

Project	Arup – Barmouth North Promenade Outline Business Case
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Prepared by	David Finch

Introduction

ABPmer has been commissioned by Arup to undertake a coastal processes assessment, wave modelling to derive extreme wave and water level conditions and overtopping analysis for North Promenade, Barmouth. This work forms part of an Outline Business Case Arup is undertaking on behalf of YGC, part of Gwynedd County Council and follows on from the:

- Barmouth North Promenade, Coastal Processes Study (ABPmer 2019a); and
- Barmouth North Promenade, Wave modelling, extremes analysis and overtopping study (ABPmer 2019b)

This note has been produced to examine potential beach nourishment options for the Northern Promenade frontage, including the likely extent and location of beach control structures that would be required to hold the nourished material. This work supports the shortlisting and costing of options to inform the selection of a preferred option.

The scope of this assessment is set out in an Email sent on 19th February 2019, namely

“ABPmer proposes to assist Arup with coastal processes support to allow the development of up to 3 potential feasible schemes, including a combination of breakwaters and/or groynes, enabling Arup to develop outline costs for the schemes. The concept schemes will be developed based on expected beach profile requirements and knowledge of sediment transport pathways. Consideration will be given to minimising footprints and material quantities, but no formal testing or assessment is proposed. For each concept solution we will briefly describe the basis on which it has been derived from a coastal process/sediment transport perspectives and key points that should be considered, e.g. implications for access. The scheme layouts will be provided to enable Arup to review design considerations and cost. Arup will need to review the feasibility of the schemes from an engineering and environmental perspective and ensure that any requirements under CDM regulations are met. The results of the coastal process assessment will be provided in a brief technical note with sketched of the proposed layouts.”

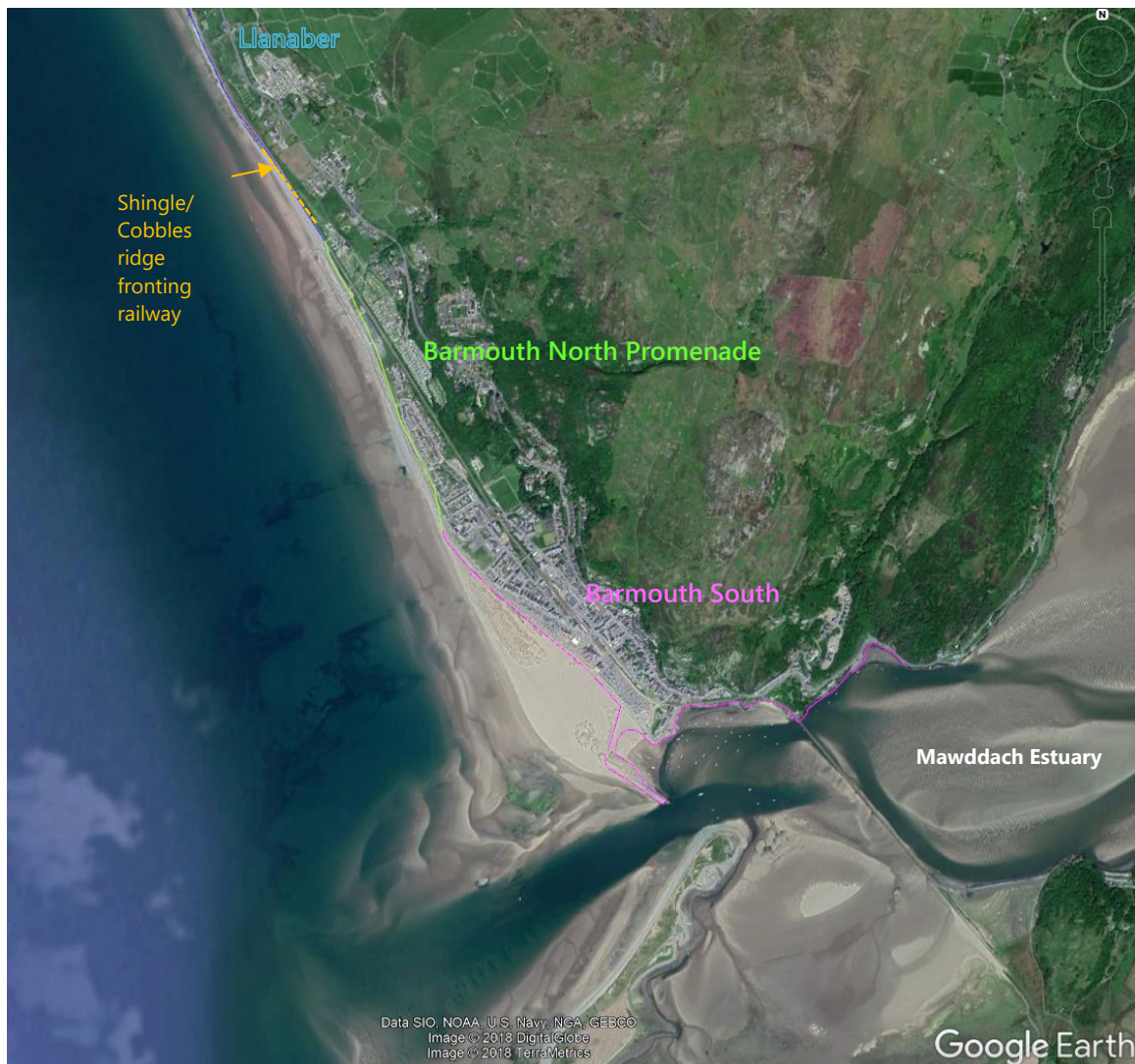


Figure 1. Location of Barmouth North Promenade with SMP2 policy units: **Llanaber (11.16)**, **Barmouth North (11.15)** and **Barmouth South (11.14)** overlaid

