Jacobs

Happisburgh: Assessment of Rock Bund and Beach Access

Document no: B2491800-JAC-RPT-001 [P03]
Revision: P03

North Norfolk District Council
Coastwise- Happisburgh
8 May 2025

COASTWISE

Department for Environment Food & Rural Affairs

Environment Agency

Coastal transition accelerator programme

Part of the £200m
Flood and coastal innovation programmes

Happisburgh: Assessment of Rock Bund and Beach Access

Client name: North Norfolk District Council

Project name: Coastwise- Happisburgh

Document no: B2491800-JAC-RPT-001 [P03]

Revision: P03

Date: 8 May 2025

Project no: B2491800

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File name: B2491800-JAC-RPT-001_Happisburgh Assessment of Rock Bund and Beach Access_P02

Document history and status

Revision	Date	Description	Author	Checked	Reviewed	Approved
P01	20-01-25	Draft for comment	E. Marshall/ K. Burgess	L. Baker	K. Burgess	L. Baker
P02	20-02-25	Final issue	K. Burgess	L.Baker	L.Baker	L.Baker
P03	08-05-25	Inclusion of logo block	L.Baker	L.Baker	L.Baker	L.Baker

Distribution of copies

Revision	Issue approved	Date issued	Issued to	Comments
P01	L. Baker	20-01-25	A. Zangs	Draft for comment
P02	L.Baker	25-02-25	A. Zangs	Final following comments
P03	L.Baker	08-05-25	A. Zangs	Inclusion of funding logo block

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Acronyms and abbreviations

ACMP	Anglian Coastal Monitoring Programme
AONB	Area of Natural Outstanding Beauty
BGS	British Geological Survey
HAT	Highest Astronomical Tide
LAT	Lowest Astronomical Tide
MHWN	Mean High Water Neap
MHWS	Mean High Water Spring
mOD	meters Ordnance Datum
MSL	Mean Sea Level
NCC	Norfolk County Council
NNDC	North Norfolk District Council
SSSI	Site of Special Scientific Interest

1. Introduction

1.1 Background

The North Norfolk coast has some of the most rapidly eroding coastlines in Europe, due to its soft erodible cliffs and natural coastal processes. Aging time-expired defence assets and a long-term trend of falling beach levels means North Norfolk District Council (NNDC) have in the past introduced a range of measures at Happisburgh to help the community transform and be better prepared for the challenges posed by climate accelerated coastal erosion.

A key element of that has been the installation of a low level rock bund, designed to help manage the erosion in front of Happisburgh village. This is in accordance with the Managed Realignment policy in the Shoreline Management Plan (SMP) (EACG, 2012).

The intertidal zone is privately owned and leased to NNDC for coastal management.

1.2 Scope

North Norfolk District Council engaged Jacobs to assess the effectiveness of the existing rock armour approach at Happisburgh, identify any possible alternative approaches to utilise that rock, and to assess continued provision of beach access.

The key objectives are:

- To identify the most realistic beneficial approach to utilise the existing rock armour placed on the beach at Happisburgh with regards slowing erosion rates, when considering the constraints (e.g. policy, designations, site, practicality and economic).
- To assess and identify viable options to provide ongoing and predictable beach access for pedestrians and where practicable, coastal risk management vehicles at Happisburgh.

1.3 Structure of this report

Section 2 provides some background on erosion at Happisburgh and section 3 gives details on the rock bund.

In section 4, the rock bund is assessed, considering a range of measures, providing conclusions on its effectiveness to date.

Based upon the information derived from those previous sections, key information is drawn together in section 5 to inform the considerations for any future rock installations. Also included in this sections is any additional information that might be useful in considering those options.

Section 6 then presents potential alternative uses for the rock to provide erosion management at Happisburgh, including technical merits, potential constraints, and any other points that might need to be taken into account if alternatives are to be considered in the future.

Attention is then drawn to both pedestrian and vehicular beach access in Section 8, where options for the continuation of that are considered.

2. Overview of Erosion at Happisburgh

2.1 Shoreline Change

Erosion along the cliffed North Norfolk coastline is not a recent occurrence, but has been happening for centuries. The Doomsday book mentions Whimpwell, a lost village that would have been situated slightly to the south of Happisburgh. This is believed to have extended nearly 2 miles seaward of the present coastline. Later references also indicate erosion concerns at Happisburgh as far back as the late 19th Century, around the Low Light being claimed by the sea, with this ceasing to function in 1883 (Weston, 1994).

Aerial photography from the middle of the last century (date believed to be 1948) shows the shoreline prior to the construction of defence assets (Figure 2-1, ref NCC). Although it was and would continue to erode, this provides a template for how the whole shoreline orientation might look had there been no defences constructed. This natural orientation has been superimposed onto the latest aerial photograph from 2024, to show how defence interventions have since altered the shoreline. (Figure 2-2).

Figure 2-1. Happisburgh coastline prior to defences being built (believed to be circa 1948, ref NCC)

Figure 2-2. Happisburgh coastline October 2024 (blue dotted line indicates 'natural' alignment of the shoreline had it not been defended)

2.2 Erosion mechanisms

2.2.1 Coastal processes

Surveys and mapping commissioned by NNDC has recorded the change in cliff position over the past two decades, see Figure 2-3. These illustrate that the ongoing changes that have occurred along the Happisburgh frontage are not linear, i.e. retreating by the same amount year-on-year, but can vary considerably. This is the result of a combination of factors, including the variability in the occurrence of storm waves and surge events and the natural input or loss of sand from beaches in front of the cliffs.

Figure 2-3. Cliff top lines from 2000 to 2024 along the Happisburgh frontage (zoomed in view on lower image)

Sediment input to the beaches here is primarily from the erosion of cliffs further to the north, and material arising from the erosion of the cliffs at Happisburgh itself. But those same transport mechanisms also continually move that material on further to the south. Clay eroded from the cliffs does not form beach building material so it removed altogether by waves and tidal currents.

2.2.2 Geology

Happisburgh cliffs are composed of a sequence of several glacial tills, separated by beds of stratified silt, clay and sand (BGS, nd), making them prone to erosion and groundwater failures. BGS provide a conceptual model of seasonal coastal erosion at Happisburgh, shown in Figure 2-4. This suggests that in winter, groundwater causes gullying of the cliff face and thus small-scale but frequent shallow land sliding of the weak, easily erodible sand. Undercutting of the cliff toe by wave forces reduces cliff stability and causes cliff failure. Storms are also more severe and frequent in winter. BGS suggest that due to the elevated beach levels in the summer and thus the coverage of the 'winter platform,' in summer, wave attack is the most dominant form of erosion, combined with land sliding at Happisburgh (BGS, nd).

The level of the clay does undulate along the frontage, so is of inconsistent height above the beach. It's composition also varies, ranging from a more resistant grey (siltier) clay to a softer brown (sandier) clay

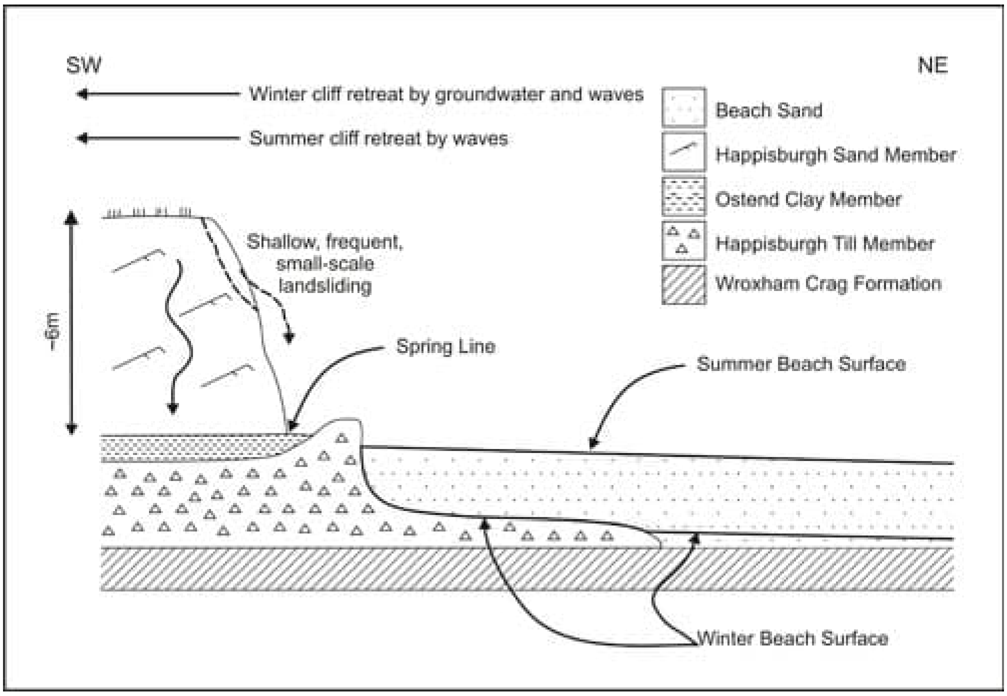


Figure 2-4. Seasonal erosion mechanisms at Happisburgh. Source: BGS (nd)

2.2.3 Surface water

Surface water run off also plays a part in erosion of Happisburgh Cliffs. For example in 2021 it was reported that there had been two significant ground failures (washouts) of the field in front of the Lighthouse resulting in deep cliff slips. These failures, one near the car park, and one 400 metres east, were caused by surface water run-off from the field which slopes seaward resulting in a significant water flow sufficient to make deep cuts in the cliff edge. More recently the development of the cut known locally as the 'Grand Canyon' appears to be a result of this process. This mechanism is probably exacerbated by the presence of the clay near to ground level, preventing the water from penetrating deeper into the soil.

This is an issue not just on the agricultural frontages but also noted to be a likely contributing cause of a large cut back into the cliff at the end of the lane off Beach Road that led to the original beach ramp.

3. Rock Bund

3.1 History/Timeline

The following details summarise the timeline of works along the frontage leading up to the present bund configuration.

3.1.1 Pre-bund (pre-2000)

Prior to construction of the rock bund, a timber revetment and groynes were constructed between Ostend and Cart Gap. These still remain in part to the north of Happisburgh village. The revetment to the south of the village was the lost as a result of storms in the 1990s.

The timeline of these events is presented in Table 3-1 below.

Table 3-1. Timeline of pre-2000 works

Date	Event
1959 to 1961	Timber revetment and groynes constructed between Ostend and Cart Gap
1968	Beach Road groynes constructed
1982	Partial reconstruction of damaged revetment and groynes
1986	Cart Gap Seawall Constructed & old revetment partially removed leaving cill.
1991	Following storm damage, unsafe section of revetment (300m long) removed to south of village.
1996	Storm damage results in the loss of a further 400m of revetment and the end of beach road.

3.1.2 Initial rock work (2002-2004)

In front of Happisburgh village, initial emergency works were carried out along the line of the original timber revetment, bringing in rock to enhance defences.

The timeline of these works is presented in Table 3-2 below.

Table 3-2. Timeline of initial rock works (2002 – 2004)

Date	Event
2002 (Dec) to 2003 (Jan)	Emergency works installed (initial rock bund)
2003 (March)	Additional rock placed on beach.
2003 (Aug)	More rock placed on beach
2004 (Feb)	Repairs to timber revetment.
2004 (Sept)	Some rocks relocated.

3.1.3 Rock Bund (2007-present)

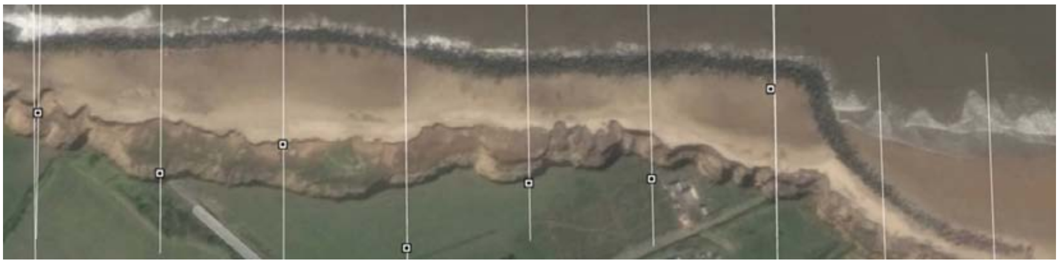
The fuller bund and configuration seen today in front of Happisburgh village dates back to 2007. This was in accordance with the planned implementation of this structure, the bund has been reconstructed and moved landward to optimise effectiveness and remain accessible for future recovery and reuse of the rock.

The timeline of these works is presented in Table 3-3.

Table 3-3. Timeline of Rock Bund (2007 to present)

Date	Event
2007	Enlarged rock berm completed
2009	4-5,000 tonne of surplus / out of specification rock delivered week commencing 26th January to Decca Field area (north of Cart Gap)
2010	Decca Field rock scheme completed. Rock moved into Happisburgh
2013	Extension of rock bund with short section to provide some protection to the new ramp (February)
2015	Rolling back of rock bund to new position further landward and closer to since eroded cliffs (October)
2019	Relocated the rock bund from low water mark to within 5m off the toe of the cliff to the present configuration (April-May)

The current structure is consented and allows for it to be ‘rolled back’ up the beach over a ten-year period (expiring on 31 August 2028), planning consent reference PF/18/0751, marine licence reference MLA/2018/00136. Figure 3-1 below shows aerial images of the bund in each of its three main configurations since 2007, with those positions relative to one another illustrated in Figure 3-2.



(a) Bund configuration 2013-2015

(b) Bund configuration 2016-2018

(c) Bund configuration 2019-present

Figure 3-1. Changes in position and alignments of the Rock Bund

Figure 3-2. Comparison of Rock Bund positions and alignments

3.2 Current bund performance (2019-present)

3.2.1 Principles of construction

The present configuration of the rock bund was constructed at approximately 400m in length, 6 m wide and to and elevation of +4.0mOD. There are approximately 9000 tonnes of rock placed in the current structure ranging in size from approximately 3-5 tonnes. The construction, broadly based on being a trapezium shaped mound of armour rock, one layer on top of the other, as illustrated in Figure 3-3 below. This is sat on top of a fabric geotextile to help resist sinking into the substrate. The photographs below show the rock as constructed in 2019 (Figure 3-4).

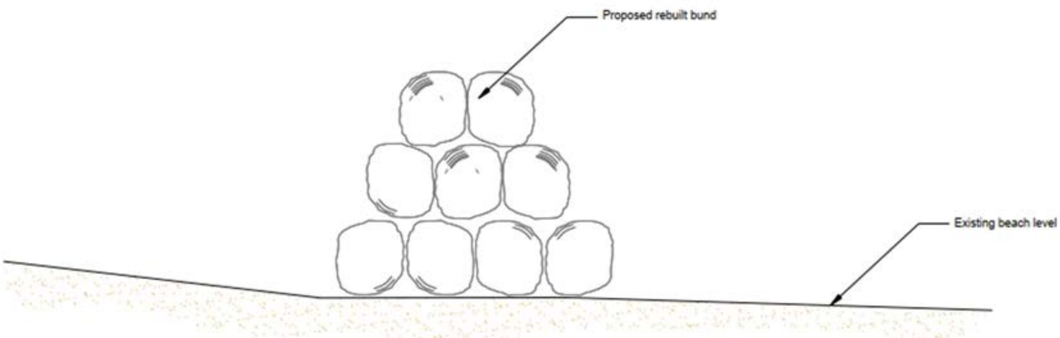


Figure 3-3. Schematic of Bund cross section

Cross section at the ramp

Consistent elevation along length when built

Figure 3-4. Rock Bund as constructed in early 2019

Through this placement, each rock will typically have at least a three-point contact with neighbouring rocks, which adds to their stability and increases their resistance against displacement from waves. The voids created between the rocks also serves to help dissipate wave energy as they break on the structure before they reach the cliff face.

As already noted, the intent of the bund is to help manage and reduce the rate of erosion, not halt it altogether. The principle is that the cliffs will have a reduced exposure to wave-induced erosion through installation of this bund. In addition to the structure limiting the frequency/impact of waves hitting the cliff, some of the sand eroded from the cliffs is also removed more slowly, being temporarily captured between the bund and the cliff, thus offering a little more of a buffer between those cliffs and the sea.

3.2.2 Post-construction changes

It is understood that the 2019 reconfiguration of the bund was all built to an approximate consistent elevation along its length (estimated to be approximately +4.0mOD). However, as can be seen from LiDAR data below in Figure 3-5, the bund elevation since reduced dramatically along all of the length with the exception of the southern-most end adjacent to the beach access ramp.

