (1325m frontage + 50m tie-in)
Improve 1 – Rock armour revetment / sill	2.05	£511k	£2,813k

**Note that a 30% optimism bias has been applied to Unit A costs*

Whole life costs for the next 100-years are presented in Table 5-2 (Cash and PV). The whole life costs include construction and maintenance costs and are discounted based upon the estimated year of intervention over the next 100-years. Different intervention periods have been considered, constructing the defence now (i.e. present day), year 15 and also in year 50 (doing nothing up until this point). Year 50 has been assumed as the point at which it will be necessary to protect the full length of the frontage to reduce the rate of erosion to prevent properties being lost at the cliff top in the future.

The present value whole life cost to deliver a 250m length of defence from present day is estimated to be £636k. To protect the full length of the frontage the present value whole life cost is estimated to be £3,498k from present day and £669k from year 50.

Table 5-2: Whole life cost for Improve 1 – rock armour revetment / sill

Approach	Cash whole life cost	PV whole life cost
Pilot study (250m) from present day	£972k	£636k
Pilot study (250m) from year 15	£921k	£381k
Pilot study (250m) from year 15, then remainder of frontage from year 50 (1075m)	£4,092k	£922k
Full frontage from present day (1325m)	£5,345k	£3,498k
Full frontage from year 50 (1325m)	£3,938k	£669k

An environmental assessment of this approach has been undertaken and is presented in Table 5-3 below. In summary, a rock revetment in this location is likely to lead to significant impacts on the landscape and coastal processes in the area (specifically the sediment feed to the beach) and will have a relatively large footprint on the beach.

Table 5-3: Environmental assessment for Improve 1 – rock armour revetment / sill

Key positive effects	Key negative effects	Mitigation or enhancement opportunities
- No significant impacts to the foreshore (will not reduce access/amenity use of the beach) - Will slow the cliff receding and therefore protect socio-economic receptors against erosion - The rock armour is a natural material - Rock armour will potentially create a new habitat along the frontage - Unlikely to inhibit tourism - The location of the rock armour away from the cliff will avoid any significant impact on the habitats located on the cliff	- Use of rock armour in this area is limited; this will lead to significant change in landscape aesthetics - The cliff erosion sediment inputs into the environment will be reduced and therefore there will be reduced sediment supply to the beach and other sites down drift - Rock works will potentially have a relatively large footprint on the beach - slowing of erosion may harm the geological interest of the Cliffs as a SSSI	- Reduces the need for regular maintenance of e.g. timber defences

5.1.2 Improve 2 – Timber revetment

This option involves constructing a new tropical hardwood timber revetment (e.g. Greenheart or Ekki). The revetment will include 5 rows at the front of the structure to provide abrasion resistance and prevent undermining. For costing purposes the design of the revetment has been based on the arrangement and dimensions from a similar project in North Norfolk. It should be noted that the cliff toe at the site consists of a large amount of rocky material and therefore the installation of timber piles at the toe of the cliff would be very challenging and labour intensive as a result.

Figure 5-2: Example photographs of timber revetments in front of steep cliffs

Protection for the full length of the unit (1325m) and for just the pilot study (250m) have been costed based on a unit rate of £2.01k per metre length of defence (rate includes a 30% optimism bias).

Table 5-4 below presents the undiscounted capital costs for construction for each length of defence. The total capital cost for constructing 250m of defence for the pilot study is estimated to be approximately £502k. To protect the entire length of the frontage in this unit (1325m + 50m tie-in) the undiscounted capital cost is estimated to be approximately £2,764k.

Table 5-4: Undiscounted capital construction costs for Improve 2 – timber revetment

Description	Price rate (£k/m)*	Pilot study cost (250m frontage)	Full frontage cost (1325m frontage + 50m tie-in)
Improve 2 – Timber revetment	2.01	£502k	£2,764k

**Note that a 30% optimism bias has been applied to Unit A costs*

Whole life costs for the next 100 years are presented in Table 5-5 (Cash and PV). The whole life costs include construction and maintenance costs and are discounted based upon the estimated year of intervention over the next 100 years. Different intervention periods have been considered, constructing the defence now (i.e. present day), year 15 and also in year 50 (doing nothing up until this point). Year 50 has been assumed as the point at which it will be necessary to protect the full length of the frontage to reduce the rate of erosion to prevent properties being lost at the cliff top in the future.

The present value whole life cost to deliver a 250m length of defence from present day is estimated to be £826k. To protect the full length of the frontage the present value whole life cost is estimated to be £4,545k from present day and £769k from year 50.

Table 5-5: Whole life cost for Improve 2 – timber revetment

Approach	Cash whole life cost	PV whole life cost
Pilot study (250m) from present day	£1,809k	£826k
Pilot study (250m) from year 15	£1,708k	£500k
Pilot study (250m) from year 15, then remainder of frontage from year 50 (1075m)	£5,276k	£1,066k
Full frontage from present day (1325m)	£9,949k	£4,545k
Full frontage from year 50 (1325m)	£4,974k	£769k

An environmental assessment of this approach has been undertaken and is presented in Table 5-6 below. In summary, a timber revetment in this location is likely to lead to impacts on the coastal processes in the area (specifically the sediment feed to the beach) and will have a footprint on the beach.