Principles and assumptions

The principal aim of the assessment was to derive up to three potential beach nourishment options for the North promenade, together with the likely requirement for associated beach control structures. These options are developed to concept level for consideration at OBC Options Appraisal. The options have been developed from information contained in the Barmouth North Promenade Coastal Process Report (ABPmer, 2019a) and the Barmouth North Promenade Wave Modelling, Extremes Analysis and Overtopping Report (ABPmer, 2019b) along with expert judgement. Should any of the options be taken forward additional studies and assessments will be required.

In developing the options, the following principles and assumptions have been adopted:

- A design horizon of 2119 (in 100 years' time), with the beach providing the primary defence for events up to a 1:200 year return period (0.5% AEP).

- The frontage has been compartmentalised from adjacent shorelines based on the different alignments of the existing sea walls/infrastructure.
- Nourishment will be coarser shingle sized material, rather than sand sized material, this is because coarser material lies at much steeper angles and is less prone to be drawn down and transported offshore. The footprint of beach nourishment and size of required beach retaining structures is less. Using coarser material and thus restricting the spatial footprint of the options will reduce effects on the sand transport regime.
- All options assume a minimal maintenance requirement, i.e. no need for frequent, recycling of material. However, it is recognised that some re-nourishment will be required to account for some small losses from the frontage over the frontage.
- The options minimise impact on adjacent SMP units
- No consideration has been given to the existing groynes, which are providing limited protection to the frontage. There is potential that these could affect the feasibility of the proposed options, either from a performance perspective (e.g. they may not be compatible with breakwater type option), or from an aesthetic/ health and safety perspective.
- The potential impacts on the Pen Llyn a'r Sarnau SAC have not been considered.

The approach is briefly summarised below:

- Assessment of expected minimum beach cross shore profile required to limit overtopping to acceptable levels in 2119.
- Assessment of expected variability beach alignment due to different incident waves.
- Utilise above to identify potential width of beach compartments (e.g. groyne bays), and the average beach width required within each compartment.
- Identify likely extent of beach control structures that would be required to hold the beach together with the indicative crest height of these structures.

These steps are described in further detail in the following sections.

Minimum beach cross-shore profile

It is assumed the nourished material will be shingle, which typically maintains an average beach slope of around 1:8. This nourished material would respond in a similar fashion to that of the shingle/cobbles beach which directly fronts the railway to the north of the Northern Promenade frontage. Figure 2 shows the typical levels and extent of these shingle ridges, as taken from the Lle composite 1m DSM (<http://lle.gov.wales>). This DSM contains LiDAR data flown on different (unknown) dates. The northern section identified on the figure shows a crest height of around 6mODN with a crest width of around 10-12m.

During the 3 Jan 2014 storm event, which is understood to have an AEP of around 0.5% (1:200 year, Figure 3), overtopping and breaching of the shingle/cobble bank was observed (Figure 4). The time these photographs were taken and exact location is unknown, but it is believed that they represent conditions, directly north of the North Promenade frontage (i.e. the most southerly section of the shingle ridge). From Figure 2, the crest level associated with the bank in this region are slightly lower than those of the ridge to the north, possibly due to the over washing of material that occurred during the 2014 event.

On this basis, it is proposed that the minimal beach profile for a nourished beach (present day), would have a beach crest height of 6m, a crest width of 15m and would slope down to the existing seabed at a slope of 1:8.

For the design horizon of 2119 an allowance for Sea Level Rise is required. From ABPmer (2019b), this allowance has been calculated to be 1.1m. Therefore, the proposed minimum beach profile for 2119 would have a crest height of 7.1m, a crest width of 15m and would slope down to the existing seabed

at a slope of 1:8. This profile is shown in Figure 5. The profile is defined from the vertical seaward limit of the existing seawall. For reference the present day tidal levels and predicted extreme water levels for the frontage are provided in Table 1 and Table 2 respectively.

Interim design considerations:

To identify beach and structural layout extents for the design horizon of 2119, the minimum 2119 beach profile is used in the subsequent assessment. This is because, this minimum beach profile will need to be held by the beach controls structures in 2119. However, during earlier epochs, it would be possible to limit the crest height of the nourished beach. For a 2069 horizon it should be possible to limit the beach crest height to 6.4m. This is based on SLR allowance of 0.4m from 2019 to 2069 (ABPmer 2019b).