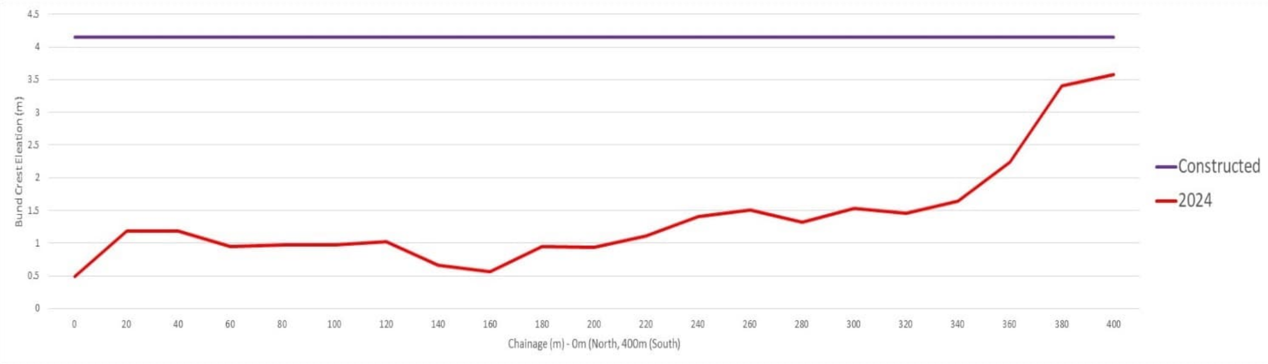


Figure 3-5. Reduction in Present Bund Crest Elevation (*Note – left to right, chainage 0 is at north end of the bund, chainage 400 is the southern end where the beach access ramp is located*)

What is particularly notable is how soon the bund elevation dropped. As Figure 3-6 shows, this reduction in elevation occurred in the most part within the first few months (the 2019 LiDAR was conducted in November while the construction of the bund had been completed in January/February). Along the southern half, there was over 2m lowering within just the first few months.

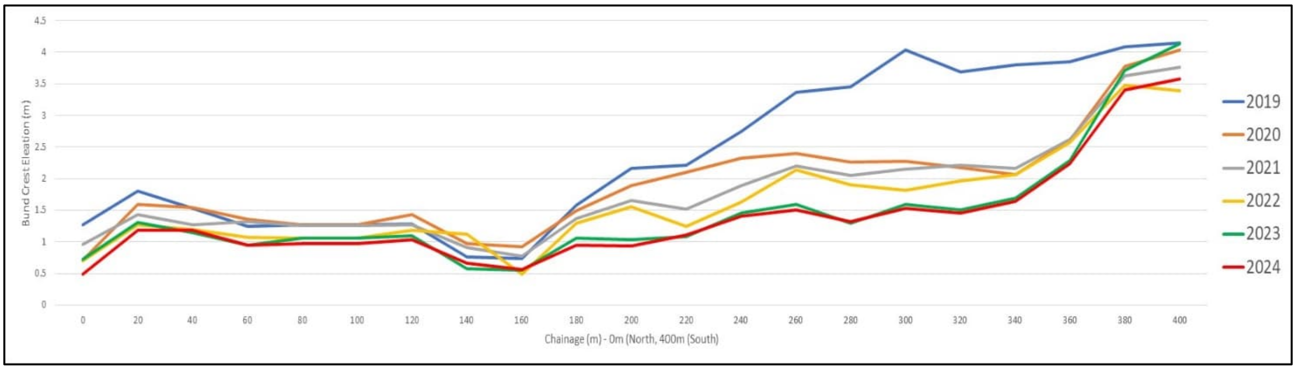


Figure 3-6. Rock Bund Crest Elevation 2019-2024 (present configuration)

Similar reductions and variations in elevation are also seen on the previous bund configurations (2007 plus 2013 extension at the ramp, and 2015 relocation) – see Figure 3-7. These are again are believed to have been constructed originally at an approximately consistent elevation along their full length (although the actual constructed level in each case is not recorded).

The reasons for this rapid lowering has been considered.

Figure 3-7. Rock Bund Crest Elevation (upper graph shows first configuration of bund post-2013, lower graph shows second configuration of bund between 2015 and 2018)

Due to the geotextile beneath the rocks, it is unlikely that the structure simply settled, as illustrated in Figure 3-8 (a) below. Indeed had that been the case then the time for that to occur to the extent shown in Figure 3-7 above would have been much slower than just a few months. What is likely is that, because the bund had to be placed on sand rather than the underlying clay, scouring of the sand at the edges has led to the structure being undermined. As the sand lowered, the edge rocks will have been displaced, leading to those above also becoming destabilised and falling away from the crest, as illustrated in Figure 3-8 (b).

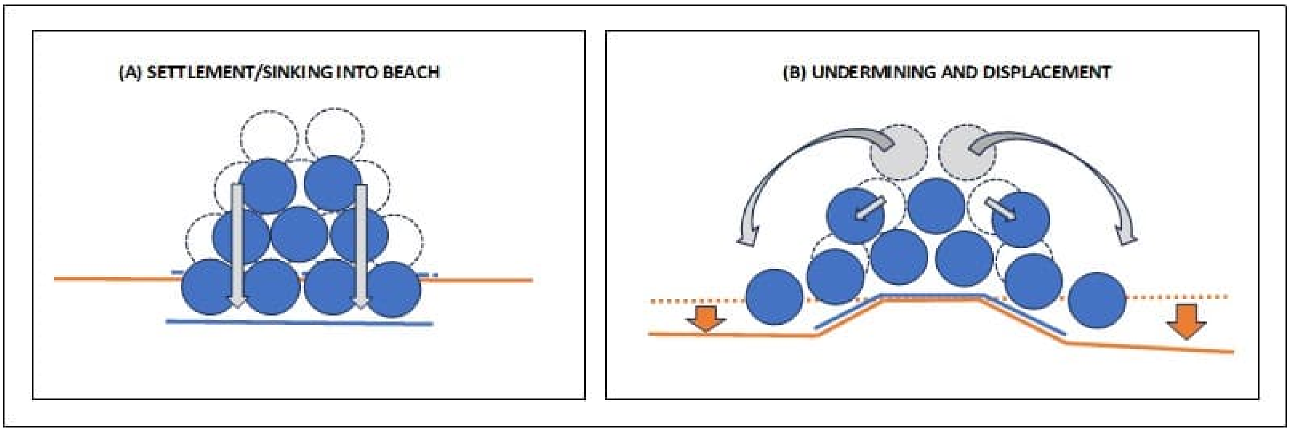


Figure 3-8. Mechanism for reduction in elevation of the Rock Bund

The rock would be best placed directly on the wave cut clay platform (over geotextile) rather than on the unconsolidated sand veneer to restrict or at least slow the rate to which the structure lost. However, the reasons this was not done for parts of the existing (and previous) bunds is recognised. This was due to depth at which the wave cut clay platform is found, which would have therefore required excavating deeper to locate this. This would have also resulted in a lower elevation (or shorter) bund from the outset due to the finite quantities available. Placing the rock directly on the clay would have also been contrary to restrictions that exist due to archaeological/heritage interests (discussed later in Section 5.1.6).

4. Assessment of Effectiveness of the Rock Bund

4.1 Actual Recession vs Expected Recession

The simplest assessment of effectiveness of the rock bund is a comparison of recession between the cliffs defended by the bund and recession of undefended cliffs. The cliffs immediately to the south, where the timber revetment failed in the 1990's, can justifiably be used to provide this comparison as they are geologically very similar and they will have close to identical levels of exposure to storm waves and surge conditions.

Having also been defended in the past by the same form of timber structures, they will have also had a similar influence on pre-failure recession rates and post-failure shoreline response. This is particularly important as, rather than a shoreline simply reverting to what would have been the natural erosion processes, what is observed after defences fail is a phenomena known as 'coastal catch-up'. This 'catch-up' is a period of accelerated erosion whilst the shoreline seeks to regain its natural equilibrium, best explained as it attempting to return to the position it would have been had defences not been built. For example, if defences built 100 years earlier had prevented 100m of erosion, after failure the shoreline will not revert to 1m/yr recession but likely rapidly retreat that full distance over an initial period of perhaps just 20-30 years before tailing off towards the natural rate. As it happens, the cliffs immediately south of Happisburgh village have been the location of most research into the process.

In Figure 4-1 below, the year-on-year recession of the cliffs following failure of the timber revetment to the south of Happisburgh from 1992 onward is shown by the blue line. This indicates an average recession of approx. 9m/year over the initial ten years, falling to an average of approx. 5m/year over the following ten years, and reducing to approx. 2m/year over the next ten years. If the rock berm had not been constructed, then it is reasonable to assume that similar rates of recession would have also occurred along the village frontage following failure of the timber revetment there too. However, the actual recession that has taken place in the 17 years since installation of the full rock bund in 2007, is shown by the red line on the same figure. What this shows is that the rock bund has provided a reduction in recession of up to 50% compared to that which might have been otherwise expected.

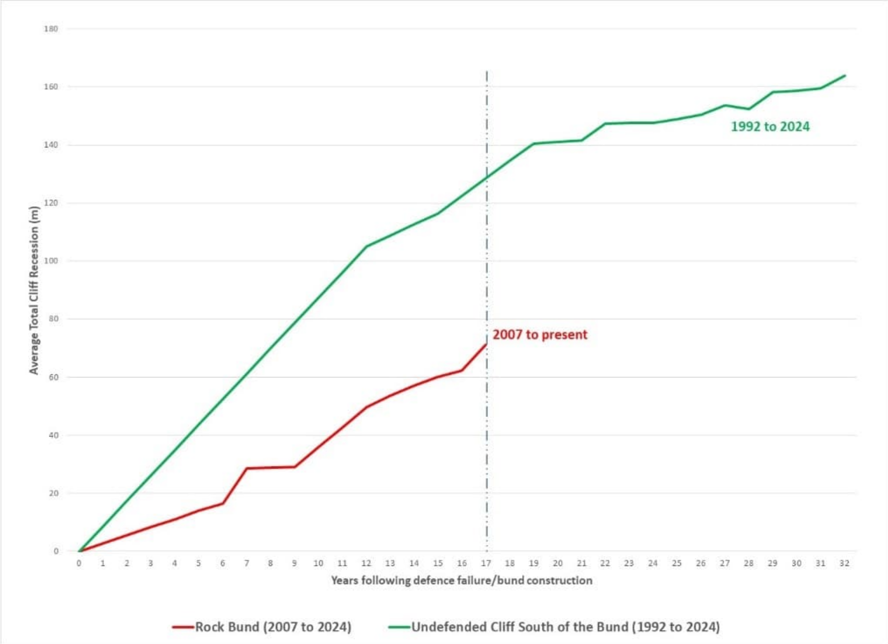


Figure 4-1. Comparison of the recession rates of the undefended cliff line and the rock bund defended cliff line (rates averaged over full lengths).

4.2 Recession variation along length of the bund (bund elevation)

The earlier section illustrates the average impact that the bund has had upon recession rates overall. However, recession rates can also be seen to vary along the length of the bund.

Figure 4-2 shows a series of transects taken through the shoreline along the length of the bund, corresponding with profiles measured as part of the Anglian Coastal Monitoring Programme (ACMP). These have been used for reference points throughout the remainder of this section.

Figure 4-2. Transect locations along length of the rock bund (reference numbers shortened for convenience (e.g. '3b00646' referred to as '646')

The recession distances along each of these transects is show in Table 4-1. These are plotted as timelines in Figure 4-3, with the timelines for 649 and 650 shown from just 2013 onwards when the bund was extended to those extents.

Table 4-1. Cliff recession distances behind the rock bund (relative to cliff top position in 2004 prior to enlarged bund construction)

Year	Transect Number								
	642	643	644	645	646	647	648	649	650
2004	0 m	0 m	0 m	0 m	0 m	0 m	0 m	n/a	n/a
2007	Bund Enlargement								
2011	3 m	5 m	5 m	11 m	7 m	9 m	22 m	n/a	n/a
2012 (Aug)	6 m	10 m	6 m	12 m	7 m	9 m	33 m	n/a	n/a
2012 (Nov)	6 m	12 m	8 m	12 m	7 m	10 m	34 m	n/a	n/a
	Bund Extended (Southern End)								
2013 (Mar)	7 m	18 m	12 m	14 m	8 m	10 m	-	0 m	0 m
2013 (Jun)	10 m	20 m	15 m	14 m	8 m	10 m	40 m	0 m	0 m
2014 (Aug)	22 m	39 m	33 m	29 m	15 m	11 m	52 m	0 m	0 m
2015 (Oct)	Bund Reconfiguration								
2016	22 m	39 m	33 m	29 m	15 m	13 m	52 m	0 m	3 m
2018 (Mar)	31 m	44 m	38 m	32 m	35 m	40 m	74 m	1 m	10 m
2018 (Aug)	31 m	44 m	39 m	32 m	-	-	80 m	26 m	15 m
2019 (Mar)	32 m	47 m	44 m	33 m	-	-	93 m	27 m	-
2019 (Apr/May)	Bund Reconfiguration								
2020	35 m	48 m	49 m	44 m	-	-	94 m	29 m	-
2021	38 m	49 m	61 m	51 m	49 m	55 m	97 m	29 m	24 m
2022	40 m	53 m	69 m	55 m	49 m	56 m	100 m	30 m	24 m
2023	41 m	56 m	70 m	57 m	52 m	57 m	102 m	35 m	24 m
2024	48 m	58 m	80 m	63 m	73 m	71 m	112 m	36 m	26 m

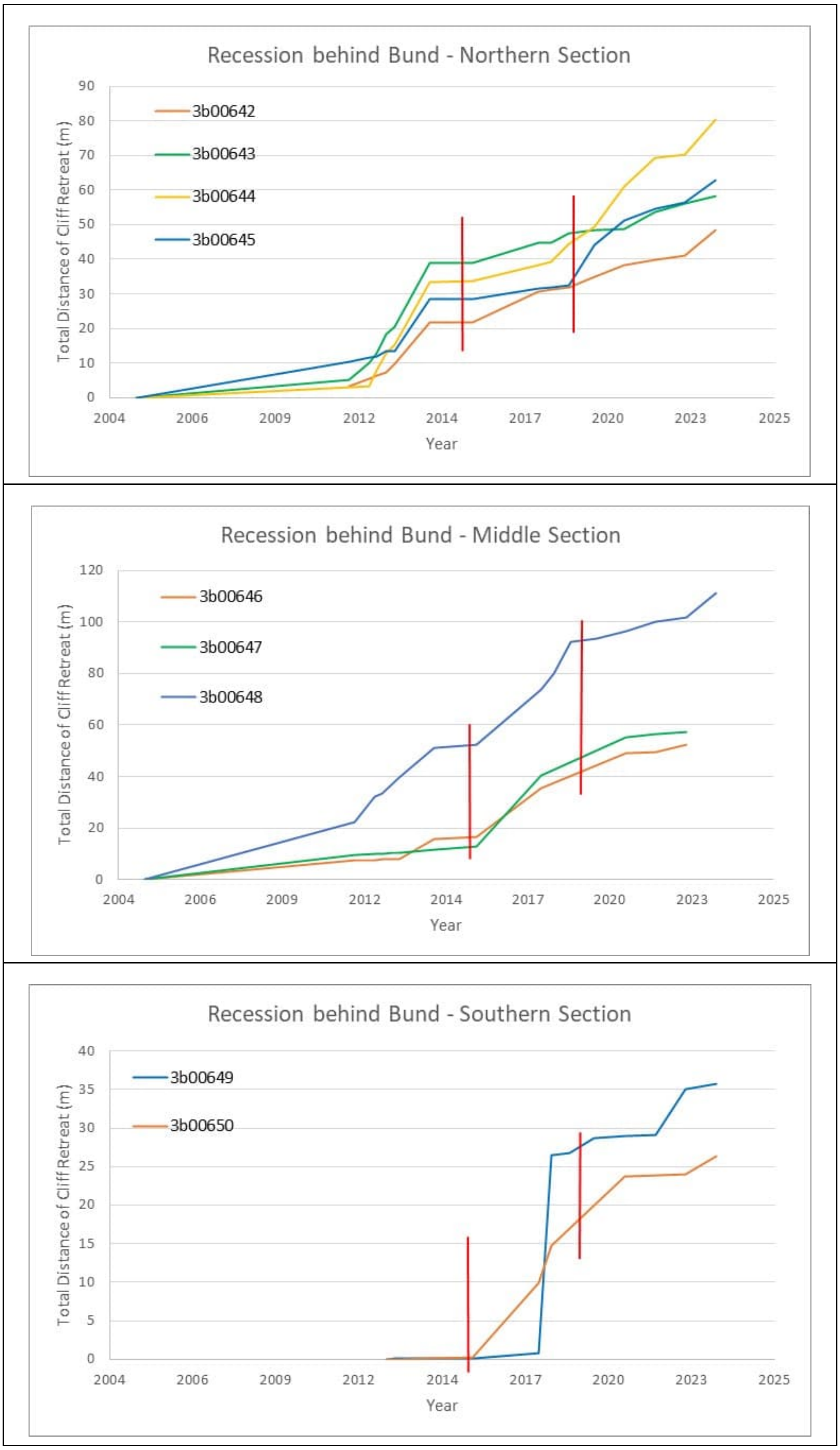


Figure 4-3. Cliff recession behind the rock bund (red lines indicate times of bund reconfigurations in 2015 and 2019, and extension of bund at southern end in 2013)

In assessing the impact of the bund upon this recession, consideration is given to the elevation of the bund along its length (see Figures 3-6 and 3-7):

- The northernmost section of the bund (transects 642 to 645) is where the bund elevation has typically been lowest across all configurations, generally at a level of between **+1.0m and +1.5mOD**.
- Bund elevation has generally been a little higher across the central section (transects 646 to 648), more often in the range **+1.5m to +2.0mOD** other than during the second configuration (2016-2018) when it was closer to **+1.0mOD**.
- At the southern end (transects 649 and 650) where the ramp is located, the elevation of the bund has remained higher since the bund extension in 2013 – generally always in excess of **+2.0m to +3.0mOD**.