Table 5-6: Environmental assessment for Improve 2 – timber revetment

Key positive effects	Key negative effects	Mitigation or enhancement opportunities
- No significant impacts to the foreshore (will not significantly impact access or amenity use of the beach) - Will slow the cliff receding and therefore protect socio-economic receptors against erosion - Will not inhibit tourism - The location of the timber revetments away from the cliff will avoid any significant impact on the habitats located on the cliff	- By slowing cliff erosion the sediment inputs into the environment will be reduced and therefore there will be a reduced sediment supply to areas downdrift of the defences - Timber revetments will have a footprint on the beach - Tropical hardwoods have to be imported with significant carbon footprint - Sourcing sustainably managed tropical hardwood is difficult / expensive - Aesthetically very different to the existing frontage with potentially detrimental impacts on the existing landscape - slowing of erosion may harm the geological interest of the Cliffs as a SSSI	- By opting for tropical hardwood it reduces the impact of future maintenance activities when compared to oak

5.1.3 Improve 3 – Geotube / sandbag revetment

This option involves placing Tencate Geotube units (or similar) in front of the cliff. Each Geotube will have an approximate 4m diameter. The Geotubes will be stacked to provide the required crest height. Where necessary the existing beach profile will be prepared and infilled with a suitable rock infill to establish an appropriate bed for the Geotubes. The Geotube units will be hydraulically filled in situ with local sand to provide a mass-gravity structure that is erosion resistant.

Figure 5-3: Example photographs of sand filled Geotubes in front of steep cliffs

Protection for the full length of the unit (1325m) and for just the pilot study (250m) have been costed based on a unit rate of £2.07k per metre length of defence (rate includes a 30% optimism bias).

Table 5-7 below presents the undiscounted capital costs for construction for each length of defence. The total capital cost for constructing 250m of defence for the pilot study is estimated to be approximately £516k. To protect the entire length of the frontage in this unit (1325m + 50m tie-in) the undiscounted capital cost is estimated to be approximately £2,840k.

Table 5-7: Undiscounted capital construction costs for Improve 3 – Geotube revetment

Description	Price rate (£k/m)*	Pilot study cost (250m frontage)	Full frontage cost (1325m frontage + 50m tie-in)
Improve 3 – Geotube revetment	2.07	£516k	£2,840k

**Note that a 30% optimism bias has been applied to Unit A costs*

Whole life costs for the next 100 years are presented in Table 5-8 (Cash and PV). The whole life costs include construction and maintenance costs and are discounted based upon the estimated year of intervention over the next 100 years. Different intervention periods have been considered, constructing the defence now (i.e. present day), year 15 and also in year 50 (doing nothing up until this point). Year 50 has been assumed as the point at which it will be necessary to protect the full length of the frontage to reduce the rate of erosion to prevent properties being lost at the cliff top in the future.

The present value whole life cost to deliver a 250m length of defence from present day is estimated to be £1,106k. To protect the full length of the frontage the present value whole life cost is estimated to be £6,081k from present day and £1,120k from year 50.

Table 5-8: Whole life cost for Improve 3 – Geotube revetment

Approach	Cash whole life cost	PV whole life cost
Pilot study (250m) from present day	£2,840k	£1,106k
Pilot study (250m) from year 15	£2,788k	£677k
Pilot study (250m) from year 15, then remainder of frontage from year 50 (1075m)	£8,674k	£1,429k
Full frontage from present day (1325m)	£15,618k	£6,081k
Full frontage from year 50 (1325m)	£9,087k	£1,120k

An environmental assessment of this approach has been undertaken and is presented in Table 5-9 below. In summary, a Geotube revetment in this location is likely to lead to impacts on the coastal processes in the area (specifically the sediment feed to the beach) and will have a footprint on the beach.

Table 5-9: Environmental assessment for Improve 3 – Geotube revetment

Key positive effects	Key negative effects	Mitigation or enhancement opportunities
- No significant impacts to the foreshore (will not significantly impact access or amenity use of the beach) - Will slow the cliff receding and therefore protect socio-economic receptors against erosion - Will not inhibit tourism - The location of the Geotubes away from the cliff will avoid any significant impact on the habitats located on the cliff	- By slowing cliff erosion the sediment inputs into the environment will be reduced and therefore there will be a reduced sediment supply to areas downdrift of the defences - Geotube revetment will have a footprint on the beach - Aesthetically very different to the existing frontage with potentially detrimental impacts on the existing landscape - slowing of erosion may harm the geological interest of the Cliffs as a SSSI	- The area of beach immediately behind the Geotubes will be protected from wave action and new habitats could develop there

5.1.4 Improve 4 – Beach nourishment

The beach nourishment option involves the addition of new imported material to the beach to increase the level of the beach. The recharge would supply material via spraying from a barge onto the beach; the material would match the existing beach material in terms of grain size so that is performs equally under the local hydrodynamic and wave conditions. The increase in the beach level will cause waves to break further down the beach which will reduce the amount of wave energy reaching the cliff.

For costing purposes the design of the beach includes increasing the level of the top of the beach to a greater height than the present day 1:200 year water level (annual exceedance probability). It has also been assumed that the scheme will terminate at the line of mean sea level. In addition to the recharge, the scheme may also require groynes to be constructed to help to hold the material in place, but costs for groynes have not been included. The option will also require periodic 'top-ups' and repeat recharges in order to maintain the beach level and account for the removal of beach material over time.

Figure 5-4: Example photographs of beach nourishment

Table 5-10 below presents the undiscounted capital costs for beach nourishment for each length of beach defence. The total capital cost for nourishing 250m of defence for the pilot study is estimated to be approximately £1,648k. To protect the entire length of the frontage in this unit (1325m) the undiscounted capital cost is estimated to be approximately £8,733k.

Table 5-10: Undiscounted capital construction costs for Improve 4 – beach nourishment

Description	Price rate (£k/m)*	Pilot study cost (250m frontage)	Full frontage cost (1325m frontage)
Improve 4 – Beach nourishment	6.6	£1,648k	£8,733k

**Note that a 30% optimism bias has been applied to Unit A costs*

Whole life costs for the next 100 years are presented in Table 5-11 (Cash and PV). The whole life costs include the initial nourishment and subsequent top up and recycling costs and are discounted based upon the estimated year of intervention over the next 100 years. Different intervention periods have been considered, constructing the defence now (i.e. present day), year 15 and also in year 50 (doing nothing up until this point). Year 50 has been assumed as the point at which it will be necessary to protect the full length of the frontage to reduce the rate of erosion to prevent properties being lost at the cliff top in the future.