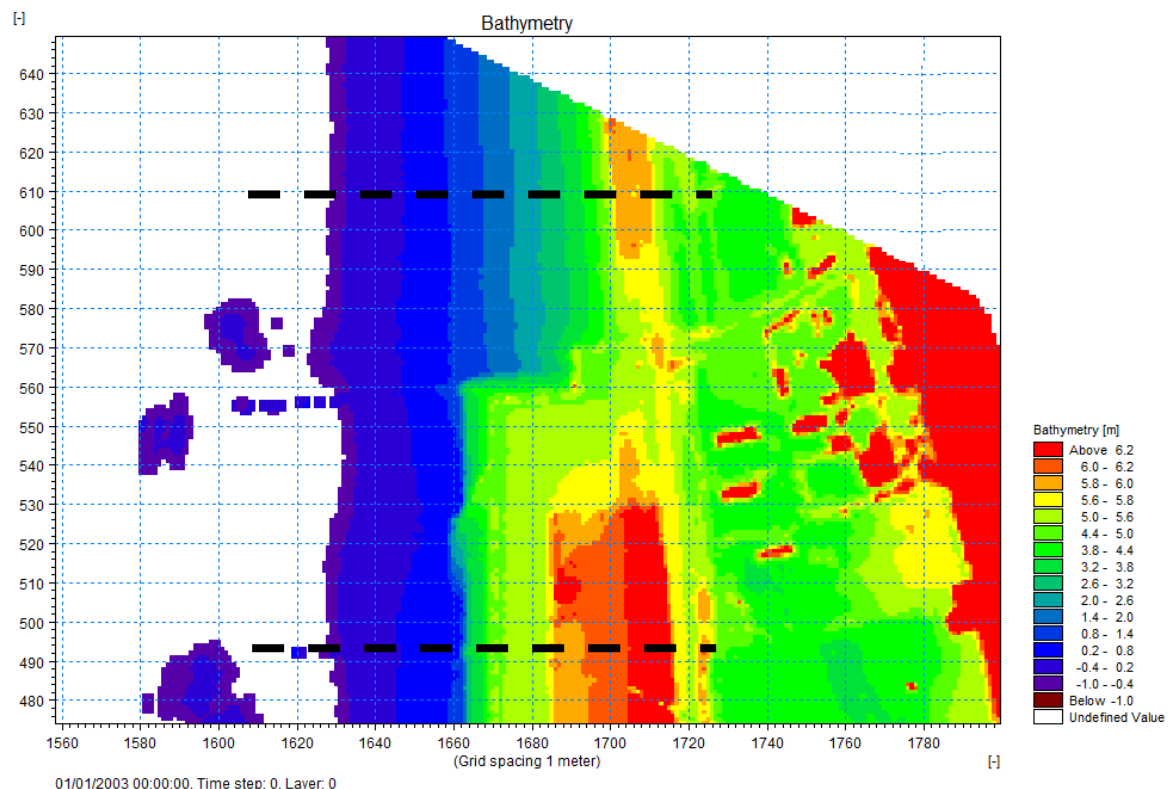


Figure 2 Composite DSM topographic levels relative to mODN, with section through shingle bank (top dashed line), and indicative section through the northern promenade