As might be expected, less recession is seen at the southern end where the bund has remained highest, although the extents seen there since its installation (37m and 27m respectively) are only a little less than seen at the far northern end (transects 642 and 643) where recession was approximately 40m over the same 11 year period since 2013 despite a considerable difference in bund elevation. One possible explanation for the latter is that there is some sheltering effect and influence exerted by the timber revetment and less eroded cliff line further to the north.

Over the remainder, the transects all indicate a relatively comparable amount of recession along the whole length of the bund, ranging from approximately 60m to 80m since initial construction (50m to 70m since 2013), the exception to this being transect 648 where considerably more recession has taken place. Here, there has been close to 80m recession since 2013, and approximately 110m overall.

Although data is not available in 2019/2020 for all transects (so interpolated for those), since the latest bund configuration was installed, there is a little more correlation between elevation and recession. Where the bund has been lowest throughout that period, typically below +1.5mOD, recession has been in excess of 20m and even more than 30m. At the other end of the scale, where the bund has remained above +3.0mOD, less than 10m recession has occurred. From this it might be concluded that the areas where the bund has maintained a higher elevation it has been more effective and perhaps more predictable, but where it is lower the extent of its influence on recession is more variable.

Given some marked variations in bund elevation between the southern and central sections, the absence of a wider differences in cliff recession is a little surprising, as it might have been expected that more recession would take place to the north and reducing to the south. But, other locally specific factors also contribute to the erosion, including variations in the level and strength of the clay layer at the base of the cliffs, and surface water run-off with significant water flows sufficient to make deep cuts in the cliff edge.

However on inspection of the recession profiles (Figure 4-3) it can be seen that the erosion patterns are also different through time, which may provide some other indication of bund effectiveness. Irrespective of the differences in total recession extent, along the southern section (transects 642 to 645) there was a marked erosion of the cliffs in 2013, ranging between 12m and 18m. This is where the bund elevation was lowest, typically around +1.0mOD. This is also noted at transect 648 (11m erosion), where the bund was also at a similar level, but not so noticeable in those areas where the bund was at an elevation of +2.0mOD and above. Notably, this significant erosion event coincides with the major storm surge event of December 2013.

Another notable spike in recession ranging between 10m and 28m is seen in transects 646 to 650, occurring in early 2018. Interestingly this occurs over the central and southern section's when the elevation of the bund appeared to have been much lower than at other times, having also reduced to levels of around +1.0mOD. This erosion coincides with another notable storm event, the "Beast from the East" which occurred in late February 2018. Although less noticeable, along the cliffs behind the northernmost section of bund, where elevations were slightly higher, erosion of 5m to 9m was also recorded.

What might be deduced from this is that, although the bund has some effect in reducing erosion by reducing exposure during normal tides, when a large surge event occurs the effectiveness of the bund can diminish significantly. However, it must also be recognised that these are not the only two storm or surge events that this coast has experienced over the past 12 years, so it also cannot be concluded that the berm is completely ineffective under such conditions. But bund elevation may have had some influence on that effectiveness – the data set is extremely limited but there are indications that a level of +1.0mOD has had a more limited effectiveness under such extreme exposure conditions, whereas a bund elevation of +2.0m or higher did appear to have some potential benefits in reducing erosion during a significant event.

A third consideration is whether there is any relationship between the recession of the cliffs and the distance from the bund. However, from inspection of the graphs in Figure 4-3 and values in Table 4-1, there is nothing to conclude an increasing rate over time following each bund reconfiguration, i.e. as the distance increases. Rather, it would appear that the incidence of storms and surges are a more dominant factor.

4.3 Influence on beach levels (and cliff protection)

The above section considered the direct correlation between the bund elevation and cliff recession distance. Another factor to consider is how effective the bund has been in holding up beach material and thus helping to reduce the rate of cliff recession. Figure 4-4 below shows year-on-year differences in beach levels landward and seaward of the current bund, along its full length.

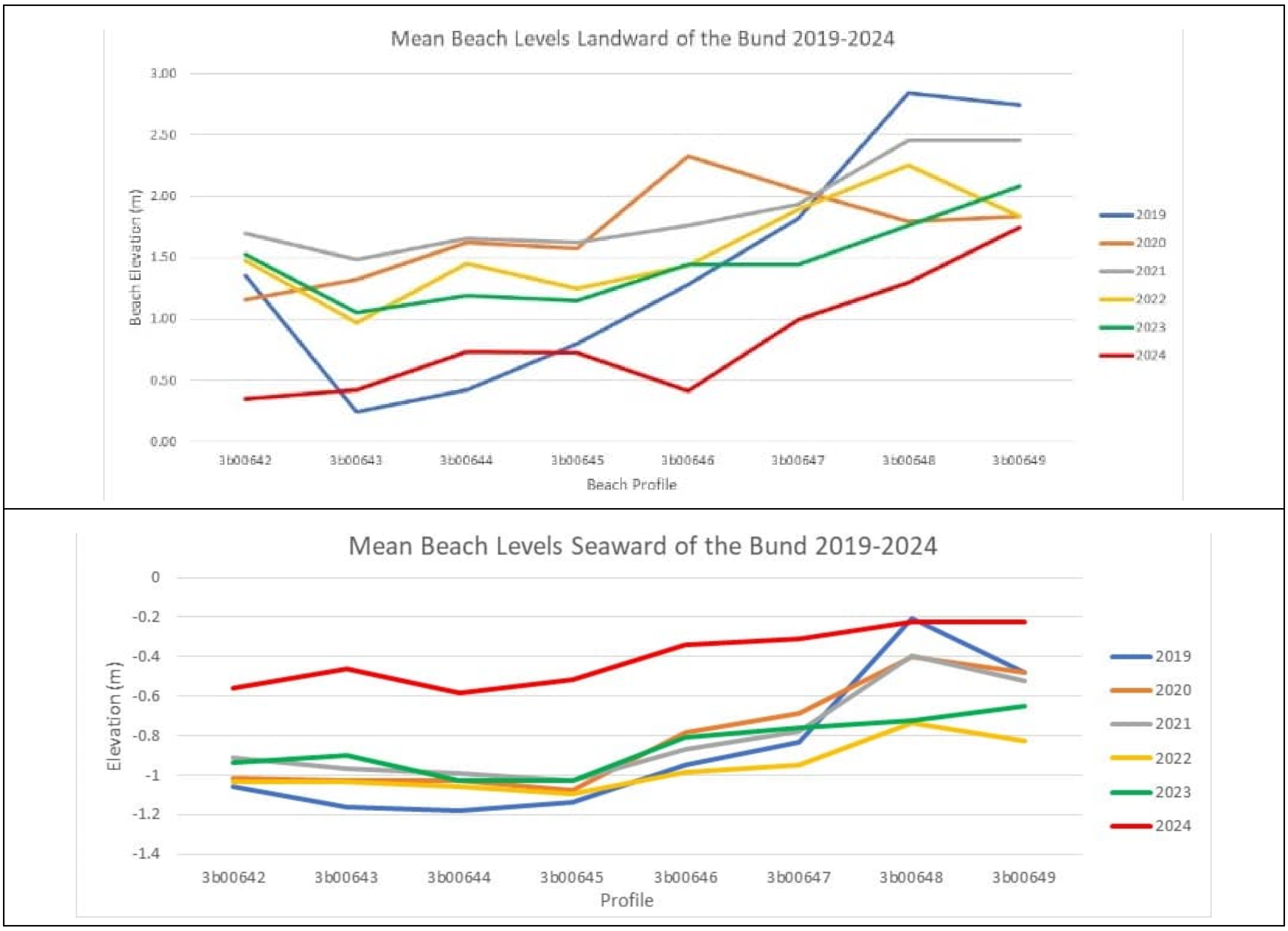


Figure 4-4. Variations in beach level along the current rock bund (*taken from annual LiDAR surveys (Nov 2019, Dec 2020, Nov 2021, Apr 2022, Feb 2023, Mar 2024*)

These show that the retained beach levels landward of the bund vary along its length, rising to the south, which broadly mirrors the changes in elevation of the bund itself, indicating that this is potentially having an influence in retaining sand. There is also a slight increase in the beach levels seaward of the bund too, increasing by up to 0.5m to the south. Whether the latter is a natural variation in level or an additional influence of the bund is unclear.

It may therefore be concluded that there does appear to be a direct correlation between bund elevation and beach retention on the landward side. This will have some impact upon the degree to which the cliffs are therefore exposed to day-to-day tidal, and thus wave, action.

To assess whether this is just a function of the current bund, a similar check has been made on the levels for the previous bund configuration (2016-2018), shown in Figure 4-5.

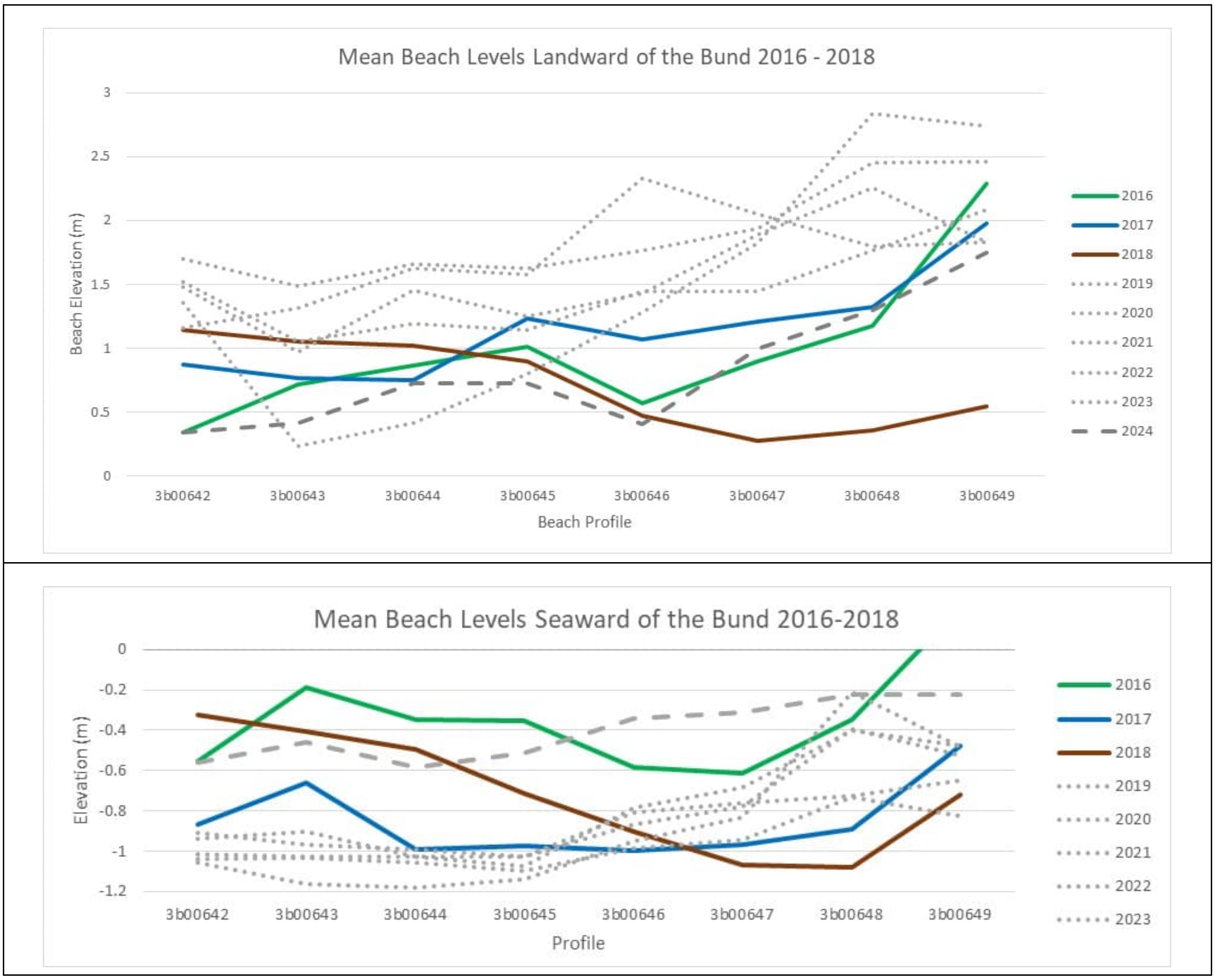


Figure 4-5. Variations in beach level along the previous rock bund

Again the landward beach level broadly follows the bund elevation, including the reduction recorded in 2018 (see Figure 3-7).

For comparative purposes, the levels for the present bund have been included as a backdrop in Figure 4-5. Generally the retained sand levels were at the lower end of what has been achieved more recently, particularly across transects 646 to 648, where the bund elevation was generally lower than in the most recent configuration. This is despite beach levels on the seaward side being higher.

To assess the retention capacity of the bund(s), Figure 4-6 shows the differential in levels seaward and landward of the bund for each year. Details for the current bund are shown in yellow and the previous bund in green. The results for 2024 have been identified separately in these graphs (in red), for reasons discussed further below.

What must also be considered is the natural differential that would be expected over the measured distance between front and back of bund if it were not there. The natural beach slope taken from profiles along the undefended frontages to the south of Happisburgh (averaged from 4 profiles x 3 years) is approximately 1:20. Based upon that, the natural differential would be expected to be approximately 1 metre.

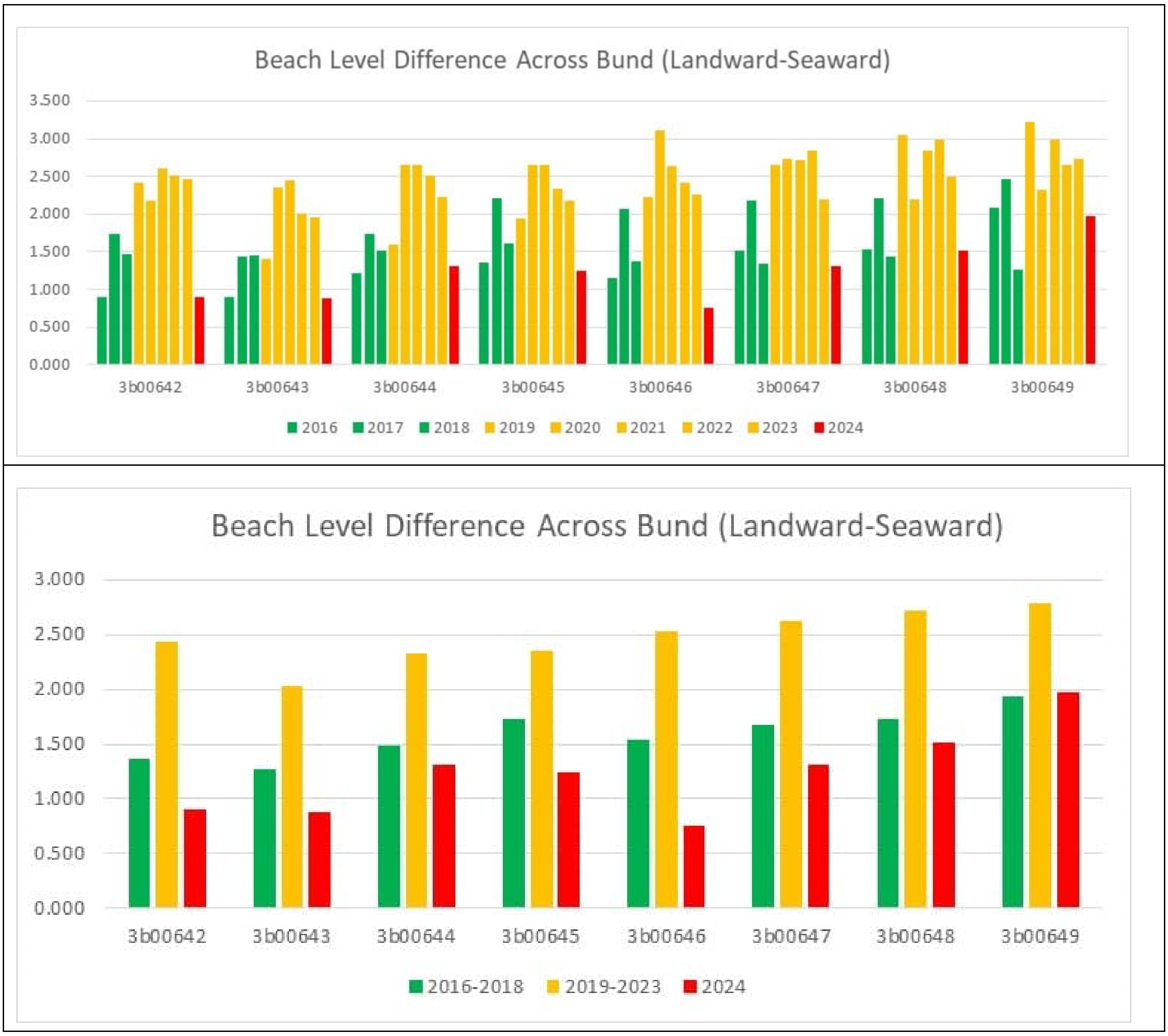


Figure 4-6. Beach Retention due to the rock bund

Despite some year-on-year variability, the effect of the bund appears to be fairly consistent between 2019 and 2023, generally resulting in a perched beach 2.0m to 2.5m higher on its landward side (or 1.0m to 1.5m when discounting the natural beach slope). Interestingly, this is having a similar effect along the entire length of the bund despite the variations in beach level (as shown in Figure 4-4) and the corresponding variations in bund elevation (as shown in Figure 3-6). This may therefore indicate that the overall size of the structure (i.e. width as well as elevation) is a primary influence, limiting transmission of waves (from seaward) and sand (from landward) passing through it – noting the construction included a similar volume of rock along its entire length.