The present value whole life cost to deliver a 250m length of defence from present day is estimated to be £2,696k. To protect the full length of the frontage the present value whole life cost is estimated to be £17,859k from present day and £3,322k from year 50.

Table 5-11: Whole life cost for Improve 4 – beach nourishment

Approach	Cash whole life cost	PV whole life cost
Pilot study (250m) from present day	£6,591k	£2,696k
Pilot study (250m) from year 15	£6,064k	£1,628k
Pilot study (250m) from year 15, then remainder of frontage from year 50 (1075m)	£25,960k	£4,226k
Full frontage from present day (1325m)	£43,665k	£17,859k
Full frontage from year 50 (1325m)	£25,763k	£3,322k

An environmental assessment of this approach has been undertaken and is presented in Table 5-12 below. In summary, beach nourishment in this location is likely to lead to impacts on the coastal processes in the area (specifically the sediment movement around the beach) and have a negative impact by changing habitats.

Table 5-12: Environmental assessment for Improve 3 – Geotube revetment

Key positive effects	Key negative effects	Mitigation or enhancement opportunities
- Likely to have a positive impact on the local landscape - Will enhance the amenity use of the beach - Enhanced beach levels will offer the cliffs greater protection and therefore protect socio-economic receptors against erosion - Enhancing beach levels will benefit local tourism (beyond construction) - Works will not directly impact on the designated cliffs - Introducing additional sediment to this frontage will be a benefit for down drift locations	- Re-nourishment activities are likely to have a negative impact on the local environment by changing habitats - Re-nourishment activities are likely to interfere with existing coastal processes - Significant disruption during construction - slowing of erosion may harm the geological interest of the Cliffs as a SSSI	- Increased levels are likely to enhance the local amenity values of the beach and enhance local tourism - Likely to have a positive impact on the local landscape

5.1.5 Improve 5 – Relocation of key assets

This option involves the relocation of the key assets along the frontage which are at risk of erosion. The most prominent of these are the lighthouse (holiday let) and the ruins of St. Edmunds Chapel, but also the Coastguard Lookout (holiday let) and the Lighthouse Café. Moving the structures 15-20m inland is potentially feasible but would not provide a long term solution as continued erosion of the cliff and the presence of properties behind the seafront road ensure that space for additional asset moves in the future are limited.

Figure 5-5: Lighthouse which would require relocation

High level estimated costs for moving the lighthouse inland by 15-20m are approximately £750k. It has therefore been assumed that similar proportionate costs will be incurred for moving the other structures as well. The cost estimates do not include appraisal or land purchase costs which could increase the costs still further. In addition, moving the assets inland would not prevent future erosion, only delay the impact. Table 5-13 provides a summary of the relocation costs for this option.

Table 5-13: Undiscounted capital construction costs for Improve 5 – relocation

Asset to be moved	Approx cost
Lighthouse	£750k
Coastguard Lookout and Lighthouse Cafe	£800k (2x £400k)
Ruins of St Edmund's Chapel	£750k (Gross estimate)
Optimism bias (60%)*	£1,380k
Total	£3,680k

**Note that a 60% optimism bias has been applied to this cost as it is more uncertain than Improve options 1-4*

Whole life costs for the next 100 years are presented in Table 5-14 (Cash and PV). The whole life costs are for one relocation (assumed to be in from the present day).

The present value whole life cost to relocate from present day is estimated to be £3,680k and from year 70 is £402k.

Table 5-14: Present value whole life cost for Improve 5 - relocation

Approach	Whole life cash cost	Whole life PV cost
Relocate from present day	£3,680k	£3,680k
Relocate from year 30	£3,680k	£1,311k
Relocate from year 50	£3,680k	£726k
Relocate from year 70	£3,680k	£402k

5.2 Option development – Unit B

5.2.1 Do Nothing

The Do Nothing option represents a hypothetical 'walk away' scenario which is used as a baseline against which to appraise the various 'Do Something' management options.

Under Do Nothing the existing defences will be abandoned in terms of maintenance or repair, and no remedial or additional protection works will be carried out. In addition, adaptation to sea level rise or other climate change responses will not be addressed.

With this approach, the existing defences along the frontage will fail at the end of their residual service life and the land behind will be subject to flooding and erosion.

The Do Nothing scenario is only being considered in accordance with the Defra guidance for comparison purposes and is not being considered for implementation by BCKLWN.

5.2.2 Do Minimum

The Do Minimum option essentially represents the existing 'status quo'. Under this approach, small scale reactive maintenance and patch repair work, as well as activities to maintain Health and Safety compliance will be undertaken. Doing Minimum will help to increase the residual life of the assets and delay the point at which they are expected to fail. For the purpose of the economic assessment it has been assumed that the residual life of the defences will be extended by 5-10 years compared to the Do Nothing scenario. However, once the defences fail it is assumed that no further works will take place.

In addition, with the Do Minimum approach the floodgates along the rear floodwall on the promenade will continue to operate until the defences fail which will reduce the flood risk along the frontage (compared to Do Nothing). Do Minimum does not allow for any adaptation to sea level rise or other climate change responses (i.e. no crest raising) so flood risk through overtopping of the defences is expected to increase in the future.

Table 5-15 below presents the undiscounted annual cost for patch and repair works for the full length of Unit B frontage to deliver the Do Minimum option. It has been assumed that both the groynes and seawall will require patch and repair maintenance works. The total annual cost for the Do Minimum option for Unit B, encompassing patch and repair works is approximately £21.5k per year.