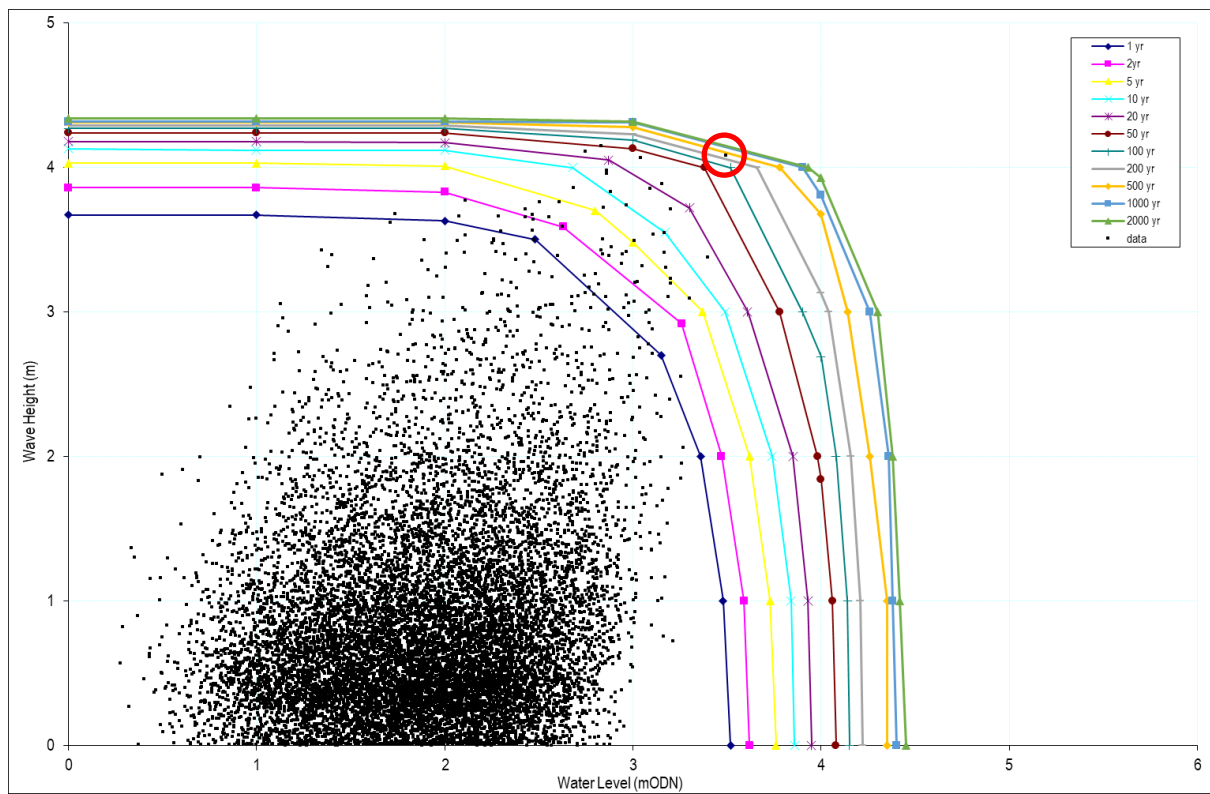


Figure 3 Joint Exceedance Curve at -7 mODN extraction location, epoch 2019



Figure 4 Overtopping of shingle bank during Jan 2015 event (source unknown)

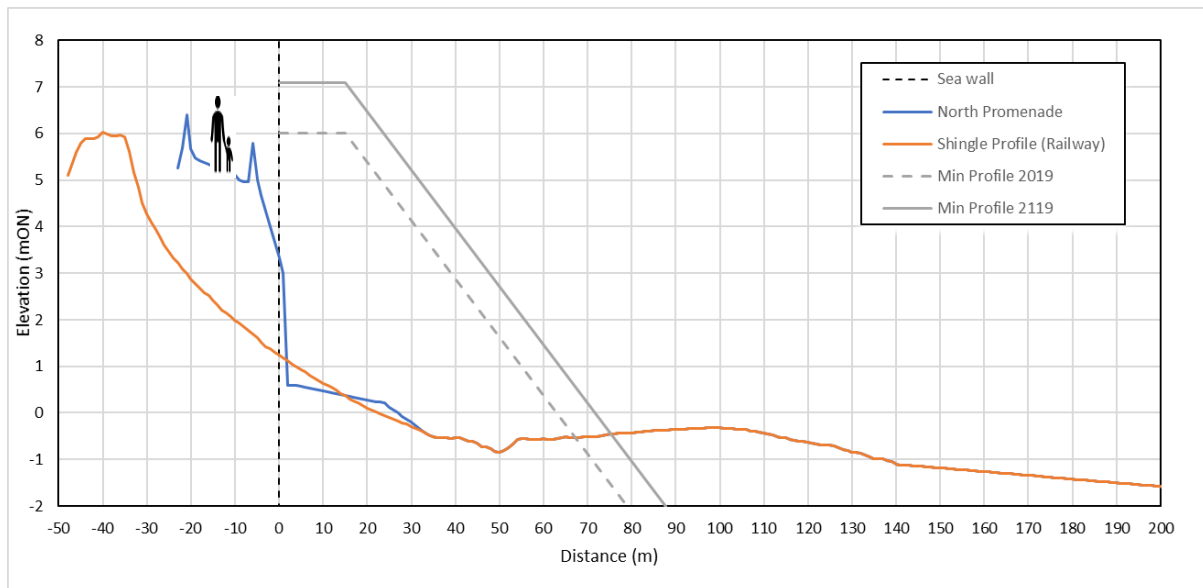


Figure 5 Proposed minimum beach profile along with present day cross sections along Northern Promenade and Shingle Ridge to north (from composite DSM)

Table 1. Tidal characteristics at Barmouth

Reference Sill Water Level	Level (mODN)
Highest astronomical tide (HAT)	3.26
Mean high water springs (MHWS)	2.56
Mean high water neaps (MHWN)	1.26
Mean sea level (MSL)	0.28
Mean low water neaps (MLWN)	-0.54
Mean low water springs (MLWS)	-1.74
Lowest astronomical tide (LAT)	-2.14
Mean Spring Range	4.30 m
Mean Neap Range	1.80 m

Source: 2018 Admiralty Tide Tables

Table 2. Extreme water levels derived from CFBD 2008

Return Period	AEP (%)	CFBD (mODN)	Total Water Level (mODN)		
		Epoch 2008	Epoch 2019	Epoch 2069	Epoch 2119
T1	100	3.48	3.52	3.94	4.62
T10	10	3.82	3.86	4.28	4.96
T50	2	4.03	4.07	4.49	5.17
T100	1	4.11	4.15	4.57	5.25
T200	0.5	4.20	4.24	4.66	5.34
T1000	0.1	4.39	4.43	4.85	5.53

Variability of beach alignment to incident wave conditions

Table 3 show the occurrence of waves from different direction sectors at the -2.1mODN depth contour (equivalent to Lowest Astronomical Tide - LAT, present day). This shows that the most significant waves, and those that have potential to move the nourished shingle beach within each beach compartment, come from a very narrow section, centred around 244°.

From Table 3, it is considered that the beach may undergo a rotation of up to 3°, either side of this central wave direction.