The perching efficiency of the 2016-2018 bund appears lesser (closer to 1.5m) despite the bund being similar elevation over much of its length. However, although levels landward of that bund were towards the lower end of the envelope, this differential is also due to the foreshore levels seaward of the bund being higher than in the most recent years, as can be seen in Figure 4-5. Arguably, when accounting for natural beach slope, the perching effect is negligible. The results for 2024 are also more comparable with those seen between 2016-2018 with a much lesser effect, but that is again due to the beach levels seaward of the bund being much higher than in previous years, and those landward of the bund generally being much lower.

The conclusion that might be drawn from this is that, when beach levels are naturally higher, the bund has limited effect, and in fact the natural beach slope dominates levels landward as well as seaward. But when natural beach levels are low, the bund has definitely been effective in retaining sand against the foot of the cliff.

4.4 Conclusions

The assessment shows that the rock bund has been successful in controlling recession of the cliffs in front of Happisburgh village. This is in line with the design principle and intent of the Shoreline Management Plan which is not to completely halt erosion, but reduce the rate at which it occurs. Key points arising from this assessment are:

- Comparisons with the immediate post-failure rates along the previously but now undefended section of cliffs to the south, indicate that the rock bund has provided a reduction in recession of up to 50% compared to that which might have been otherwise expected.
- Where the bund elevation has maintained its height, i.e. towards the southern end, it has predictably been more effective in slowing cliff recession. But where the elevation has lowered considerably, the extent of its influence on recession has been more variable. However, other factors such as surface water run-off and variations in the geology may also be factors contributing to that variability.
- There is nothing to conclude any relationship between recession and distance between the bund and the cliff, although any evidence to support that or to the contrary is limited by the relocations of the bund before that distance becomes too great.
- Although the natural beach slope seems to dominate levels on the landward side of the bund when the foreshore levels are naturally high, the bund has been effective in retaining sand against the foot of the cliff when natural foreshore levels are low.
- There does also appear to be a correlation between bund elevation and beach retention on the landward side, i.e. the higher the bund the higher the retained sand. This will have some impact upon the degree to which the cliffs are therefore exposed to day-to-day tidal, and thus wave, action.
- The degree to which the bund perches the beach on the landward side is consistent, which may indicate that the overall size of the structure (i.e. width as well as elevation) is a primary influence, limiting transmission of waves (from seaward) and sand (from landward) passing through it.
- The bund has had the effect of reducing day-to-day exposure of the base of the cliffs to waves and tides, but that effectiveness is reduced considerably during storm events, particularly surges when water levels are much higher.

5. Rock Bund - Future Reconfiguration

The assessments presented in the preceding sections demonstrate that a rock bund has reduced the amount of recession in front of Happisburgh village. If the management approach continues with provision of a rock bund, rolled back as and when necessary, there are however lessons that may be learned from that which could further improve its effectiveness in the future.

In this section, those findings have been incorporated as options for reconfiguration of the bund has been considered. Ahead of that, any other key information/constraints that may be pertinent to future implementation of this option, and also to be considered for alternative uses of the rock assessed in Section 6, are set out below.

5.1 Additional considerations

5.1.1 Water levels

Although any structures on this frontage are expected to remain relatively informal (i.e. not designed to a more formal scheme design standard), appreciation of water levels remains invaluable if developing and implementing those to try and optimise their performance. There are two aspects to this; normal day-to-day conditions and extreme high water levels.

Based upon tidal levels at Winterton-on-Sea and Cromer, the corresponding water levels at Happisburgh have been interpolated, as shown in Table 5-1. Modelling studies carried out for the Bacton Sandscaping scheme predicted extreme water levels in the vicinity for a range of return periods. This location is close enough to assume those for Happisburgh too and are also included. Below.

Table 5-1. Water levels at Happisburgh

	Condition	Sea Level (mOD)
Extreme Water Levels (Return Period – years)	1:250	+3.99
	1:100	+3.79
	1:50	+3.58
	1:10	+3.24
	1:1	+2.71
Tidal Levels	HAT	+2.66
	MHWS	+1.82
	MHWN	+1.02
	MSL	+0.10
	MLWN	-0.74
	MLWS	-1.54
	LAT	-2.16

Storm surges are a significant consideration with respect to any potential options for this location, with those being of significant magnitude compared to normal tidal levels, although the extreme levels presented in the above table do extend to elevations that cover the majority of those experienced here.

5.1.2 Waves

Again, although structures are expected to remain relatively informal, appreciation of wave conditions is also valuable to optimise their performance. There are two potential considerations with respect to waves; their direction and their size.

The dominant wave direction is from the north-east in terms of both size of waves and total wave energy. Figure 5-1 shows a wave rose for wave data from Happisburgh. Inspection of the raw data does however establish that there are gaps in the data record– for example the period cover the infamous 'Beast from the East' in early 2018 is absent. So although the wave directions below are still broadly representative it is important to note it does not cover all eventualities.

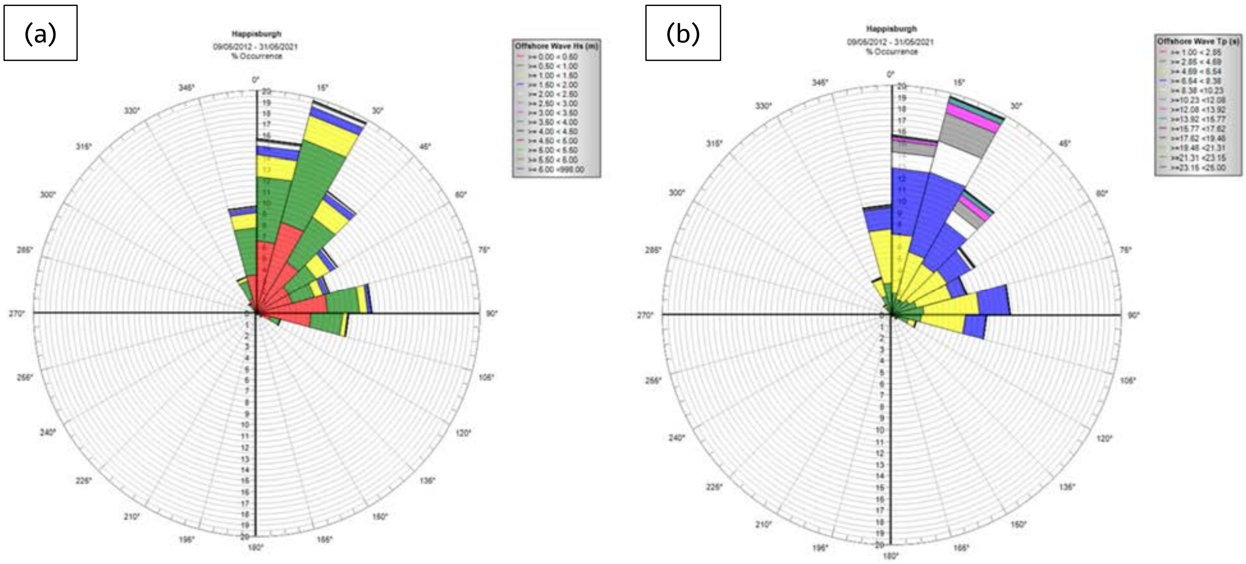


Figure 5-1. Wave rose from local wave monitoring buoy data off Happisburgh showing (a) offshore wave height and (b) wave period.

As waves propagate into shallower water they lose energy due to friction, breaking and other effects due to the shape and elevation of the seabed. Without more detailed investigation of the local seabed bathymetry and the wave transformations, the wave heights here cannot be determined. However, this premise for options here is to re-use existing rock rather than the design and introduction of new rock. So specific knowledge of wave heights is primarily going to be useful to establish the stability thresholds for that existing rock, but for now judgements have to be made based upon observed performance of that material in-situ.

5.1.3 Wave forces

To assess the potential influence of changing the elevation of the rock bund some basic calculations have been carried out. As the structure is too low to be able to utilise overtopping equations, the potential for a structure to reduce wave forces have been assessed, at different heights – wave force calculations. This is based upon the method developed by Pederson (1996) as reproduced in CIRIA; CUR; CETMEF (2007), for forces on breakwater wave walls behind a rock mound. Although not precise, this is applied to provide some indicative 'feel' for the influence of the bund upon waves impacting upon the cliff face.

The calculations were carried out for a series of water levels, with depth-limited wave heights being calculated for each of those levels also based upon established formulae for wave height estimation in the surf zone (Goda (2000), Battjes and Groenendijk (2000). Results were produced for a range of rock bund elevations between 0mOD (MSL, effectively no bund) and +4mOD (the constructed level of the most recent configuration). These are presented in Figure 5-2.

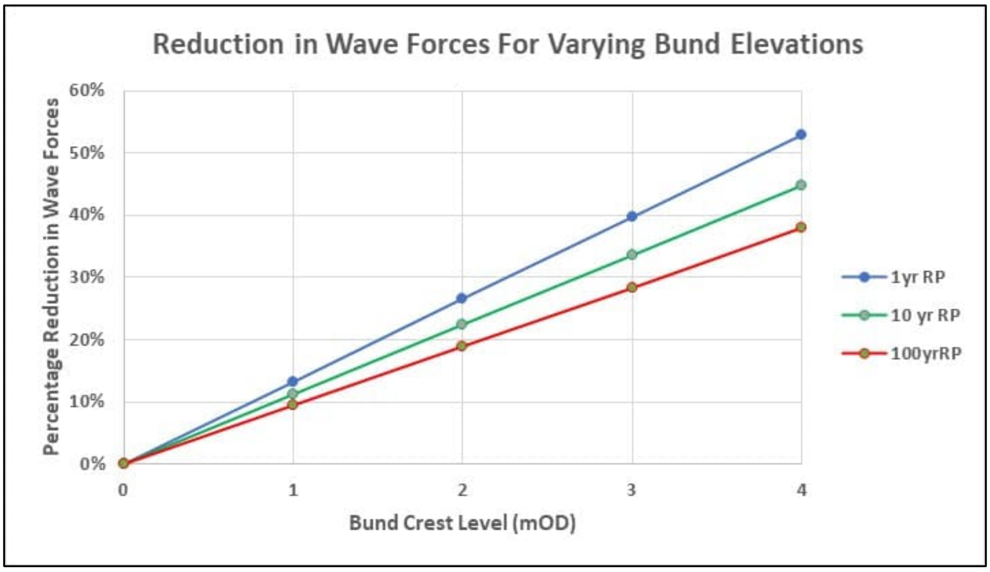


Figure 5-2. Indicative influence of rock bund elevation on waves potentially impacting the cliff face.

The results show a potential reduction in wave forces of 40-50% for a bund with elevation of +4.0mOD, compared to no bund. This reduces to having the effect of reducing the wave forces by just 20-25% for a bund at +2.0mOD.

It would be potentially misleading to attempt to find a correlation between these numbers and the recession distances presented in section 4.2, as there are a range of other factors that contribute to erosion of the cliffs. However, these might be indicative of the effectiveness in reducing impacts on the cliffs during the larger storm and surge events, which are known to result in some of the more erosive conditions here.

It must be stressed that this is an adaptation of calculation methods derived for other purposes in the absence of anything better available, and so should not be considered to be precise. With that caveat, the conclusion reached from these indicative results is that the height of a bund will make a difference to its effectiveness, but it probably needs to be above +2.0mOD and not as low as +1.0mOD (as is the case along parts of the bund), if it is to have any significant effect on reducing exposure of the cliffs to waves under storm conditions.

5.1.4 The Effect of Bacton Sandscaping

At Bacton, approximately 7km to the north of Happisburgh, a large volume of sand was placed on the foreshore to enhance protection to Bacton Gas and its associated infrastructure, as part of a process known as 'Sandscaping'. As a result of that scheme, this sand is expected to slowly redistribute along the shoreline, and eventually join the natural sediment transport regime with sand moving from north to south.

The timeframe for more of that material reaching Happisburgh is not certain, however at the time of the LiDAR being flown (March 2024) and the site inspection (November 2024), beach levels here were certainly higher than had been observed in previous years – see Figure 4-4 (lower) and Figure 5-3 respectively.

It is therefore speculated that these higher beach levels could be a result of the Bacton Sandscaping which, if so, might be expected to continue over the next few years. In respect of benefits to Happsiburgh, it must be noted that beach levels along this entire coast are dynamic and can fluctuate considerably, but this would likely mean that exposure of the cliffs could be less under normal day-to-day conditions. They would however remain exposed to high tides, surges and storm waves which will exceed the natural levels on this beach, so options would still need to be tailored to those extremes.

Figure 5-3. Southern section of Rock Bund, November 2024.

5.1.5 Happisburgh Cliffs SSSI

Happisburgh Cliffs include a 5.9-hectare Site of Special Scientific Interest (SSSI) due to the geological significance of the exposed cliff face (Natural England, nd). Figures Figure 5-4 and 5-5 show the location of the SSSI at the northern end of Happisburgh beach, north of Beach Road.

Although a lesser constraint on any reconfiguration of the rock bund as it is set away from the cliff face, this designation would impact upon the viability of any alternative options that would involve placing rock directly against the cliffs, especially if those involved any cutting into or reshaping of the cliff face (see Section 6) within that area.

However, this designation does mean that vehicles should also not operate directly on the clay layer as it should be preserved in its natural state. This may be a constraint on bund construction if seeking to found deeper directly onto the wave-cut platform. Such works will require consent from Natural England, which would be advisable to seek early as this could be a lengthy process and may require additional approaches to be adapted as a consequence.

Figure 5-4. Location of Happisburgh Cliffs SSSI

Figure 5-5. Happisburgh Cliffs SSSI (Photo: November 2024)

5.1.6 Archaeological Interests

Some areas of the beach area are sensitive with regards to finds of historic importance, notably the oldest human footprints in Europe at 900,000 years old were found here following previous erosion events. As a result of these interests, activities that are directly cutting into the clay (e.g. to form a foundation for any structures) or indeed even tracking directly on the clay (e.g. machinery used for maintenance) is deemed to be unacceptable. This may be less of a constraint in respect of reinstating the rock bund, but may be a more significant restriction for some of the other options for use of rock discussed in Section 6. Nonetheless, activities involving any reconfiguration of the bund needs to remain cognisant of this.

5.2 Rock Bund Option

5.2.1 Description

The current rock bund extends for approximately 410m in length, comprised of approximately 9000 tonnes of rock estimated to be in the range 3 to 8 tonnes apiece. Although geotextile is currently placed on the bottom of the bund, this is unlikely to be able to be re-used and as such will need to be replaced in any options proposed.

Reconfiguration of a rock bund would continue to be to provide a low level rock structure, placed along the shoreline, consisting of two or three layers of the same large armour rock, a short distance away from the toe of the cliff. In the absence of smaller bedding stone, these rocks would sit directly upon a geotextile fabric.

Although designed to not fail structurally, overwashing of the structure during high water level events is accepted, which will result in some occasional erosion of the exposed cliff behind, in line with the management policy for this frontage. The design concept of the bund is to retain or 'perch' higher beach levels between the bund and the cliff than would ordinarily exist, this reducing exposure of the cliff toe to more regular erosion and undercutting.

It is assumed that the previous practice of 'rolling back' the bund would continue, when the distance from the cliff and foreshore levels becomes such that recovery of the rock for re-use could become compromised.