Table 5-15: Undiscounted costs for Do Minimum

Description	Seawall patch and repair rate	Groyne patch and repair rate	Total annual cost
Patch and repair	£820 per km per year	£1,050 per groyne per year	£21.5k per year

Present value whole life costs for the next 100 years are presented in Table 5-16. The whole life costs assume a consistent annual investment of £21.5k per year for the duration of the 100-year appraisal period. This level of investment will not be sufficient to maintain the defences in their current condition and the defences are likely to fail at the end of their extended service life. This could lead to both erosion and flood risk to the properties and infrastructure behind the defences.

The present value whole life cost to implement the Do Minimum option is approximately £641k. In cash terms this equates to £2,150k over the next 100 years.

Table 5-16: Whole life costs for Do Minimum

Option	Includes	Cash whole life cost	PV whole life cost
Do Minimum	- Seawall patch and repair - Groynes patch and repair	£2,150k	£641k

Note that a 60% optimism bias has been applied to Unit B costs

An environmental assessment of this approach has been undertaken and is presented in Table 5-17 below. In summary, Do Minimum is likely to lead to loss of habitats and significant social and economic damage.

Table 5-17: Environmental assessment for Do Minimum

Key positive effects	Key negative effects	Mitigation or enhancement opportunities
- Will allow nature to take its course - Potential expansion of the intertidal area - Avoids construction works	- Significant loss of habitats and amenity areas - Significant social and economic damage	- Low cost environmental enhancement possible such as groyne vertipools

5.2.3 Maintain

The Maintain option represents a proactive approach to maintenance and refurbishment and involves scheduled capital refurbishments of the existing defences to extend the life of the defences throughout the entire 100 year appraisal period. The approach will require increased investment compared to the existing 'status quo'. The Maintain approach will ensure that the existing line of defences is kept in place at its current height for the duration of the appraisal period and will support the SMP Hold the Line policy. This will provide significant erosion benefits to the study area.

The most suitable combination of long list measures for Unit B has been identified to implement this option, balancing feasibility and cost. The approach involves re-facing the existing defences by encasing the face of the existing seawall and promenade with a reinforced concrete layer. This is expected to extend the service life of the defences by approximately 30 years and represents the most cost-effective way to maintain the line of the existing defences and prevent erosion. In addition to this, the floodgates situated along the floodwall will also be replaced.

In addition to the re-facing of the seawall this option will also include the significant refurbishment of the timber groynes and potentially modification of the concrete groynes along the frontage. This will help to sustain beach levels which will in turn support the defences at the back of the beach by absorbing wave energy along the frontage. For more information on the groyne refurbishments refer to section 5.2.6.

The initial capital refurbishments of the seawall and the groynes will not be carried out immediately but towards the end of the residual service life of the existing structures. For costing purposes this has been assumed to be from year 15 for the seawall and year 5 for the groynes. Repeat interventions will be required over the duration of the next 100 years towards the end of the extended service lives of the re-faced / refurbished defences. For the purpose of costing it has been assumed that repeat interventions will be required on average every 30 years.

As with the Do Minimum approach, the floodgates along the rear wave return wall at the back of the promenade will remain operational with the Maintain option which will reduce the flood risk along the frontage (compared to Do Nothing). However, the Maintain option does not allow for any adaptation to sea level rise or other climate change responses (i.e. the crest of the defences will not be raised during capital refurbishment works) so flood risk through overtopping of the defences is expected to increase in the future.

Figure 5-6: Photograph examples of re-facing seawall defences

The whole life cash (undiscounted) and present value costs for the Maintain option are presented in Table 5-18. The present value whole life cost for the option is estimated to be approximately £7,853k. In cash terms this equates to £31,001k over the next 100 years.

Table 5-18: Whole life costs for the Maintain option

Option	Includes	Cash whole life cost	PV whole life cost
Maintain	- Repeat re-facings of seawall, promenade and floodwall, approx. every 30 years - Repeat refurbishments of timber and concrete groynes	£31,001k	£7,853k

Note that a 60% optimism bias has been applied to Unit B costs

An environmental assessment of this approach has been undertaken and is presented in Table 5-19 below. In summary, Maintain is likely to lead to disruption during construction and there is the potential for contaminants to be released during construction although this should be investigated further and mitigated accordingly.

Table 5-19: Environmental assessment for Maintain

Key positive effects	Key negative effects	Mitigation or enhancement opportunities
- Will enable the seawall to continue to protect socio-economic receptors against erosion - Likely to be supported by the public - No significant change in the footprint / aesthetic of the structure	- Some disruption to public access of the promenade and beach during the construction works - Potential release of contaminants during construction - Will not enhance the natural environment	- Low cost environmental enhancement possible such as groyne vertipools - Construction during off-peak times (i.e. during winter)

5.2.4 Sustain

The Sustain option involves raising the crest level of the defences over time to keep pace with sea level rise and ensure that the flood risk does not increase (compared to the existing Standards of Protection). In addition, the approach to maintaining the defences as outlined in the Maintain Option will also be implemented to prolong the residual life of the existing seawall ensuring that the defences remain structurally sound and continue to protect against erosion.

By maintaining the position of the defences and sustaining the Standard of Protection (SoP) this option provides both erosion and flood risk benefits in the future. The approach will support the SMP policy of Hold the Line for the duration of the appraisal period.

The most suitable long list measure for Unit B to implement this option has been identified, balancing feasibility and cost. The approach will involve raising the height of the floodwall at the rear of the promenade. This could be achieved by installing an additional reinforced concrete capping on top of the existing defence. If it is decided to raise the floodwall at the back of the defence it will also be necessary to replace the floodgates with new higher gates (as these are situated along the wall).