Beach Nourishment Options

Table 3. Wave scatter table wave height vs direction for conditions at lower limit of intertidal zone (Frequency shown as hourly events from 39 year hindcast)

Hs (m) / Dir Scatter Table		216	218	220	222	224	226	228	230	232	234	236	238	240	242	244	246	248	250	252	254	256	258	260	262	264	266	268	270	272	274	276	278	280	282	284	284
Lower bound	Upper bound	218	220	222	224	226	228	230	232	234	236	238	240	242	244	246	248	250	252	254	256	258	260	262	264	266	268	270	272	274	276	278	280	282	284	286	
4.5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
4	4.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
3.5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
3	3.5	0	0	0	0	0	0	0	0	0	0	0	0	3	18	14	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
2.5	3	0	0	0	0	0	0	0	0	0	0	0	3	113	322	250	80	30	10	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
2	2.5	0	0	0	0	0	0	0	1	0	1	18	96	764	1846	1615	743	392	182	58	18	19	5	1	3	1	0	0	1	0	0	0	0	0	0	0	
1.5	2	0	0	0	0	0	1	0	4	10	42	172	708	2510	5223	6192	2828	1449	809	448	261	160	108	59	20	22	14	3	2	4	0	0	1	0	0	0	
1	1.5	0	0	2	1	4	7	20	56	154	352	796	2077	5475	12058	18616	8320	2848	1740	1204	783	556	410	351	241	191	142	97	67	47	26	19	15	8	3	1	
0.5	1	8	9	17	24	49	78	127	247	468	926	1989	4148	8798	18456	40822	24770	5427	3502	2429	1986	1540	1327	1052	865	702	611	486	383	271	241	214	180	118	105	84	
0	0.5	58	55	71	92	116	128	185	297	473	689	1219	2275	4939	13473	39051	23378	9154	5735	4059	3048	2298	1837	1594	1295	1158	1069	930	841	842	734	650	565	522	436	419	

Beach Nourishment Options

Three concept beach nourishment options have been developed. These are:

- Option 1 – 4 Groyne Option;
- Option 2 – 7 Groyne Option; and
- Option 3 – Terminal Groynes and Breakwater Option.

Appendix A, provides an overview of the workings associated with the development of Option 1, specifically the sequence of figures shows:

- The initial setting out of the minimum beach crest (initial indicative toe extent of structures also indicated);
- Overlay of beach compartments and beach alignments (envelopes). The location of each compartment is an iterative process within this assessment, to minimise the length of the structures. Note the three sections in this option have different general alignments, some more aligned to the prevailing incident wave direction of 244°;
- Overlay of the average beach width in each compartment;
- Overlay of the groyne extent required to hold the beach over the beach envelope anticipated; and
- Overlay of the full structure length. This length represents the crest of the proposed structure.

During this process the number and spacing of the groynes in Option 1 was identified through an iterative process, examining the structure lengths that would be required for different bay widths. This structure length is determined as a function the beach alignment relative to the existing primary defence. For example, when the natural beach alignment is not aligned with the existing defence, a wide groyne bay requires a much larger (groyne) structure to hold the beach. For Option 1, this assessment also resulted in bay widths of different sizes, since the main defence varies in its orientation along the frontage.

For Option 2, a solution was examined using smaller groyne bays, which therefore result in smaller beach envelopes and shorter structures. Because these bays, and the beach envelopes within them, are smaller a more evenly spaced series of groyne bays can be developed.

Option 3, has been developed as an example of how we can retain the wider bays of Option 1, whilst reducing the offshore extent of the structures. This is done by incorporating shore parallel structures, which help to reduce the beach envelope variability within each of the bays.

The final options are shown Figure 6 to Figure 8, respectively. The length, height and form of these structures is discussed in the following section.



Figure 6 Option 1 – 4 groyne option (Background image from Google Earth)



Figure 7 Option 2 – 7 groyne option (Background image from Google Earth)



Figure 8 Option 3 – Terminal groynes and breakwaters option (Background image from Google Earth)

Structure configurations height/profile

For Options 1 and 2, the groynes will need to contain the nourished beach over the full envelope of beach rotation and change expected. Therefore, the crest of the groyne will need to be higher at the landward end at +7.6m ODN and extending out horizontally at this level for between 30 and 60m before reducing in line with the beach slope (maintaining a level 0.5 m higher than the beach).

On this basis, Table 4 and **Error! Reference source not found.**, provide key information on the extents of the structures and beaches associated with Option 1 (4 Groyne Option). The details for the northern groyne bay are also indicated as a cross-section in Figure 9. From Table 4, it is noted that the length of the horizontal groyne section varies for each groyne. This is due to the variation in beach envelopes allowed for within each of the three bays based upon shoreline orientation. This leads to a variable position of the maximum beach crest in relation to the sea wall, as can be seen in Appendix A (working 3 image).

Similar details for Options 2 (7 Groyne Option) are provided in Table 6 and Table 7.

The primary difference between Option 2 and Option 1 is the reduction in the average beach width associated with the narrower groyne bays. This also reduces the length of the associated structures but requires 7 rather than 4 structures.