5.2.2 Optimising effectiveness

The effectiveness of the rock bund concept is proven, as presented in Section 4. However, based upon that assessment of the existing rock bund, the following criteria are proposed for any future reconstruction:

- Ideal outcome would be a post-construction elevation of +4.0mOD, as was intended with previous bunds. This level has been shown to potentially having some effect in reducing the exposure during storm surge conditions.
- Accepting some movement will occur post-construction, target achieving a minimum elevation of +3.0mOD for the design life (e.g. 5 or so years). As this is higher than HAT, it should help to perch a beach at least in the upper part of the tidal range, and so limits the frequency of exposure of the cliff toe.
- As a minimum, design to prevent elevation falling below +2.0mOD. There are some indications that where the bund elevation has been in excess of this, it may have had more effectiveness on limiting recession under extreme storm surge events. The wave force analysis also point to that, Section 5.1.3. By doing so, this will provide a higher perched beach than currently found along some stretches of the bund, so also limiting exposure under day-to-day conditions.

The means to achieve the above will be to seek to minimise, or at least slow the rate of bund lowering by reducing the potential for settlement/displacement of rocks. There are three ways in which this might be done:

1) Build the bund higher, accepting some displacement of rocks from the crest after construction but with the resultant mound left at the desired elevation.
2) Build the bund directly onto the clay wave-cut platform to improve its structural stability. If this is overlain by sand at the time, then either consider excavating down to it.
3) Build a wider bund, with a flatter slope/‘falling toe’, so even if the toe rocks are undermined, those can drop into scour hole without the overall elevation being unsupported and thus compromised.

If the bund is simply reconstructed as in the past, the evidence from three different configurations all indicate that the bund will lose elevation relatively quickly as sand washes out from beneath the toe, resulting in a 1m to 3m reduction in height and consequential reduction in effectiveness.

5.2.2.1 Build the bund higher

The principle of this approach is that by overbuilding by at least one to two metres and accepting similar displacement of rocks to that already experienced, the resultant post-construction bund will end up at the desired elevation.

This is considered less favourable to the other two approaches however. The post-construction evolution of the bund profile is less certain and the potential to achieve the desired elevations is unmanaged. With rocks from the crest displaced onto the beach either side, they may contribute little to the effectiveness of the bund, so the benefit of the finite material is not being optimised.

5.2.2.2 Build the bund deeper

This would involve excavating down through the sand to reach the underlying clay wave-cut platform and founding the structure at that level. The bund will have an improved structural integrity if built on clay rather than sand as this has more resistance to erosion (although note that it is still erodible – ultimately this clay will also be eroded and reduce in level). By placing the rock on the clay, it is less likely to suffer the significant and immediate settlement and elevation drop as seen in the 2019 rock bund, as such maintaining an elevation closer to its as-built profile.

However, this will require a larger amount of rock to achieve the intended elevations as there will be more rock buried beneath the beach to provide this foundation. Given the trapezium shape of the bund, there could in fact be as much or more rock buried in the beach than above it. That might be reduced by just excavating down the slopes where the toe rocks are placed, but given the relatively narrow width of the structure compared to the size of the rocks, unlikely to offer much saving in volume and adds another level of complexity to this element of the construction, which also needs to take place over the low water period.

Other complications with excavation could include health and safety risks if the trench is not cut wide and shallow enough to prevent instability and collapse during construction, and dewatering to maintain the excavation open. Although some simple geotechnical tests could establish the level of the clay ahead of construction, until then it is also uncertain how deep the clay layer is beneath the beach and thus the depths of excavation and rock volumes required will be unknown, making planning the extent of works challenging. These issues are likely to be more significant the further seaward the bund is located – closer to the cliffs, the clay layer is expected to be slightly higher.

Ultimately, when it becomes time to roll back the works once again, recovery of the buried rock will be more difficult as this will be at a much lower depth and may be permanently submerged.

5.2.2.3 Build the bund wider

An alternative approach is to design the structure to be sufficiently dynamic to be able to accommodate changes in the foreshore and thus minimise the reduction bund elevation becoming a consequence of that.

This would involve building a wider/flatter structure, so that even with undermining of the toe, the crest rocks are not displaced. It is not uncommon to build coastal rock structures with a 'falling toe', so that when the toe rocks are undermined, these drop into the scour hole to effectively 'seal' it without the integrity of the structure slope above being lost. Increasing the flatness of the seaward slope will also increase the stability of the rock under wave action making it less likely to suffer displacement.

This will again require a larger amount of rock to achieve the intended elevations due to the greater width of the bund. As there will be more rock buried beneath the beach to provide this foundation. However, most of that rock would remain above the beach level so continuing to provide some effective contribution in reducing exposure of the cliffs.

5.2.3 Other considerations

5.2.3.1 Physical impacts

The re-instatement of another rock bund should not result in any discernible changes in coastal processes, sediment transport and downdrift effects than the previous bunds which have been in place for the past 17 years.

Although the suggested improvements to effectiveness may help reduce the frequency and magnitude of cliff recession in front of Happisburgh village compared to that in recent years, the erosion is not being halted. Beach building sediment will continue to come from those cliffs, but its release into the wider system will simply be slowed. It is also expected that this small reduction will be mitigated somewhat over the next decade or so by the likely increase in sediment being transported down the coast from the Bacton Sandscaping.

5.2.3.2 Construction and maintenance

All of the approaches described above would need more rock placed per linear metre of structure however, so providing any of those would also result in a shorter bund than the current 400m length given the finite amount of rock available. For example, assuming the approach taken requires 33% more rock per linear metre, then it would only be possible to construct a 300m long berm (or 50% more rock, then just 200m long etc). There might be some trade-off between length and target elevation (between +2mOD and +4mOD), but that would a decision to be made at the time of change from the current structure and priorities at that time to reduce erosion risk to properties. Further discussion on this is set out in section 5.3.

In all cases, ensure that geotextile is placed beneath and wrapped around the toe rocks to also lay in any scour hole that develops. It is likely that new geotextile may be required, as reused material can become worn and torn. This should be of a specification appropriate to the sand/clay on the site to be effective. It should also be laid with sufficient overlapping between individual lengths.

Other than the option to excavate into the beach, construction and subsequent maintenance are otherwise relatively simple and a tried and tested procedures at this location. Through providing a corridor between the cliff and the bund, access further along the shoreline is retained, enabling machinery to reach and maintain the timber revetment to the north of Happisburgh. Importantly, this should also ensure that future recovery of the rock for subsequent re-use in rolling back protection here is achievable, although the potential caveat with respect to buried rock mentioned in section 5.2.2.2 should be noted.

5.2.3.3 Cost implications

The costs (resources and time) required for recovering the existing rock and reinstating another rock bund should be similar to the previous campaigns in 2019.

The main difference would be if the approach taken was to excavate into the beach to found the rock at a lower level. In addition to the extra effort required, this would also necessitate intertidal working and associated downtime to complete a cycle of trenching and backfilling with the rock over low tide periods.

Replacement geotextile will be an additional cost, although that applies to every option for reuse of the rock.

5.2.3.4 Consenting and environmental

Being a continuation of the existing coastal management practice, it is expected that consenting will have less challenges than any change in approach. But if a shorter bund is built, there may be issues to address with local landowners affected by the change in the extent of protection provided.

Through keeping construction away from the cliff face, it is anticipated that the constraints of working within the SSSI will be kept to a minimum.

However, If this approach being considered is to construct directly onto the clay wave-cut platform, then account must also be taken of the environmental and archaeological constraints, particularly if extending further north than the existing bund. At the very least those may impose additional working limitations and may entirely restrict any works being built directly onto the clay layer.

5.2.3.5 Health and safety

In respect of Health and Safety, it is essential to make sure that the public are made aware of the hazards associated with rock armour on the beach, with signage and warnings to discourage them from climbing on the structures due to the associated risks. This applies to the rock bund, and also any other options that involve re-use of the rock on the beach.

Likewise, with the rock bund and any of the options, the safety of construction workers is also paramount and the necessary safe working practices and protocols should be in place. Beyond construction, regular inspections and maintenance are essential to address any potential hazards.

The other potential safety hazard presented by the rock bund is the proximity of the works to the cliffs. The corridor provided by the structure encourages individuals to walk close to the base of the cliffs, which can be susceptible to slides and cliff falls. That should be taken into consideration when reconfiguring the bund, ensuring that sufficient width is provided to allow safe walking behind the bund away from the base of the cliffs. Physical measures to keep the public a safe distance away from the cliff face should be investigated, and appropriate signage provided to warn of the risks.

5.3 Targeted positioning of the bund

If any of the above recommendations for improving the effectiveness of the bund are adopted, a shorter length of bund will have to be constructed due to the requirement for a more substantial quantity of rock per linear metre. However, a shorter bund could be targeted at the locations in need of most immediate protection.

The full extent of the present bund is shown in Figure 5-6. As can be seen, a considerable length of the bund is protecting what is now open land and the cliffs would need to recede some considerable distance before property landward of that is at risk from erosion. It is therefore questionable whether maximum benefit is currently being obtained from that rock being used along that whole length and it might be directed somewhere else.

Figure 5-6. Happisburgh rock bund (North Norfolk District Council, Drone Footage from 27th Feb 2024)

The rock bund can be reconstructed as a continuous bund, or targeted protection at more than one location along the coastline. That decision is going to be based upon which assets are potentially at risk and over what timescales, which as indicated in Figure 5-7 are first the properties and infrastructure at the end of Beach Road, with the Church of St Mary the Virgin and surrounding properties next at some point in the future.

Figure 5-7. Assets closest to the cliff edge

The most immediate risk and thus need is enhanced protection at the end of Beach Road. To enhance this as per the approaches set out in Section 5.2.2, rock could be taken from the northern end of the bund to increase the volume here. Depending upon the future plans implemented for beach access (see Section 8), it may also be possible to shorten the length of bund at the southern end too. To note, however, when reducing the length of protection, care should however be taken to not build a structure that is too short, as this can be subject to outflanking by erosion around either end. With that in mind the bund ought to extend further north that the end of Beach Road, this being the predominant direction for incoming storm waves.

Providing protection to the frontage where the church and surrounding properties are located, would then be the subject of a second bund (rather than a single bund extending along the entire length including the unoccupied land between the two). Maintaining a bund of sufficient height and length at the end of Beach Road may however require all of the rock so there is the option of deferring that additional protection for now - the risk here is less immediate. Based upon cliff recession rates experienced to date, no properties are currently expected to be lost within the next 10 years, so there is likely to be at least one cycle of reconfiguration before protection needs to be split between the two locations.

6. Alternative options for use of rock armour

This section presents guidance on other forms of structure that might be considered as an alternative use of the rock at Happisburgh instead of further reconfiguration of the bund. They are all based upon the assumption that any alternatives would be limited to reuse of existing materials, not the introduction of different or additional material (with the exception of replacing worn geotextile fabric).

The suitability of the following types of structure have been considered:

1) Rock at Cliff Toe (section 6.1)
2) Rock Groynes (section 6.2)
3) Rock Breakwaters (section 6.3)
4) Rock Headlands/Bastions (section 6.4)

The guidance that follow for each include a description of the option, outlining both how it would work and what it would look like at Happisburgh – noting the premise that this is limited to the available materials. This is followed by discussion on their potential effectiveness, i.e. whether that form of structure might be suited to this location and reasons why or why not, taking account of what is now known about the recession processes here. Other points to take into consideration if the option is being contemplated in the future are then briefly listed, including:

- **Technical / Physical**: potential implications and factors to note.
- **Maintenance:** any challenges with carrying out maintenance activities.
- **Consenting:** whether the option presents different challenges to the present approach to erosion risk management.
- **Environmental**: any constraints that may impact upon ability to deliver the option.
- **Public Safety:** in addition to the general H&S considerations presented in section 5.2.3.5 (not repeated here), identifying any factors that could result in a change in risk to the public using the beach.
- **Relative cost implications:** how the level of effort required to implement the option compares with the rock bund.

In respect of the above, there are some common factors that are not repeated for each and every option but should be noted and considered for all.

Sustainability and the carbon cost of proposed schemes is typically a consideration in option assessment; however, in this instance all options will involve reuse of the same material volume, with very similar levels of operation. Therefore carbon cost calculations have not been undertaken as part of this study. It is also assumed that all works would be carried out by the councils own labour force/locally contracted under their direction. The costs of any of the works will therefore depend upon how they are delivered, the capabilities of the team delivering them, and the rates for their time. In the absence of such details, it was concluded that most useful was a broad comparison of likely requirements (higher or lower) relative to reconfiguration of the rock bund.

6.1 Rock at Cliff Toe

6.1.1 Description

This would involve placing rock directly against the cliff face. Unlike the rock berm, designed to form a barrier a short distance away from the cliff, trapping sand in its lee, this approach would provide direct protection to the clay at the toe of the cliff against incoming waves. The intention will be reduce the exposure of that clay and thus reduce undercutting of the cliff face above, thus aiding stability.

A rock revetment would typically comprise two layers of large armour rock laid on a slope of e.g. 1 in 1.5 or flatter, generally with a bedding layer of smaller rock beneath, either sitting on a geotextile fabric or more traditionally a stone filter layer. Noting that there is no smaller bedding rock on site, the approach at Happisburgh would therefore be to place the armour rock directly onto geotextile, which would need to sit between the rock and the clay on the cliff face.

With the cliff face being vertical, some regrading of the cliff slope may be required to provide a stable base upon which to construct. Alternatively, and perhaps more pragmatically, the rock could just be placed up against the cliff face to form a triangle (in the same way as a rock toe is placed in front of a vertical seawall).

Like the rock bund and other rock structures, a key characteristic is dissipating the power of the waves, through the gaps between rocks. Each rock being of suitably large mass, and with some internal friction between them, ensures that in the main they will not be dislodged during storm events, although some isolated and occasional displacement can be accepted, especially in the circumstances at Happisburgh where the approach is to make the most of what exists.

A rock revetment is also a 'dynamic' and flexible structure, so can naturally accommodate some movements and readjustment that may result from large wave impacts and/or foreshore lowering. In the latter case, a 'falling toe' is often designed to ensure that undermining of the structure due to scouring will be mitigated and the integrity of the revetment remains intact.

6.1.2 Potential effectiveness

This would provide direct protection to the toe of the eroding cliff face. The intent is that by directly protecting the clay layer, this will reduce its erosion and this reduce the overall amount of cliff recession whilst the revetment is in place.

Erosion of the higher cliff above the rock can still occur, but would potentially be slowed by fixing the toe, thus preventing undercutting. The extent to which further upper cliff erosion occurs will be partially dictated by the height of the revetment and its influence on limiting wave run-up. But it is possible to attain a higher structure than the bund for the comparable volume of rock – this structure is essentially only half a bund width rather than full bund width.

This 'extra' rock availability also offers an opportunity to found the structure deeper into the beach. Ideally the base on the revetment should be placed on the clay wave-cut platform to minimise settlement and potential for instability due to undermining. In this respect an advantage of this option over the bund is that they clay layer is likely to be at a higher elevation closer to the cliff than it is several metres seaward.

However, natural ongoing erosion of the foreshore, including the clay wave-cut platform, will continue – this structure will not prevent that. The toe would therefore need to be either trenched into the clay or sufficient rock placed at the toe to accommodate the lowering so that the revetment does not collapse.

Although the armour rock is placed directly against the clay on the cliff, over a geotextile, the absence of further underlayer bedding rock means that waves breaking on the structure will still result in some liquification of the clay behind the geotextile, so there may be some potential for localised settlements/collapse.

Ultimately, as the cliff above any revetment erodes, overwashing wave action will also result in some scouring of the clay immediately behind the structure. As this propagates, the rock will eventually fall back into that space, potentially creating a new informal bund, albeit with some of the clay potentially captured in its core beneath the geotextile. By virtue of this, the rock will still provides some protection even though the revetment has structurally 'failed'. The extent to which this would occur, and to which this self-forming bund would have structural integrity cannot be established without trialling this approach, as there are no existing examples of this to refer to. At this point it may be possible to track machinery behind the structure if necessary to recover the rock for re-application.

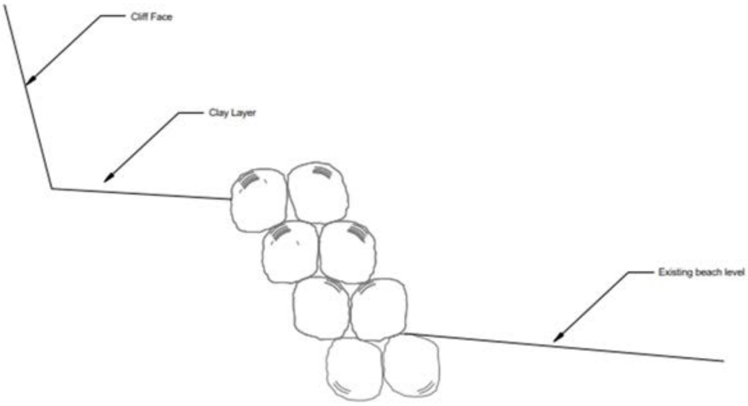


Figure 6-1. Potential revetment configuration

Figure 6-2. Example areas at Happisburgh where the revetment could be built against the clay layer.