For the purpose of costing it has been assumed that the crest levels of the defences will be raised in three intervals over the appraisal period to match the levels of sea level rise which are observed over the next century. It has been assumed that these will coincide with the timings of refurbishing the defences as per the Maintain Option (i.e. not immediately and roughly every 30 years thereafter). By adopting this approach it ensures that the Sustain option is adaptive and means that future heights of raising can be adjusted based on the rates of sea level rise that are observed / predicted in the future.

Like the Maintain option, this option also includes for the significant refurbishment of the timber groynes and potentially the modification of the concrete groynes along the frontage.

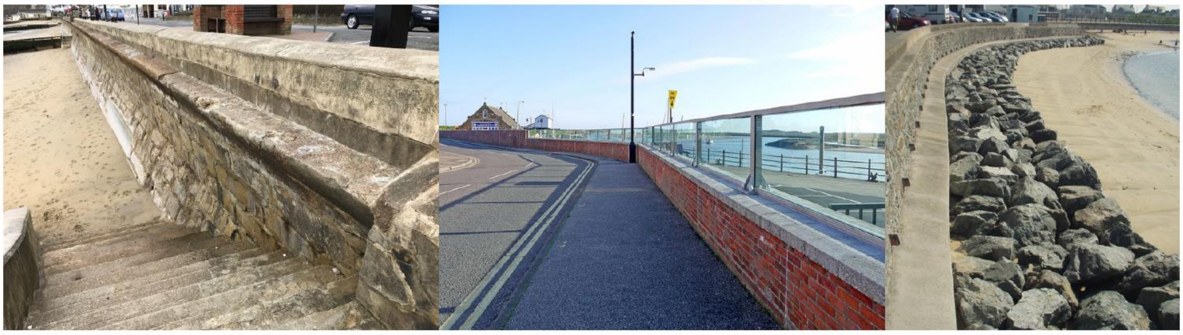

Figure 5-7: Photograph examples of crest raising to structures to increase the existing height of the defences

The whole life cash (undiscounted) and present value costs for the Sustain option are presented in Table 5-20. The present value whole life cost for the option is estimated to be approximately £9,208k. In cash terms this equates to £36,656k over the next 100 years.

Table 5-20: Whole life costs for the Sustain option

Option	Includes	Cash whole life cost	PV whole life cost
Sustain	- Crest raising at 30 year intervals - Repeat re-facings of seawall, promenade and floodwall, approx. every 30 years - Repeat refurbishments of timber and concrete groynes	£36,656k	£9,208k

Note that a 60% optimism bias has been applied to Unit B costs

An environmental assessment of this approach has been undertaken and is presented in Table 5-21 below. In summary, Sustain is likely to lead to disruption during construction and there is the potential for contaminants to be released during construction although this should be investigated further and mitigated accordingly. Increasing the height of the existing defences could also impact the visual and landscape aesthetics of the area.

Table 5-21: Environmental assessment for Sustain

Key positive effects	Key negative effects	Mitigation or enhancement opportunities
- Will enable the seawall to provide the same level of flood protection to socio-economic receptors in spite of climate change predictions - Will enable the seawall to continue protecting against erosion risk - No significant change in the footprint / aesthetic of the structure	- Some disruption to public access of the promenade and beach during the construction works - Potential release of contaminants during construction - Will not enhance the natural environment - Will potentially impact on visual and landscape aesthetics	- Low cost environmental enhancement possible such as groyne vertipools - Construction during off-peak times (i.e. during winter) - Glass based crest raising to sustain views of the seafront

5.2.5 Improve

The Improve option involves actively improving the standard of protection against flooding and erosion. This approach requires the greatest investment of the management options but will deliver the highest SoP and the largest economic benefits.

The Improve option is precautionary in that crest levels will be raised in one implementation (rather than in multiple interventions as in the Sustain option). It has been assumed for costing purposes that this will be undertaken toward the end of the residual life of the existing defences.

The most suitable long list measure for Unit B to implement this option has been identified, balancing feasibility and cost. The approach will involve the construction of a new seawall along the frontage, in place of the existing defences (including floodgates) at the end of their service life. In addition, where there are currently groynes present, these will be replaced with new structures at the end of their residual service life. For more information on the groyne works, refer to section 5.2.6.

Figure 5-8: Photograph examples of new seawall structures

The whole life cash (undiscounted) and present value costs for the Improve options are presented in Table 5-22. The present value whole life cost for these options are estimated to be between £18,992k and £21,014k. In cash terms this equates to between £44,283 and £50,777k over the next 100-years.

Please note at this stage of the option development process the size, scale and nature of a new enhanced seawall in Hunstanton has not yet been fully determined, therefore for cost estimation and comparison purposes the Environment Agency's cost estimation for coastal protection guidance (Report –SC080039/R7) has been used.

Table 5-22: Whole life costs for the Improve options

Option	Includes	Cash whole life cost	PV whole life cost
Improve 1	- Construction of new seawall - Construction of new timber groynes (all sections)	£50,777k	£21,014k
Improve 1A	- Construction of new seawall - Construction of new timber groynes (sections A-E) - Extended concrete groynes (section G)	£50,081k	£20,277k
Improve 2	- Construction of new seawall - Construction of new rock groynes (all sections)	£44,283k	£18,992k
Improve 2A	- Construction of new seawall - Construction of new rock groynes (sections A-E) - Extended concrete groynes (section G)	£45,632k	£19,231k

Note that a 60% optimism bias has been applied to Unit B costs

An environmental assessment of this approach has been undertaken and is presented in Table 5-23 below. In summary, Improve is likely to lead to disruption during construction and there is the potential for contaminants to be released during construction although this should be investigated further and mitigated accordingly. Increasing the height of the existing defences could also impact the visual and landscape aesthetics of the area and will lead to a larger defence footprint than currently in place.