Assuming the groynes would be constructed of rock it is recommended the footprint is designed to the 2119 beach including crest width, side slopes and form of the toe protection.

Table 4. Structure description: Option 1

	Length (m)
Groyne 1	
Horizontal Crest	30
1:8 Sloping Crest	65
Groyne 2	
Horizontal Crest	45
1 in 8 Sloping Crest	65
Groyne 3	
Horizontal Crest	50
1 in 8 Sloping Crest	65
Groyne 4	
Horizontal Crest	55
1 in 8 Sloping Crest	65

Table 5 Beach extents: Option 1

	(m)
Groyne Bay 1	
Average horizontal beach crest width	30
Average width of sloping beach	60
Length of bay	400
Groyne Bay 2	
Average horizontal beach crest width	30
Average width of sloping beach	60
Length of bay	310
Groyne Bay 3	
Average horizontal beach crest width	30
Average width of sloping beach	60
Length of bay	540

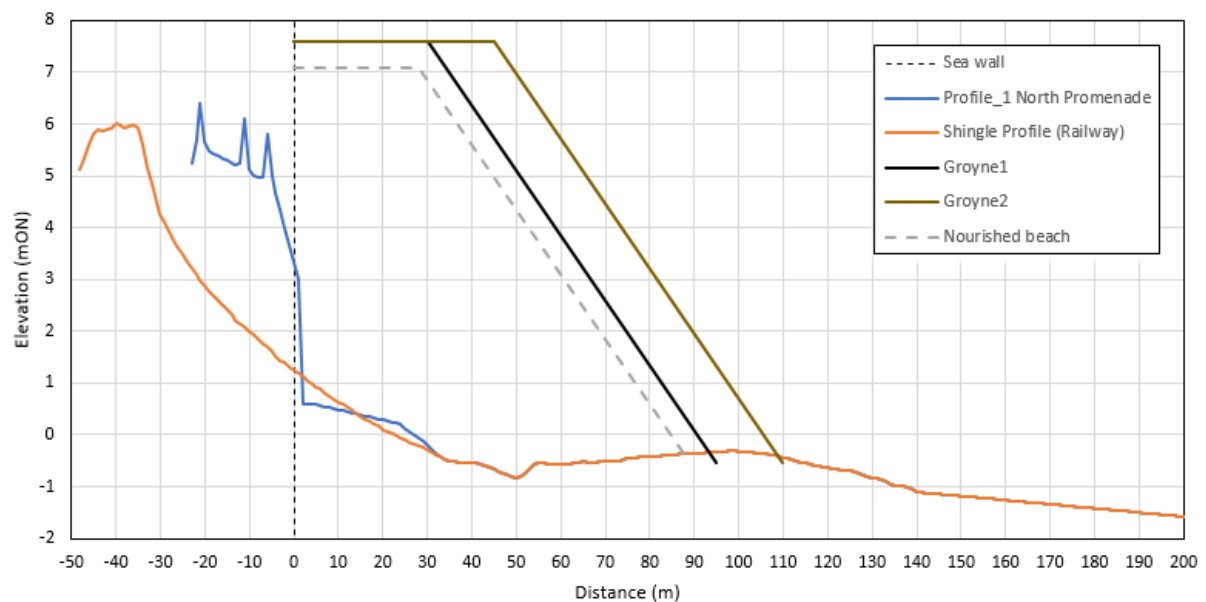


Figure 9 Example cross section – Option 1: Groyne Bay 1

Table 6. Structure descriptions: Option 2

	Length (m)
Groyne 1	
Horizontal Crest	25
1 in 8 Sloping Crest	65
Groyne 2	
Horizontal Crest	30
1 in 8 Sloping Crest	65
Groyne 3	
Horizontal Crest	35
1 in 8 Sloping Crest	65
Groyne 4	
Horizontal Crest	40
1 in 8 Sloping Crest	65
Groyne 5	
Horizontal Crest	30
1 in 8 Sloping Crest	65
Groyne 6	
Horizontal Crest	35
1 in 8 Sloping Crest	65
Groyne 7	
Horizontal Crest	55
1 in 8 Sloping Crest	65

Table 7 Beach extents: Option 2

	(m)
Groyne Bay 1	
Average horizontal beach crest width	25
Average width of sloping beach	60
Length of bay	195
Groyne Bay 2	
Average horizontal beach crest width	25
Average width of sloping beach	60
Length of bay	200
Groyne Bay 3	
Average horizontal beach crest width	25
Average width of sloping beach	60
Length of bay	200
Groyne Bay 4	
Average horizontal beach crest width	25
Average width of sloping beach	60
Length of bay	210
Groyne Bay 5	
Average crest width	25
Average width of sloping beach	60
Length of bay	210
Groyne Bay 6	
Average horizontal beach crest width	25
Average width of sloping beach	60
Length of bay	235

Option 3 consists of two shore parallel breakwaters and two terminal groyne structures. The two terminal groynes also include a component that is shore parallel. This solution utilises the shore parallel components of the structure to both help hold the beach in their lee, and to reduce the length over which the beach can vary. This reduces the overall beach envelope, helping to limit the offshore extent of the structures.