6.1.3 Other considerations

Other key factors to consider are presented in Table 6-1.

Table 6-1. Rock Revetment Option Considerations

Rock Revetment	
Technical / Physical	Consider all lessons from bund effectiveness analysis, including founding on the clay layer and use of geotextile. The revetment uses less rock per linear metre than the bund, so possible to build to higher elevation, deeper (and/or wider) toe for same volume. Rock volume re-distribution may also offer potential to extend further along the shoreline/ target more areas. Beach levels directly in front of the revetment are not controlled, so will vary naturally and generally likely to be lower than they are behind the rock bund.

Rock Revetment	
Maintenance	A risk that low beach levels in front of the revetment result in machinery being unable to access works for any necessary maintenance to this structure. Access to the timber revetment to the north would be similarly be compromised if this occurs. Until such time that it is possible to access the area behind the structure, the ability to recover the rock for future re-use could be compromised.
Consenting	Potential challenges in obtaining consent due to change in structure type and positioning.
Environmental	Archaeological/heritage interests mean it is not acceptable to cut into the clay (either on cliff face or foreshore). So forming a sloped revetment may be constrained by this. Happisburgh Cliffs SSSI along northern length of frontage will likely preclude placing a revetment structure directly against the cliff face. So unlikely to be possible to implement this option over that particular part of the frontage.
Public Safety	If beach levels are low, public access along the frontage may be constrained. This could present safety risk if walking north at low tide but unable to return on rising tide. Structure at base of cliffs may give false sense of security and public may even use rocks to sit on. Cliff falls however remain an active risk at all times, so risk to those individuals.
Relative Cost implications	Construction of a revetment is more complicated than simple rock bund, so likely to require more time (cost) to build. Maintenance time (cost) could be higher than bund, particularly if more downtime due to access constraints.

6.2 Rock Groynes

6.2.1 Description

Groynes are structures built generally perpendicular to the shoreline, extending from the top of the beach down towards the sea. They are designed to interrupt the movement of sand or shingle naturally moving along the shoreline, the intent being that these would trap sediments coming from the north, thus building up beach levels in the groyne bays between. These higher beach levels then in turn reduce exposure of the cliffs to the more erosive wave forces.

Traditionally groynes were timber structures but are today frequently constructed from rock armour similar to that currently used for the rock bund, so offer a potential alternative use of that same material.

The cross-section of each groyne would not be dissimilar in principle to that of the existing rock bund, but might be constructed to a lower elevation – this needing to be just higher than the beach levels that they are seeking to retain and that level can follow the beach slope, e.g. 1 in 20, to be higher at the root (landward end) and lower at the seaward end.

6.2.2 Potential effectiveness

The principle purpose of the groynes is to build up beach levels in front of the cliffs, which will depend upon a number of factors.

Groynes do not typically work in isolation, but as part of a system formed from the interaction of several groynes acting together. Design of an effective groyne system therefore requires following some basic principles of structure length and their spacing, which will depend upon the predominant wave direction and beach characteristics. In particular it is important to recognise that groynes will not result in a consistent beach level along the cliff toe but will be higher on the updrift side adjacent to the structures and lower further away from them.

Beach forming sediments are generally arriving from the north, in addition to any sand and shingle arising directly from erosion of the Happisburgh cliffs themselves. However, the effectiveness of groynes will depend upon the mechanism by which those sediments move – whether that is alongshore along the upper beach, or alongshore around low water, with onshore-offshore movements bringing it onto the upper beach from that transport. If the latter, then the groynes will be relatively ineffective in trapping sediment.

However, the groynes situated to the north do appear to have some trapping effect on sediment moving southwards, giving some indication that groynes might help retain some sand on their updrift side, albeit the levels of the beach in those bays is relatively low. On this frontage, therefore, groynes may need to be relatively closely spaced to hold up a beach of sufficient height to offer additional protection to the cliffs. An illustrative diagram of possible rock groyne distributions at Happisburgh is shown in Figure 6-3. However, given the constraints on available rock quantity, this may restrict the number of groynes that can be constructed and thus the length of frontage protected.

Although the influence of potential additional sand input from the Bacton Sandscaping project is still uncertain, if this does materialise then this could see the groynes being more effective in helping to trap that sand when it arrives on the Happisburgh frontage and help to retain more material here during storm events from the north, although would do nothing to prevent beach draw down under easterly weather conditions.

Despite the groynes, further cliff erosion is still expected to occur, so the cliffs will retreat further back, meaning that the root of the groynes (landward ends) become detached from the groynes themselves. With further recession this could see their effectiveness in trapping sand at the toe of the cliffs being diminished.

Figure 6-3. Illustration of potential rock groyne defences (yellow) at Happisburgh

Like all the rock options, the groynes would ideally be constructed directly onto the clay wave-cut platform, on top of a geotextile. However, if that is not possible and they have to be constructed on sand – which is likely especially at their seaward ends where that clay layer is probably deeper. The groynes will settle in much the same way the rock bund has settled. Although not entirely compromising their performance – they will still have some effect on sediment movements – they will be less effective than intended. Therefore, the construction of these may require a larger volume of rock to be placed at the seaward ends to mitigate this.

6.2.3 Other considerations

Other key factors to consider are presented in Table 6-2.

Table 6-2. Rock Groynes Option Considerations

Rock Groynes	
Technical / Physical	Consider all lessons from bund effectiveness analysis, including founding on the clay layer and use of geotextile. Armour size would ideally be 6-10 tonne, as these extend further seaward than berm, so structure may suffer more displacement of rocks under storm conditions. Outline design assessments will be needed to establish optimum groyne length/spacing to be efficient. Further assessment of the potential increase in sand arriving from the Bacton Sandscaping would be beneficial. Although groynes have potential to create downdrift erosion, these are unlikely to be substantial enough that the majority of alongshore transport is interrupted. Effectiveness will diminish when the groynes are outflanked by cliff erosion at landward end.
Maintenance	Until such time that cliff recession means access is possible landward of the groynes, these structures will initially impede machine access along the shore for any necessary maintenance to these. This will also impact on maintaining the timber revetment located to the north, unless temporary measured such as sand ramps are created at the time to track over the groynes. Variable beach levels between the groynes could result in low spots which are not passible until those levels recover. Maintenance of the seaward ends of the groynes could be more difficult due to becoming continually submerged. As the shoreline recedes, recovery of the rock from the seaward ends for future re-use will be difficult.
Consenting	Potential challenges in obtaining consent due to significant change in approach and configuration of structures. Although outside of North Norfolk AONB, changed aesthetic to the current landscape may require additional permissions/approvals
Environmental	Whilst unlikely to be significant, the potential for downdrift impacts would need to be confirmed as approach will alter sediment transport and erosion/deposition patterns
Public Safety	These structures will be an obstacle to people walking along the beach, and potentially being able to exit the beach on incoming tides. Going over these structures is also contrary to Health & Safety advice to discourage people from climbing on the rocks. Once cliff retreats, it will be possible to walk along the beach landward of the groynes. However, that encourages individuals to walk close to the base of the cliffs, which is unadvisable due to the risk of cliff falls.
Relative Cost Implications	Construction of the groynes requires working further seaward than the bund so likely to have more intertidal downtime and thus require more time (cost) to build. Maintenance time (cost) would be higher than bund due to greater access impediments to be overcome, more downtime due to intertidal working for seaward elements.

Rock Groynes	
	Additional resource and time (costs) potentially required for outline design and assessments for consents. End of life rock recovery will likely be considerably more challenging and expensive due to seaward extents (longer time required, potentially larger/different plant).

6.3 Rock Breakwaters

6.3.1 Description

Rock breakwaters are detached structures generally built parallel to the shoreline and intended to act as wave breaks. They are designed to both provide some sheltering to the cliffs immediately behind and to diffract the wave fronts around them as they reach the shoreline, thus promoting beach accumulation behind which would also reduce exposure of the cliff toe. This is a quite different principle to groynes, where the structure itself traps the beach material.

The cross-section of each breakwater would be similar in principle to that of the existing rock bund, but these would typically be higher in elevation than the existing (post-constriction lowered) bund, to limit the wave transmission over and through them, to further encourage accumulation of beach sediment on the landward side.

Examples of rock breakwaters, albeit at a much larger scale than envisaged here, can be seen at Sea Palling.

6.3.2 Potential effectiveness

Like groynes, shore-parallel breakwaters do not typically work in isolation, but as part of system formed from the interaction of several structures acting together. There are again basic principles of design relating to structure length and spacing, and the expected degree to which sand might accumulate as a result of that.

The suggestion for Happisburgh would actually be slightly different - to construct these in a stepped fashion, so each is perpendicular to the predominant wave direction (north-east), as illustrated in the upper image in Figure 6-4. This may serve to provide a greater level of protection against storm waves along the same length of frontage, by having shorter lengths of structure enabling them to be built to a higher/wider structure for the same total volume of rock. Taking into account the potential for easterlies (such as the 'Beast from the East') to occur, these might in fact be curved to face both directions, as shown in the lower image in the same figure.

Beach forming sediments are generally arriving from the north, in addition to any sand and shingle arising directly from erosion of the Happisburgh cliffs themselves Although the influence of potential additional sand input from the Bacton Sandscaping project is still uncertain, if this does materialise then this could see these structures being more effective in helping to trap that sand when it arrives on the Happisburgh frontage and help to retain more material here during storm events from the north. Unlike groynes, these may also help to reduce the amount of on-offshore draw down of sand and shingle from the upper beach.

Maintaining elevation of the breakwaters is likely to be more important than for the rock bund. Once again, these structures would ideally be constructed directly onto the clay wave-cut platform, on top of a geotextile. But if that is not possible and they have to be constructed on sand they will settle in much the same way as the rock bund and effectiveness will be reduced. So they may either need to be trenched into the beach to reduce the undermining potential, or built higher or wider to accommodate any displacement, so utilising more rock. This may therefore limit the number of structures that can be built from available material.

One potential drawback of these structures is that as waves diffract around the ends of them, this can increase the instability of rock on those ends, but through concentrating the wave energy also possible create more scouring of the beach in those areas. That might result in local low spots in the beach near the cliff face, and in fact exacerbate cliff erosion at specific points behind the structures.

Irrespective of the above, these would again be an erosion-controlling rather than erosion-halting measure, so despite the breakwaters, further cliff erosion is still expected to occur.

Figure 6-4. Illustrations of potential rock breakwaters (yellow) at Happisburgh

6.3.3 Other considerations

Other key factors to consider are presented in Table 6-3.

Table 6-3. Rock Breakwater Option Considerations

Rock Breakwater	
Technical / Physical	Consider all lessons from bund effectiveness analysis, including founding on the clay layer and use of geotextile.

	Armour size would ideally be 6-10 tonne, as these extend further seaward than berm, so structure may suffer more displacement of rocks under storm conditions. Outline design assessments will be needed to establish optimum configuration to be efficient. Although these structures have potential to create downdrift erosion, these are unlikely to be substantial enough that the majority of alongshore transport is interrupted.
Maintenance	Unlike groynes, access along the shoreline should still be possible landward of these breakwaters for maintenance of these and the timber revetment to the north. However, the potential for localised scouring around the ends of these structures could result in low spots which may then affect moving between them and the cliffs. Maintenance of the seaward ends of the breakwaters could be more difficult if they become continually submerged. As the shoreline recedes, recovery of the rock from the seaward ends for future re-use may be more difficult.
Consenting	Potential challenges in obtaining consent due to significant change in approach and configuration of structures. Although outside of North Norfolk AONB, changed aesthetic to the current landscape may require additional permissions/approvals
Environmental	Whilst unlikely to be significant, the potential for downdrift impacts would need to be confirmed as approach will alter sediment transport and erosion/deposition patterns
Public Safety	These structures should not present an obstacle to people walking along the beach. However, the potential for localised scouring around the ends of these structures could result in low spots which may then hamper access.
Relative Cost Implications	Construction of the breakwaters will involve working further seaward than the bund so likely to have more intertidal downtime and thus require more time (cost) to build. Additional resource and time (costs) potentially required for outline design and assessments for consents. End of life rock recovery may be more challenging and expensive due to seaward extents (longer time required, potentially larger/different plant).

6.4 Headlands/Bastions

6.4.1 Description

Artificial headlands are man-made structures designed to mimic the natural headlands found along coastlines. Typically these are, or result in, large promontories which are strategically placed to create 'stable' bays. Acting to modify the direction of the waves to help form those shapes in the backing shoreline, either through the resultant cliff erosion and helping to reduce the alongshore movement of sediment deposited within the bays between these headlands.

Whilst offering enhanced protection to the cliff immediately behind them, there will still be erosion in the bays between, which can be relatively deep cut backs before a position of relative 'stability' is reached. The benefit of that however is that the deeper the bays, the efficiency in trapping beach sand is likely to increase, in that respect effectively acting like very large groynes. That deposition would also see the higher beach levels then in turn reduce exposure of the cliffs to the more erosive wave forces.

To achieve this, the structures need to be substantial enough to not be overwhelmed by wave action, so will have to comprise large mounds of armour rock placed against the cliff face and much larger than other rock structures discussed in this report. These also need to be of sufficient size to provide the diffractive influence on waves, and to not be easily outflanked by erosion either side, so would likely be higher, wider and longer than other options. A potential arrangement for these is illustrated in Figure 6-5.

An alternative approach of a similar nature could be to build smaller mounds of rock to create a series of 'bastions' placed up against the cliffs at closer intervals. Unlike the headlands described above, these will not be so influential on the waves and sediment deposition, but could form a series of hard points where erosion is better resisted. Although more susceptible to outflanking, they will offer a little more protection to the cliffs immediately behind, and creating some differential in erosion, helping to form crenulations in the cliff line which may themselves offer more scope for beach sand retention.

An illustration of what a bastion-fronted shoreline might look like is shown in Figure 6-6.

6.4.2 Potential effectiveness

Once more, these are structures that do not typically work in isolation, but as part of a system formed from the interaction of several structures acting together. However, due to the necessary size of some of these structures, the extent to which that is possible may be limited. In the case of headlands, it would be necessary to construct at least two of these, and ideally a minimum of three. More bastion structures could be built from the available rock, but they would also need to be much more closely spaced to have the desired effect.

Although the headlands might be substantial enough to remain connected to the cliff face, by resisting erosion immediately behind them, there is a strong likelihood that bastions would be vulnerable to outflanking by cliff erosion. This would not render them ineffective, as they would still be influencing the direction of the incoming waves – they would essentially become detached breakwaters, but much shorter and thus less effective.

The larger headland and resultant bays are likely to be more effective in trapping beach sediments, arriving either through alongshore drift from the north or directly from the ongoing erosion of the cliffs at Happisburgh, which will certainly continue between these structures. However, these will also be subject to some of the same limitation as groynes, in that they will not prevent on-offshore movement of sand – certainly until those bays become deep enough for the beach processes to be dominated by the modified wave fronts. For these reasons, it is less likely that the crenulations created by the smaller bastions would be very effective in retaining sand. Their principal effectiveness will most likely just be in offering some modification to the erosion patterns.

In both cases, there will be unabated erosion of the cliffs between the structures until some form of equilibrium is reached. However that is likely to be some considerable distance landward – in the case of the headlands, potentially a far back as the undefended cliff line to the south has now reached. That might ultimately be acceptable in the area between cliff top developments, but probably not in front of those. That equilibrium may also take many years to reach, during which time the benefits of a 'stable bay' are not fully realised, so this is not necessarily desirable as an approach over short timescales.

As with other structures formed of the rock, these would ideally be constructed directly onto the clay wave-cut platform, on top of a geotextile. However, unlike those, due to the much more substantial size of the headlands or bastions, it is less critical if there is some displacement.

Figure 6-5. Illustration of potential rock headlands (yellow) at Happisburgh

Figure 6-6. Illustration of potential rock bastions (yellow) at Happisburgh

6.4.3 Other considerations

Other key factors to consider are presented in Table 6-4.

Table 6-4. Rock Headland/Bastion Option Considerations

Rock Headland/Bastion	
Technical / Physical	These structures will require a substantial volume of rock each, so the numbers that can be built will be limited, which could affect how much shoreline is managed.