Table 5-23: Environmental assessment for Improve

Key positive effects	Key negative effects	Mitigation or enhancement opportunities
- Will enhance the level of flood protection to socio-economic receptors in spite of climate change predictions - Will enable the seawall to continue protecting against erosion risk - Could potentially enhance the public amenity space	- Some disruption to public access of the promenade and beach during the construction works - Potential for new defence to have larger footprint and encroach into the intertidal area - Potential release of contaminants during construction - Will not enhance the natural environment - Will potentially impact on visual and landscape aesthetics - Could potentially be detrimental to the public amenity spaces	- Low cost environmental enhancement possible such as groyne vertipools - Construction during off-peak times (i.e. during winter) - Promenade improvements for access etc. - Landscaping opportunities for new defences

5.2.6 Details of groyne refurbishments / improvements for Maintain and Sustain and Improve

5.2.6.1 Existing timber groynes

The existing timber groynes in Unit B (sections A-E) currently appear to be performing well and act to hold the beach material in front of the seawall, despite being in a mixed state of repair.

Maintain / Sustain Options

Therefore, for appraisal and pricing purposes the Maintain and Sustain options look to prolong the life of the existing timber groynes through refurbishment at regular intervals throughout the appraisal period. This will include replacing the various timber elements that are either damaged or missing with a like-for-like tropical hardwood replacement. No significant changes would be made to the design of the groynes and they would remain permeable. Typically the majority of the timber elements that need replacing are located at the seaward end of the groynes. Future works will also include the continuation of on-going routine maintenance on an annual basis.

Figure 5-9: Photographs of the timber groynes in Unit B

The advantages and disadvantages of refurbishing the existing timber groynes are presented below:

Advantages

- Existing structure is very effective at maintaining beach levels in front of the seawall, refurbishing or replacing will prolong the life of the existing structures.
- Refurbishing or replacing the existing groynes will improve their performance retaining beach levels.
- Construction can be staggered; through condition assessment as different elements/groynes can be prioritised and planned at intervals.
- The additional structure will be similar in appearance to the existing defence and therefore will have only limited impact on the visual landscape.
- Known construction methodology
- Tropical hardwood is comparatively more effective in marine environments than locally sourced oak.
- Works will avoid impacting on the promenade

Disadvantages

- Refurbishing/replacing the existing groynes will increase their ability to retain material and therefore reduces the amount of sediment available for down drift locations.
- Refurbishment can be technically challenging particularly with the groynes partially hidden beneath the beach.
- The groynes extend far down the beach which means that there will be a reduced tidal window to work in which has an impact on safety and cost through an extended programme.
- Although better than oak, tropical timber still has a relatively short residual life and as a consequence is expensive to maintain.
- Environmental implications of importing tropical timber (and added cost of ensuring sustainably sourced).

Whole life costs for the timber groyne works for the next 100 years are presented in Table 5-24 below. The refurbishment costs have been included in the whole life costs for the Maintain and Sustain options and the replacement costs have been included in the whole life costs for the Improve option (i.e. the costs presented inTable 5-24 are not additional to the option costs presented in the sections above).

Improve options

For the Improve options it is assumed that the existing groynes will need to be replaced with either a new timber groyne field or an alternative rock groyne option, both of which will be designed to optimise performance, yet minimise their impact on the amenity areas of the beach.

Enhanced timber groynes

The advantages and disadvantages of new enhanced timber groynes are presented below:

Advantages	Disadvantages
- A new timber structure will be similar in appearance to the existing groynes and therefore will have only limited impact on the visual landscape	- Increasing the performance of the groynes will increase their ability to retain material and therefore reduces the amount of sediment available for down drift locations
- Known construction methodology	- The groynes will extend further down the beach which means that there will be a reduced tidal window to work in, which has on impact on safety and cost through an extended programme
- Longer impermeable timber groynes will have a greater ability to trap material, maintain beach levels and therefore protect the seawall	- Construction can be technically challenging particularly with the groynes extended into the intertidal zone
	- Although better than oak, tropical timber has a relatively short residual life and as a consequence is expensive to maintain
	- Environmental implications of importing tropical timber (and added cost of ensuring sustainably sourced)

Alternative rock armour groynes

The advantages and disadvantages of new alternative rock groynes are presented below:

Advantages	Disadvantages
- Very durable and therefore low maintenance compared to timber alternatives	- Increasing the performance of the groynes will increase their ability to retain material and therefore reduces the amount of sediment available for down drift locations
- Rock can easily be relocated or adjusted to optimise their position	- The groynes will extend far down the beach which means that there will be a reduced tidal window to work in which has an impact on safety and cost through an extended programme
- Longer rock groynes will potentially increase their ability to trap material, maintain beach level and protect the seawall	- Construction can be technically challenging particularly with the groynes extended into the intertidal zone
- Deliveries via the sea prevent any disruption to the town (i.e. traffic etc.)	- Environmental implications of importing rock
- Rock armour has the potential to create some new habitats in the intertidal zone	- Aesthetically different to the existing structures on the frontage, potential visual and landscape impact
	- Potential planning and consenting issues

Costs

Whole life costs for the groyne works in Sections A-E of Unit B over the next 100 years are presented in Table 5-24 below. Please note that these costs have respectively been included in the whole life costs for the Maintain and Sustain and Improve options presented in the sections above (i.e. the costs presented in Table 5-24 are not additional to the option costs presented above).