With shore parallel components being associated with all four structures, the structures will need to be sufficiently high enough to prevent significant overtopping. This will prevent the washout of material in their lee and help prevent conditions which could have significant health and safety issues for the public. For this option stage, it is estimated that the crest of the structures would be horizontal at approximately 7.6mODN (0.5m higher than the beach crest).

The extent of the structures and beach for Option 3 are provided in Table 8 and

Table 9. In general, the structures do not extend as far seaward as Option 1 with the same number of embayments. This is because the beach envelope of change is anticipated to be less for the shore parallel structures. However, the higher crest height would need to be retained over the full length of the structures crest.

Assuming the groynes would be constructed of rock it is recommended the footprint is designed to the 2119 beach including crest width, side slopes and form of the toe protection.

Table 8. Structure descriptions: Option 3

	Length (m)
Groyne 1	
Trunk	65
Arm	65
Total	130
Approximate seaward position	95
Breakwater 1	
Total	120
Approximate seaward position	90
Breakwater 2	
Total	120
Approximate seaward position	90
Groyne 2	
Trunk	85
Arm	65
Total	150
Approximate seaward position	120

Table 9 Beach extents: Option 3

	(m)
Groyne Bay 1	
Average horizontal beach crest width	25
Average width of sloping beach	60
Width of bay	400
Groyne Bay 2	
Average horizontal beach crest width	25
Average width of sloping beach	60
Width of bay	390
Groyne Bay 3	
Average horizontal crest width	25
Average width of sloping beach	60
Width of bay	460

*Average beach crest width is provided over centre portion of the bay. Additional material will build up in the lea of the shore parallel structures.

Further considerations

The concept options developed through this assessment, have given due consideration to the coastal processes at the site and expected allowances for Sea Level Rise. The options have been developed through a high level appraisal to support the OBC.

Within the OBC options appraisal the following issues will also need to be considered:

- **Phased development:** The options have been developed based on consideration of conditions in 2119. In the interim period sea levels will be lower. There would therefore be the potential to reduce the level of nourishment required when the options are first constructed, increasing the beach volume and associated crest level with time;
- **Designing for beach losses:** At this stage a minimum 15m beach width is the basis for design (slightly wider than the adjacent shingle frontage). Although sediment losses are not considered to be significant, allowances for beach loss should be included in the final designs and form part of the capital scheme. An initial estimate of the recharge requirement is in the order of 22,000m³. This is based on having to replace a 3m width of beach along full frontage 1.2km every 20 years, where the crest level is 7.1m and the average existing sea bed level is +1m. Limited erosion of the sandy foreshore is also expected.
- **Designing for coastal processes:** Should any of the options be taken forward, subsequent engineering designs should take full account of local coastal processes including the positioning and alignment of the groynes or possible addition of a small spur on to the end of the terminal control structures.
- **Access:** Consideration would need to be given to access (both for public and maintenance);
- **Visual:** Consideration will need to be given to visual impact of the options. In particular, it is noted that the crest height of the shingle beach in 2119 is significantly higher than the existing promenade, which would restrict sea views (please see Figure 5).
- **Maintenance:** Beach nourishment will be required as discussed above. If the single barrier is higher than the sea wall there is also the potential for shingle to be moved onto the promenade during storm events. All options have been designed for minimal maintenance. However, consideration of access to the different groyne bays would be required, particularly for Option 2.
- **Impacts on adjacent SMP Policy Units:** The schemes compartmentalise the North Promenade frontage from the adjacent shoreline in very similar ways. This compartmentalisation is undertaken to hold the coarser nourishment material along the North Promenade frontage, whilst still allowing sand to be transported more freely along the lower foreshore. The shingle

ridge along the railway line to the north has no significant exchange of shingle material with North Promenade. To the south of the frontage the sandy beach appears to be in a dynamic state of equilibrium. Given this, and the general shore normal incident wave conditions, the coastal process effects of the options on the adjacent shorelines is likely to be minimal. Local effects would need to be investigated as part of design development.

- Impacts on coastal processes: it is noted that the introduction of shore parallel structures can lead to more complex flow conditions, which can be potentially more dangerous to the public, both from overtopping and from a bather safety perspective. Within the lee of a shore parallel structure the water may appear calmer, whilst in reality there could be an offshore directed current.
- Form of construction/adaptability: Consideration should be given to the form of the groyne/breakwater structures to help ensure future adaptability and potential reuse of material; and
- CDM: requirements under CDM to be considered by Arup.

References

ABPmer (2019a) - Barmouth North Promenade, Coastal Processes, February 2019

ABPmer (2019b) - Barmouth North Promenade, Wave modelling, extremes analysis and overtopping, March 2019

Appendix A: Development of Option 1

Minimum beach width



(Background image from Google Earth)

Commentary:

- Boundary of frontage (dashed black line).
- The minimum beach crest width (dashed yellow line) is set out from the existing primary defence (solid yellow line).
- Indicative toe extent of structures is defined (dotted yellow line).
- Wave incident angles of $244^{\circ} \pm 3^{\circ}$ identified (blue lines).