	Headlands, through their design are intended to have a significant effect on the shoreline evolution. If they are effective in trapping more sand within their embayments they could have potential to create some downdrift erosion.
Maintenance	The low water line will soon reach the end of any headlands, so access beyond these will no longer be possible for maintenance to these or the timber revetment to the north. Alternative means of access would have to be created. This will be less immediate with bastions, although they will become detached structures with deeper water immediately around them in due course, leading to the same constraints. As the shoreline recedes, recovery of the rock from the seaward ends for future re-use will become difficult and could even become impossible without marine-based plant.
Consenting	Potential challenges in obtaining consent due to significant change in approach and configuration of structures. Although outside of North Norfolk AONB, changed aesthetic to the current landscape may require additional permissions/approvals.
Environmental	Happisburgh Cliffs SSSI along northern length of frontage will likely preclude placing headland or bastion structures directly against the cliff face. So unlikely to be possible to implement this option over that particular part of the frontage. Due to the potential effect on shoreline evolution, the potential for downdrift impacts would need to be confirmed as approach will alter sediment transport and erosion/deposition patterns.
Public Safety	The headlands would restrict public access along the beach. There is a risk that the structures may be passable at low water, but would be quickly under way with a rising tide, presenting a safety risk to people walking along the shoreline being unable to safely exit. The local community might feel more 'exposed' by the gaps in protection between the structures where erosion will not be attenuated until an equilibrium position is reached, which is likely to take several years.
Relative Cost Implications	Additional access points for maintenance plant may need to be created and maintained, particularly to reach the timber revetment to the north. End of life rock recovery could be more challenging and expensive due to seaward extents (longer time required, potentially larger/different plant).

6.5 Combinations of options

Most of these alternative approaches could be implemented across the whole area (subject to sufficient rock being available) or targeted to specific areas as discussed in section 5.3.

Some approaches could also be combined, e.g. a revetment or bund at priority locations, bastions in others where full length of protection is not provided.

There are numerous permutations so cannot all be developed here, and indeed it would be fruitless to do so without further decisions on the use of the rock. However, the guidance provided in this section on each of those potential uses of the rock, together with that in section 5 regarding the bund, remains applicable to help inform those discussions and choices – the assessments of potential effectiveness and other considerations all remain applicable to those whether implemented in isolation or in combination.

7. Options for Provision of Beach Access

This section provides an overview of the existing beach access routes along the Happisburgh frontage and assessment of potentially viable options for continued provision of beach access.

Consideration has been given to both pedestrian access and the access requirements for vehicles and plant necessary to undertaken maintenance works along this frontage and that to the north where the timber revetment and groynes remain.

It should be noted that all options are likely to require planning consents and licences for works taking place, and will also be subject to satisfactory negotiations and approvals from any landowners. Note that any alternative options to the existing ramp are unlikely to be covered by the current MMO and Planning Licences, as they all fall outside of the existing footprint/co-ordinates.

7.1 Past and Present Beach Access

The original beach access consisted of a ramp down to the beach, located at the end of the lane off Beach Road, with the foot of this reaching the beach around what is now the northern end of the rock bund. This was lost to storm damage in 2002.

To enable continued public access to the beach, a steel staircase was installed the following year (see Figure 8-1). However, following further cliff recession, these had to be removed in 2012 as no longer safe to use. These have since been placed in storage for potential reuse.

Figure 7-1 Staircase units previously used for beach access to the north of Happisburgh (September 2009)

With removal of the steps, an access ramp was created to the south of Beach Road near the current car park (Figure 8-2), with the rock bund extended to provide protection to that in 2013. This follows the line of the cliff face, with a side slope of 45º cut back into the cliff for stability, and the cut clay has been used as extra packing for the unsurfaced ramp slope. The current ramp is between 4m and 5m in width and now has a steep slope of between 1 in 5 and 1 in 6. As a general rule the maximum ramp slope would be 1 in 12, but this has not been possible here due to constrictions on available space and being able to maintain the ramp in the face on continued erosion.

This still exists, although the ramp has been recut and reshaped several times as erosion has occurred. More recently this recutting has been required every few months. This remains the primary route down to the beach for both pedestrians and maintenance vehicles, although in periods of low beaches and inclement weather can be closed for long periods of time.

Figure 7-2 Location of the current beach access ramp at Happisburgh

A cut in the cliffs to the south of Happisburgh village, locally known as the 'Grand Canyon' developed in early 2021. This is located approximately 250m south of the current access ramp (Figure 7-3). and has recently become an informal and unmanaged access to the beach for pedestrians.

The 'Grand Canyon' now extends approximately 40m inland from the main cliff frontage and spans approximately 50m at its widest point after just four years. It is thought that this was initially triggered by Storm Christoph in the January of 2021, and resulted from an erosion induced 'landslide' (Petley, 2021), which formed a small but ever growing 'gully' feature (Figure 7-4). Certainly surface water runoff has contributed to its development, this being a noticeable low spot in the surrounding field, and there also appears to be sub-surface groundwater running off through this location too.

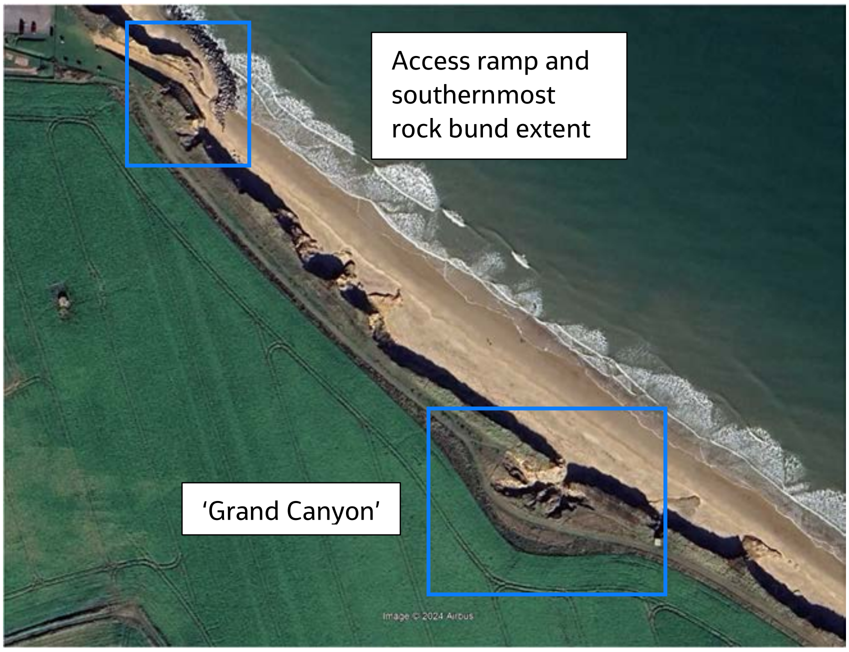


Figure 7-3 Location of 'Grand Canyon' at Happisburgh, shown on an aerial photo from 2024.

Formation of Grand Canyon after Storm Christoph, January 2021 (Source: Getty Images)

November 2024

Figure 7-4 Photographs of 'Grand Canyon' site

Beyond these, beach access is also possible through the seawall at Cart Gap, approximately 1.5km to the south of Happisburgh'

7.2 Re-instatement of the steel staircase

Assessment has been made of the potential reuse of the old steel staircase which is currently in storage and remains in visibly reasonable condition, although it would need to be thoroughly checked from a structural perspective for safety reasons before considering its installation.

In respect of reinstalling this on the Happisburgh frontage however, this is not considered an option to be considered further. As will be described further below, there are better, safer and more cost effective options to provide beach access to pedestrians, noting also that this would not fulfil the requirement for vehicle access which would still need to be provided.

From a purely technical perspective there are several reasons to discount this at the outset. Ongoing erosion of the cliffs in front of Happisburgh village means this is time limited and the issue of becoming detached from the cliffs (as before) will reoccur rendering these redundant. Although the cliffs to the south are now receding much more slowly, they are still eroding. The viability of this access is therefore time limited and could become redundant after a single storm event.

This structure requires a substantial piled concrete block support to be built into the beach. With beach levels volatile here this could become undermined by a drop in those levels, rendering it unsafe unless founded to a considerable depth. As a complex structure, it is also likely to require regular and potentially significant monitoring and maintenance to ensure it remains safe for public use.

7.3 Access at Happisburgh village

There are a few options for beach access at or around its current location, all being close to the new car park which is set to be moved landward into the adjacent field. Mostly these are different variations on the same themes, falling into two sub-categories of shore-parallel ramps (similar to the present ramp) or shore-normal ramps, as follows:

Shore-parallel

(A) Maintain the existing ramp as present practice.

(B) New shore-parallel ramp at the existing car park.

(C) New shore-parallel ramp along the cliffs further to the south.

(D) New ramp that is north-facing rather than south-facing

Shore-normal

(E) Create a shore-normal ramp south of the current location.

(F) Create a shore-normal ramp going through the existing Car Park.

7.3.1 Shore-parallel ramp options

Each of the shore-parallel ramp options are shown in Figure 8-5 and are discussed below.

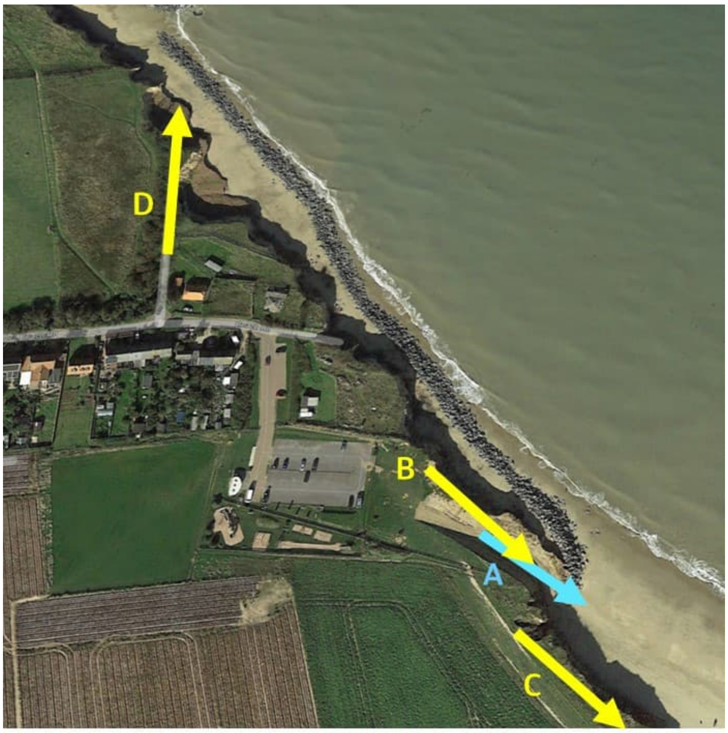


Figure 7-5 Shore-parallel ramp options at Happisburgh (yellow arrows indicate ramp slope top to bottom)

Common to these options are the following points:

- This is a continuation of the existing process of re-cutting the access ramp along the cliff face, but for slightly different locations. This cutting process has been ongoing since 2014 and has ensured that a beach ramp access is maintained. There is therefore good knowledge of the current erosion regime at this location and the nature of works required.
- Side cuts need to be maintained at 45º (or flatter - this should be confirmed for the ground material type as this criteria varies) to reduce the risk of cliff falls from above onto the ramp which would present a safety risk. An advantage of running shore-parallel is that this slope only needs to be cut into the cliff on one side (landward) of the ramp.
- There is the option for the materials used on the slope surface to be changed from the current post cut and compacted clay, to timber or hard surfacing.

7.3.1.1 Maintain the existing ramp as present (Option A)

This is 'business-as-usual' and simply involves continuing to carry out operations as in the past, at the same location. This is least disruptive and likely to be of least cost, as the ramp is already there.

However, this is a steep ramp with an uneven surface, making it more challenging for pedestrian access. Furthermore, although the location benefits from the presence of the rock bund, erosion does still occur, resulting in its temporary closure at times and ongoing works to maintain this as a usable access point.

7.3.1.2 New shore-parallel ramp at the existing car park (Option B)

This would be a ramp similar in orientation to the existing ramp, but cut further to the north that the current location, in front of the existing car park. This is the approximate location where the ramp was first cut, but has crept south when being recut over the years. This would also remain behind the rock bund so is afforded some protection from the sea, although it would still benefit from some enhanced protection, e.g. bolstering the rock bund locally.

By moving north, and recutting further landward across the seaward edge of the existing car park, this may also defer the next recutting of the ramp for longer.

A benefit of making this new cut further north is that this provides a longer distance behind the bund to cut a shallower slope than the present ramp (e.g. 1:12 minimum), which would make it more likely to be pedestrian-friendly. Side cuts (into the cliff landward and seaward) would be cut similar to those adopted for the existing ramp for stability.

A further benefit of this approach is that the car park is land owned by NNDC, whereas other land to north and south is not.

7.3.1.3 New shore-parallel ramp further to the south (Option C)

This would again be a ramp similar in orientation to the existing ramp, but created further to the south where recession of the cliffs is slower, the rationale being that cliff recession here is now much slower than to the north. Like option B, it would be possible to create a longer ramp with shallower slope to make it more pedestrian friendly.

But despite being a slower rate, this is still an area where erosion is still active, so this is not without risk and a ramp to the south would be outside of the limits of the rock bund with the protection that affords. Consequently it would likely require some of the rock from the bund to be relocated to protect this access, taking it away from the areas where it is also required – the advantage of locations further north is that the rock bund has the dual benefit of protecting the ramp <u>and</u> other assets.

A further disadvantage is that for vehicular access to use the ramp, there would need for those to be able to track across an agricultural field to reach the ramp, potentially needing to create a better hardstanding track to do so. This would involve additional cost, repeatedly as this track would be vulnerable to erosion as the cliff recedes, and also going across land which is not owned by NNDC.

For the reasons above, this is not unlikely to be an effective approach to provide beach access here.

7.3.1.4 New ramp facing north (Option D)

This would involve cutting a ramp facing the opposite way – with the downslope going northwards rather than southwards. For the purposes of illustration this has been shown as running off the edge of the lane that previously led to the original lifeboat ramp structure, but could be located anywhere along the cliff.

The key reason this has not been done in the past is that this is then open to the predominant wave direction. That means it will subject to wave run-up during storms which will lead to direct erosion and damage to the ramp itself. The toe of the ramp where it meets the beach will be regularly eroded by waves, creating a step making access un-usable until further maintenance undertaken.

In contrast, the benefit of a southward facing shore-parallel ramp, as has been the approach up until now, is in maintaining this interface between the beach and the bottom of the ramp. As a result of this orientation, the foot of the ramp is better sheltered from incoming waves and there is less potential for a drop in beach levels to create this step.

For these reasons, this is unlikely to be an effective option for providing beach access here.

7.3.2 Shore-normal ramp options

Both of the variations on a shore-normal ramp are shown in Figure 8-6, which are discussed below.

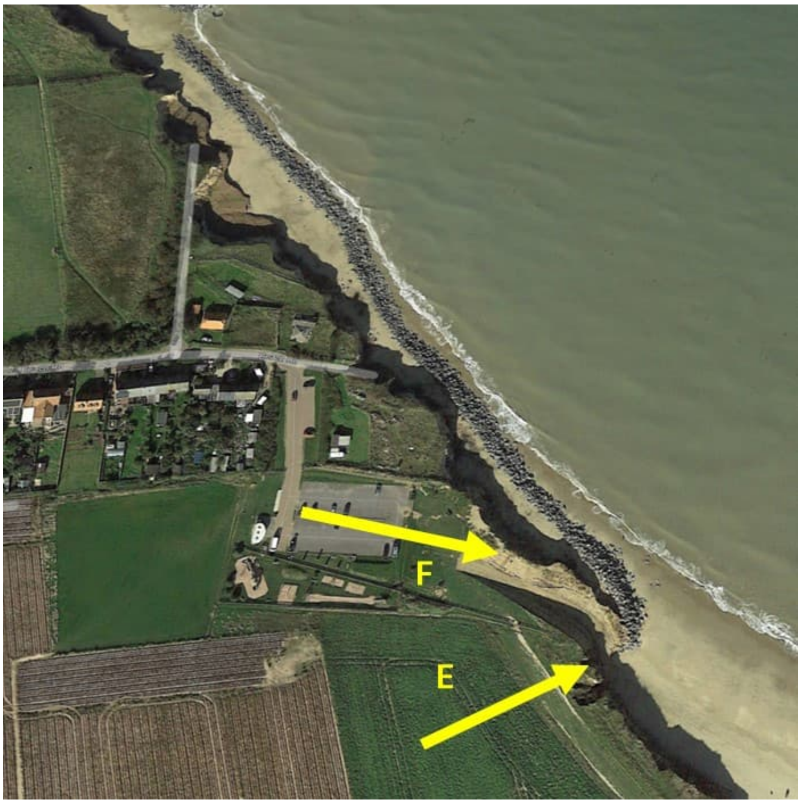


Figure 7-6 Shore-normal ramp options at Happisburgh (yellow arrows indicate ramp slope top to bottom)

Common to both of these options are the following points:

- They will both extend further inland, so will result in greater land-take than the shore-parallel approach (approximately double the area and the volume to be cut).
- Side cuts (to both sides) need to be 45° (or flatter - this should be confirmed for the ground material type as this criteria varies) to reduce the risk of cliff falls from above onto the ramp and thus minimise safety risk.
- There is the option for the materials used on the slope surface to be changed from the current post cut and compacted clay, to timber or hard surfacing.