Table 5-24: Whole life cost estimates for timber groyne works

Approach	Options included in	Cash whole life cost	PV whole life cost
Refurbish the existing timber groynes	Maintain Sustain	£6,736k	£2,141k
New enhanced timber groynes	Improve	£10,054k	£3,415k
Alternative rock groynes	Improve	£5,604k	£2,369k

Note that a 60% optimism bias has been applied to Unit B costs

Environmental assessment

An environmental assessment of the timber groyne works has been undertaken and is presented in Table 5-25 below. In summary, refurbishment or replacing the timber groynes in this location is likely to lead to impacts on carbon footprint and beach access, but will have a number of significantly positive impacts.

Table 5-25: Environmental assessment for groyne works (Section A-E)

Key positive effects	Key negative effects	Mitigation or enhancement opportunities
Refurbish existing timber groynes		
- The continued use of permeable groynes will avoid interfering with existing coastal processes - Aesthetically similar in appearance to the existing defences, i.e. will not significantly impact on the existing landscape - No significant change to the footprint of the structure - No significant impacts to the amenity use of the beach - Will continue to retain beach levels to protect the seawall and therefore protect socio-economic receptors against erosion	- Tropical timbers are likely to be sourced internationally with large carbon footprints - Construction will cause significant disruption on the beach - Rock armoured toe could potentially impact on coastal processes - On-going maintenance works	- Environmental enhancement opportunities i.e. Vertipools etc. - Timing construction to cause least disruption to beach access and recreation (i.e. during the winter)
Enhanced timber groynes		
- Longer impermeable groynes will have an improved ability to retain beach levels to protect the seawall and therefore protect socio-economic receptors against erosion - No significant impacts to the amenity use of the beach - Aesthetically similar in appearance to the existing defences, i.e. will not significantly impact on the existing landscape	- Longer impermeable groynes will have a greater impact on coastal processes and local designations - Increasing the performance of the groynes will increase their ability to retain material and therefore reduces the amount of sediment available for down drift locations. - Tropical timbers are likely to be sourced internationally with large carbon footprints - Construction will cause significant disruption on the beach - On-going maintenance works	- Environmental enhancement opportunities i.e. Vertipools etc. - Timing construction to cause least disruption to beach access and recreation (i.e. during the winter)
Alternative rock groynes		
- Will potentially enhance the amenity use of the beach which will benefit local tourism (beyond construction) - Will continue to retain beach levels to protect the seawall and therefore protect socio-economic receptors against erosion - Limited future maintenance requirements	- Construction will cause significant disruption on the beach - Aesthetically very different to the existing defences, and will therefore impact on the existing landscape - The increased performance of rock groynes will increase their ability to retain material and therefore reduces the amount of sediment available for down drift locations. - Longer/larger rock groynes will have a greater impact on local coastal processes and local designations	- Environmental enhancement opportunities through new habitats created by rock armour. - Timing construction to cause least disruption to beach access and recreation (i.e. during the winter)

5.2.6.2 Existing concrete groynes

The existing concrete groynes at the northern end of Unit B (Section G) are considerably shorter than the timber alternatives to the south (Sections A-E). They appear to retain some material although the beach profile appears to have dropped from when they were installed. Historical aerial imagery indicates they have been effective in retaining material in the past.

Although refined beach modelling has not yet been undertaken for this specific section of the frontage; for option appraisal and costing purposes the following approaches have been considered for modifying / replacing the existing concrete groynes to improve their performance (these would fall under the Improve management approach, under the Maintain and Sustain approaches like-for-like refurbishment would be undertaken to the concrete groynes similar to the approach described above for the timber groynes):

1. Extend the length of the existing concrete groynes
2. Replace the existing concrete groynes with an extended timber alternative in keeping with those found to the south (sections A-F)
3. Replace the existing groynes with an extended rock armour alternative

Extend the length of the existing concrete groynes

The advantages and disadvantages of extending the existing concrete groynes are presented below:

Advantages	Disadvantages
- Extending the existing structure will potentially increase its ability to trap material, maintain beach levels and protect the seawall	- Increasing the performance of the groynes will increase their ability to retain material and therefore reduces the amount of sediment available for down drift locations
- The additional structure will be similar in appearance to the existing groynes and therefore will have only limited impact on the visual landscape	- Construction can be technically challenging particularly with the groynes extended into the intertidal zone
- Very durable and therefore low maintenance compared to the timber alternatives	- The groynes will extend far down the beach which means that there will be a reduced tidal window to work in which has on impact on safety and cost through and extended programme
- Known construction methodology	- Potential planning and consenting issues

Replace with extended timber alternative

The advantages and disadvantages of replacing the concrete groynes with new timber groynes are presented below:

Advantages	Disadvantages
- A new timber structure will be similar in appearance to the neighbouring groynes and therefore will have only limited impact on the visual landscape	- Increasing the performance of the groynes will increase their ability to retain material and therefore reduces the amount of sediment available for down drift locations
- Known construction methodology	- The groynes will extend far down the beach which means that there will be a reduced tidal window to work in which has on impact on safety and cost through an extended programme
- Longer timber groynes will potentially increase their ability to trap material, maintain beach level and protect the seawall	- Construction can be technically challenging particularly with the groynes extended into the intertidal zone
	- Although better than oak, tropical timber has a relatively short residual life and as a consequence is expensive to maintain
	- Environmental implications of importing tropical timber (and added cost of ensuring sustainably sourced)

Replace with extended rock armour alternative

The advantages and disadvantages of a new extended rock alternative are presented below:

Advantages	Disadvantages
- Very durable and therefore low maintenance compared to timber alternatives	- Increasing the performance of the groynes will increase their ability to retain material and therefore reduces the amount of sediment available for down drift locations
- Rock can easily be relocated or adjusted to optimise their position	- The groynes will extend far down the beach which means that there will be a reduced tidal window to work in which has an impact on safety and cost through an extended programme
- Longer rock groynes will potentially increase their ability to trap material, maintain beach level and protect the seawall	- Construction can be technically challenging particularly with the groynes extended into the intertidal zone
- Easy to construct	- Environmental implications of importing rock
- Deliveries via the sea prevent any disruption to the town (i.e. traffic etc.)	- Aesthetically different to the existing structures on the frontage, potential visual and landscape impact
- Rock armour has the potential to create some new habitats in the intertidal zone	- Potential planning and consenting issues

Costs

Whole life costs for the concrete groyne works for the next 100 years are presented in Table 5-26 below. The extension costs have been included in the whole life costs for the Maintain and Sustain options and the replacement with timber costs have been included in the whole life costs for the Improve option (i.e. the costs presented in Table 5-26 are not additional to the option costs presented in the sections above).