Option 1 – 4 Groyne Option (working 1)



(Background image from Google Earth)

Commentary:

- Beach alignments are overlaid for shore normal angles of 241° (light orange line) and 247° (dark orange line). The inshore extent of each line must not extend into the minimum beach width.
- Different bay width and groyne locations are explored to develop a possible scheme which will limit the length of the structures required as well as the amount of material within each groyne bay.
- In this instance, three non-equally spaced groyne bays are identified. (Note in the central bay beach aligned to 241° is not aligned closely to main defence).

Option 1 – 4 Groyne Option (working 2)



(Background image from Google Earth)

Commentary:

- For each embayment the amount of material required will be more than the minimal beach width to allow for beach rotation. Therefore, the approximate average beach width is identified for each bay (dashed purple line).

Option 1 – 4 Groyne Option (working 3)



(Background image from Google Earth)

Commentary:

- Offshore extent of proposed structures identified (solid black line) to take account of sediment transport zone including beach rotation and beach slope

Option 1 – 4 Groyne Option (working 4)

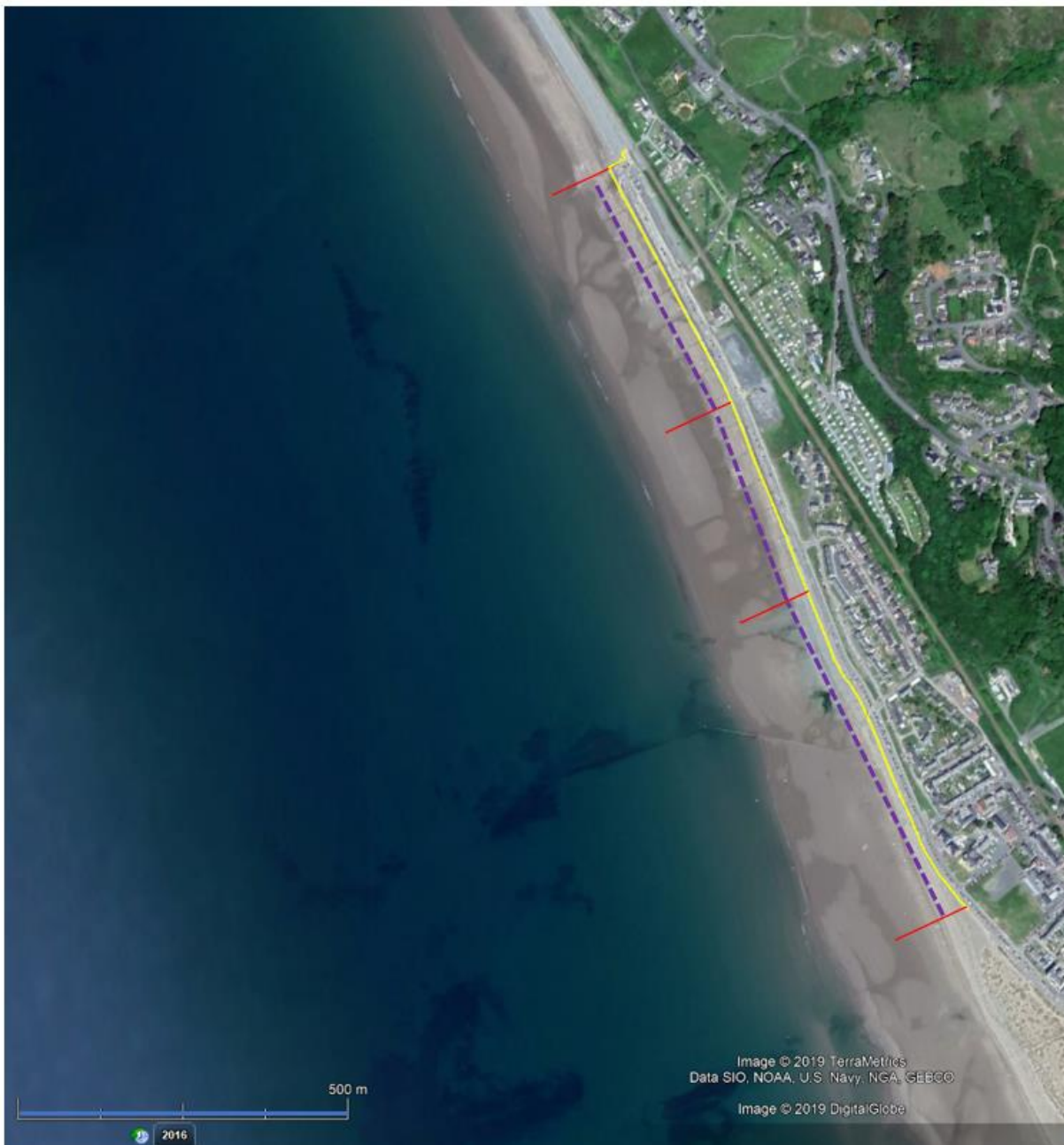


(Background image from Google Earth)

Commentary:

- Full extent of structures identified (red lines) extending from existing defence to the just beyond the toe of beach at its maximum envelope.

Option 1 – 4 Groyne Option



(Background image from Google Earth)

Commentary:

- The yellow, orange, blue and black 'working' lines are removed, to show average width of beach in each bay and the maximum extent of the structures. This is the extent of the crest of the structures.