7.3.2.1 Create a shore-normal ramp south of the current ramp (Option E)

Rather than a ramp running along the cliff face, the approach would be to cut a ramp <u>through</u> the cliff face. An advantage of this is that it may be possible to create a shallower slope than the present ramp (e.g. closer to 1:12 minimum), which would make it more likely to be pedestrian-friendly. This orientation would also remove the risk of erosion of the ramp along it's seaward edge which would not need to be maintained in the same way as the existing ramp.

A key disadvantage is beach lowering and ongoing erosion at the toe of the ramp. This will create a step profile making access un-usable until further maintenance undertaken such as recutting of the toe or placing additional clay. Although a hard step could be created from concrete blocks for example, these would be prone to undermining and/or settlement, again creating a step in the surface making use problematic. Although a hard step could be created from concrete blocks for example, these would be prone to undermining and/or settlement, again creating a step in the surface making use problematic.

However, recession of the cliffs will still occur, so over time the foot of the ramp will also become exposed and proud of the cliff edge so will need reinforcing at that point, or the ramp will need to be recut further back into the cliffs. Recutting the ramp surface may also mean recutting both side slopes to ensure that they are not over-steepened and thus become unsafe – this would be a sizeable undertaking if necessary on a regular basis, although might be mitigated by initially cutting much flatter side slopes.

These issues might be less of concern initially as long as the foot of the ramp remains behind the higher part of the rock bund. The top of the ramp and the cut slopes would though now go through private land and require agreements with the landowner to do so, particularly given the much more substantial land-take arising from this approach and especially if a shallower ramp was being provided.

A further disadvantage is that for vehicular access to use the ramp, there would need for those to be able to track across an agricultural field to reach the ramp, potentially needing to create a better hardstanding track to do so. This would involve additional cost.

7.3.2.2 Create a shore-normal ramp through the existing car park (Option F)

The alternative is to create the a ramp similar to that discussed above, but through the existing car park. Plans are already in place to close this and create a new car park in the field set further inland.

A major advantage of this are that the land is owned by NNDC and it is possible to extend the top of the ramp much further inland. By virtue of that, the toe of the ramp even with the desired shallow slope will be contained within the body of the cliffs, i.e. not exposed at the foreshore. Consequently, although cliff erosion will continue, there will be a longer period of time before this reaches the base of the ramp and any maintenance starts to become necessary.

This has the advantage of being close to the new car park, and the road, so no additional works are required to make it accessible for maintenance vehicles or pedestrians.

A negative perspective on this option might be public reaction to a large cut being made in the existing cliffs so close to properties and other infrastructure being perceived to be increasing their vulnerability to erosion. Also, the depth and steepness of cut may lead to apprehension on usage if it is seen to resemble a large canyon, especially as the seaward cliff continues to erode. However, this cut remains behind the higher section of the rock bund, so is afforded some protection at the moment and recession here is less than elsewhere.

Like every option, this is time limited, but has greater potential longevity than the other alternatives discussed above.

7.4 Access south of Happisburgh village

If it is decided to provide access elsewhere other than Happisburgh village, this would most probably be further to the south on the basis that recession rates there have now slowed considerably compared to those experienced in the years immediately following failure of the timber revetment.

These include using the opportunity to take advantage of the 'Grand Canyon' feature that has appeared through the cliff face, and providing alternative maintenance vehicle access at Cart Gap or Bush Estate.

7.4.1 'Grand Canyon'

This gap through the cliffs is already used as an informal access by the public, but does require them scrambling down the cuts which can be slippery and unstable.

Options might be considered to improve access through this gap, to better enable pedestrians to reach the beach, this being only 300m from the new car park and on the existing coastal path which runs along the top of the cliffs. The other benefits of this are the existing feature reduces required excavation and formation of a new cut through the cliffs. Notwithstanding that, the stability of the upper cliff either side of the gap onto the beach ought to be assessed and possibly trimmed back to avoid falls into the gap which are a safety hazard.

One potential approach to improve access here is to grade the slope to make it easier to walk down, potentially also adding some surfacing material or matting that provide a better grip and make the surface less slippery. However, as can be seen in Figure 8-6, this existing slope is already steep, at approximately 1:6 (not dissimilar to the existing beach access ramp at Happisburgh). So, to achieve a slope closer to 1:12 for more suitable pedestrian use) would require cutting further back inland. Although the land is not owned by NNDC.

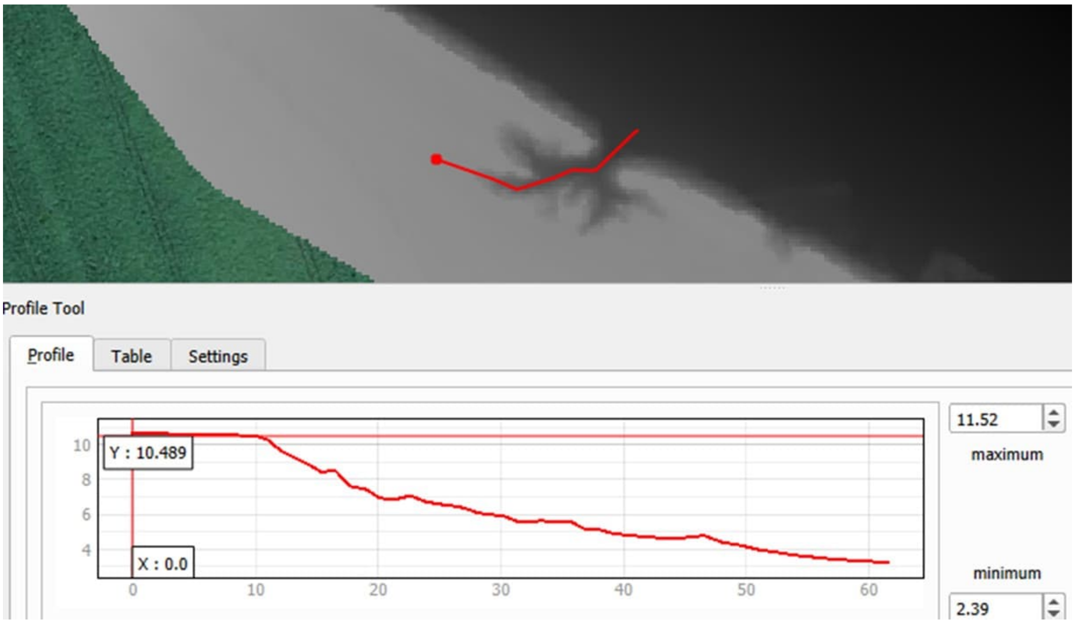


Figure 7-7 Section showing the slope though the Grand Canyon

However, despite cutting a shallower slope, the processes that have formed this feature include surface water runoff and subsurface ground water seepage, which will continue as this evolves. So this pathway may remain slippery and unstable even with some form of surfacing. Increased pedestrian use of this pathway will also cause some further erosion through wear and tear. Consequently, if access is simply improved in this way, there will be certainty of suitable access on a continual basis and may need to be closed off at times if deemed unsafe. As such it will need ongoing monitoring and maintenance if it is to be adopted as an approved access point.

Currently NNDC are not liable when the 'Grand Canyon' is used for access as they do not direct people to do so. However, this would no longer be the case should they begin to facilitate this as a formal access point, so this also needs to be taken into consideration.

Alternatives to simply re-grading the slope include incorporating steps down that slope, or a timber piled staircase through the gap. The latter in particular would reduce the safety risk, with these not being subject to the water that can run through the canyon. Although suitable for able bodied pedestrians, this would though be limiting for those with restricted mobility. This option would also have higher costs to install and, with all of these approaches, are time-limited as recession of the cliffs here will continue and in the coming years this feature will ultimately be lost to erosion.

The dimensions of this feature mean that it is currently only potentially suited to pedestrian access and not for building a maintenance vehicle ramp. To provide that would require considerably more excavation, at what is not an ideal location for that due to overland access as described elsewhere.

7.4.2 Decca Field

If there is no ramp provided at Happisburgh, alternative means of access will be required for maintenance vehicles to attend to the rock works at the village and the timber revetment to the north. As the Grand Canyon would be suitable for pedestrian access only, alternatives for maintenance vehicle access are required.

7.4.2.1 Existing access point at Cart Gap

The next formal access is located at Cart Gap, approximately 1.5km to the south at the boundary between the NNDC and Environment Agency owned sections of seawall (Figure 8-8).

Although possible to use Cart Gap as alternative access, that can be problematic for several reasons:

- Use of Cart Gap depends upon the levels of the beach at that location and in front of the wall at Bush Estate, which can be volatile. As such, there are times where it would be impossible to use this to get machinery onto the beach and track north even as far as the end of the seawall.
- There are a series of groynes along the seawall in front of Bush Estate. Unless tide levels are very low this makes the beach impassible without temporary works to go over each of those groynes.
- The time it takes to track along the beach from Cart Gap to Happisburgh reduces the working window. This is especially limiting and potentially impractical if tides are such that machinery needs to exit the beach every high tide.

Consequently, Cart Gap is not seen as a viable option for assured access by plant if required.

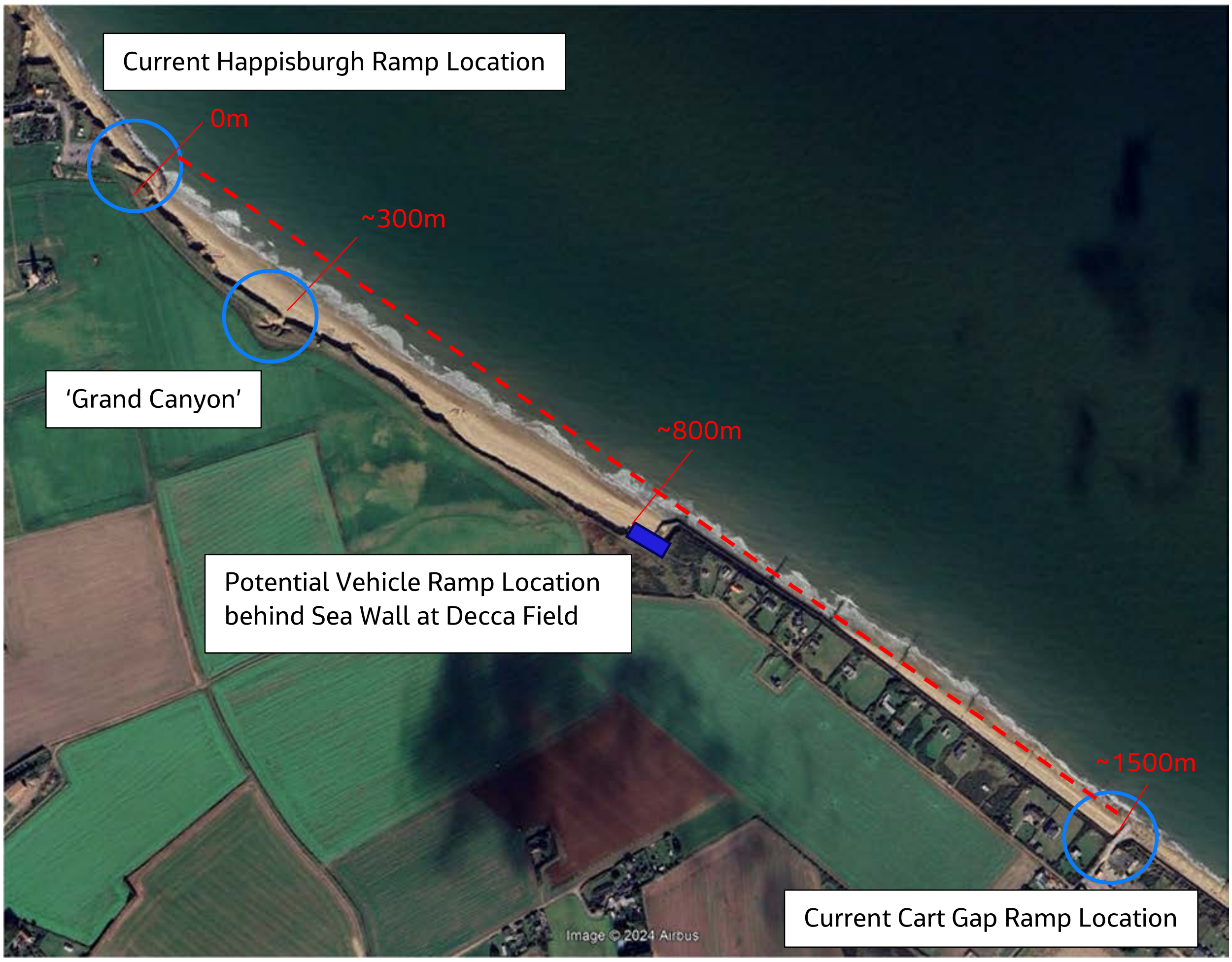


Figure 7-8 Locations of the potential Decca Field vehicle ramp and current Cart Gap ramps relative to the access ramp at Happisburgh

7.4.2.2 New ramp at Decca Field

This would involve creating a new ramp at the southern end of the cliffs, behind the steel sheet piling where the seawall terminates, as shown in Figure 8-7 and Figure 8-8. Although no longer there, this is actually the location of a former ramp used for construction access in the past.

The ramp itself could be similar to that described for Happisburgh, albeit north-facing. However, unlike those locations, the cliffs here now appear to be relatively stable and there are even signs of some dune vegetation growth on the foreshore, indicating sand deposition. Consequently, the risks of erosion to the ramp edges and to the toe of the ramp are considered to be considerably lower than at Happisburgh. In addition, there is rock already at this location which can be utilised to help reinforce and protect a ramp at this location.

It would also be possible to construct this ramp at a shallow enough slope for comfortable pedestrian use, although being 800m to the south, this distance is expected to be too great for this to become the primary access route to the beach from Happisburgh village and car park.

Figure 7-9 Happisburgh coastal frontage. Photo taken looking north from the potential Decca Field vehicle ramp location (November 2024)

This is however a considerably more favourable location than Cart Gap for maintenance vehicles, being only half the distance to travel and without the obstacles of beach structures to overcome. A longer tidal working window would also result. Although some landside work might be required to ensure access to the ramp, and noting NNDC do not currently own that land, there is already an informal access track behind properties that could be improved. Maintenance vehicles would then reach the coast from the south, rather than via Happisburgh village or any need to track along the cliffs.

8. Summary and Conclusions

The aim of this report was not to decide on the future direction for Happisburgh. Instead, it focuses on conducting technical assessments to offer guidance on various approaches. This information will help NNDC and the local community engage in well-informed discussions as they determine the best path forward.

Assessment of the performance of the existing rock bund shows that it has been successful in controlling recession of the cliffs in front of Happisburgh village. This is in line with the design principle and intent of the Shoreline Management Plan which is not to completely halt erosion, but reduce the rate at which it occurs.

Comparisons with the immediate post-failure rates along the adjacent undefended section of cliffs to the south, indicate that the bund has provided a reduction in recession of up to 50% compared to that which might have been otherwise expected. In particular, the bund has had the effect of reducing day-to-day exposure of the base of the cliffs to waves and tides by holding up beach sand between it and the foot of the cliff, particularly when natural foreshore levels are lower which, given the beaches are dynamic and can be volatile, will inevitably happen on a regular basis throughout the year. The extent to which sand moving southwards along the coast from the Bacton Sandscaping benefits Happisburgh is still to be established, although beach levels seaward of the bund were higher in 2024 than in previous years.

The main issue with the rock bund has been the rapid lowering in elevation of the bund along the northern and central sections of its length, which has reduced its effectiveness. This appears to be due to it being built directly on the beach sand rather than the underlying clay wave-cut platform, and thus being undermined with rocks displaced when beach levels have been lower or scoured by waves.

Taking these findings into account, guidance is provided on approaches to improve the effectiveness of the bund if it is reconstructed in the future, with measures to better maintain the overall elevation of the structure. Those will necessitate the bund being shorter, given the finite rock material available, so consideration as to where that rock is placed is also provided. This recognises Beach Road as having the more immediate need, but acknowledging the need to also consider the future risks to the church and surrounding properties.

Use of the same rock to create alternative erosion-management structures to the bund have been examined. They each have different merits, and some have been identified as likely to be less effective than others. The assessments contained in this report provides guidance so that future decisions on any of these can be suitably informed. The principal constraints on several of the approaches are the impediment to future access along the beach that may arise, limiting safe public use and restricting the ability of the council to maintain those structures and the timber revetment to the north. The ability to recover the rock in future to reinstate structures as the shoreline continues to recede is also a key consideration.

A range of options for access to the beach have been examined, with commentary on the various opportunities and constraints on each identified. Consideration has been given to both public pedestrian access and the need for maintenance vehicles to access the beach. These options include continuing to provide access at Happisburgh village, or alternatively providing this south of the village. Some of the options presented are noted to be unlikely to be well advised. Details on others will however help to inform the discussions on the future approach to ensuring provision of beach access.

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COASTWISE

Department for Environment Food & Rural Affairs

Environment Agency

Coastal transition accelerator programme

Part of the £200m
Flood and coastal innovation programmes