Table 5-26: Whole life cost estimates for works to existing concrete groynes

Approach	Options included in	Cash whole life cost	PV whole life cost
Refurbish existing groynes (30%)	Maintain Sustain	£2,218k	£671
Extend existing groynes (100%)	Improve	£4,526k	£1,628k
Replace with 126m timber groynes x9	Improve	£5,072k	£2,345k
126m rock groyne alternative x5	Improve	£4,526k	£1,628k

Note that a 60% optimism bias has been applied to Unit B costs
Note no allowance has been made at this stage for the demolition of existing groynes.

Environmental assessment

An environmental assessment of the concrete groyne works has been undertaken and is presented in Table 5-27 below. In summary, the concrete groyne works in this location are likely to lead to impacts on carbon footprint and beach access, but will have a number of significantly positive impacts.

Table 5-27: Environmental assessment for works to existing concrete groynes

Key positive effects	Key negative effects	Mitigation or enhancement opportunities
Concrete maintenance and improvements		
- Aesthetically similar in appearance to the existing groynes, i.e. may not significantly impact the landscape - Will potentially enhance the amenity use of the beach - Will enable the groynes to retain beach levels to protect the seawall and therefore protect socio-economic receptors against erosion - Maintaining beach levels will benefit local tourism (beyond construction)	- Extending the groynes will potentially impact on existing coastal processes - Construction will cause significant disruption to the beach - Enhancement options will significantly change the footprint of the structure and will encroach on the intertidal zone - Increasing the performance of the groynes will increase their ability to retain material and therefore reduces the amount of sediment available for down drift locations.	- Environmental enhancement opportunities i.e. Vertipools etc. - Timing construction to cause least disruption to beach access and recreation (i.e. during the winter)
Enhanced timber groynes		
- New longer timber groynes will have an improved ability to retain beach levels to protect the seawall and therefore protect socio-economic receptors against erosion - Will potentially enhance the amenity use of the beach which will benefit local tourism (beyond construction)	- Longer groynes will have a greater impact on coastal processes - Aesthetically very different to the existing defences, and will therefore impact on the existing landscape - Increasing the performance of the groynes will increase their ability to retain material and therefore reduces the amount of sediment available for down drift locations. - Tropical timbers are likely to be sourced internationally with large carbon footprints - Construction will cause significant disruption on the beach - On-going maintenance works	- Environmental enhancement opportunities i.e. Vertipools etc. - Timing construction to cause least disruption to beach access and recreation (i.e. during the winter)

Alternative rock groynes		
- Will potentially enhance the amenity use of the beach which will benefit local tourism (beyond construction) - Will continue to retain beach levels to protect the seawall and therefore protect socio-economic receptors against erosion - Limited future maintenance requirements	- Construction will cause significant disruption on the beach - Aesthetically very different to the existing defences, and will therefore impact on the existing landscape - The increased performance of rock groynes will increase their ability to retain material and therefore reduces the amount of sediment available for down drift locations. - Longer/larger rock groynes will have a greater impact on local coastal processes	- Environmental enhancement opportunities through new habitats created by rock armour. - Timing construction to cause least disruption to beach access and recreation (i.e. during the winter)

5.3 Summary of short-list options

Table 5-28 below summarises the short-list options for units A and B. Whole life costs are provided for the options being implemented now (i.e. present day) for the Pilot study for Unit A and the full frontage for Unit B. The whole life PV costs are used to compare against the option benefits to determine the benefit cost ratios in the economic assessment.

Table 5-28: Summary of short list options

Unit	Option	Involves	WL Cash cost (£k)	WL PV cost (£k)
A (pilot study)	Improve 1	- Rock armour revetment - Periodic maintenance	£972k	£636k
	Improve 2	- Timber revetment - Periodic maintenance and replacement	£1,809k	£826k
	Improve 3	- Geotube revetment - Periodic maintenance and replacement	£2,840k	£1,106k
	Improve 4	- Periodic beach nourishment and recycling	£6,591k	£2,696k
	Improve 5	- Relocation (and subsequent move if necessary)	£3,680k	£3,680k
B	Do Minimum	- Ongoing patch and repair	£2,150k	£641k
	Maintain	- Periodic re-facing of defences - Periodic refurbishment of timber groynes and concrete groynes	£31,001k	£7,853k
	Sustain	- As per maintain option with: - Defence raising in intervals	£36,656k	£9,208k
	Improve 1	- Construction of new seawall - Construction of new timber groynes (all sections)	£50,777k	£21,014k
	Improve 1A	- Construction of new seawall - Construction of new timber groynes (sections A-E) - Extended concrete groynes (section G)	£50,081k	£20,277k
	Improve 2	- Construction of new seawall - Construction of new rock groynes (all sections)	£44,283k	£18,992k
	Improve 2A	- Construction of new seawall - Construction of new rock groynes (sections A-E) - Extended concrete groynes (section G)	£45,632k	£19,231k

Appendix A – Outline designs of short-listed options

AECOM
Midpoint
Alencon Link
Basingstoke
RG21 7PP