

Ymgynghoriaeth Gwynedd
Consultancy (YGC)

Barmouth North Promenade OBC

Economic Appraisal Technical
Report

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Executive Summary

Ymgynghoriaeth Gwynedd Consultancy (YGC) of Gwynedd Council (GC) appointed Ove Arup and Partners (Arup) to review coastal flood and erosion risk at Barmouth North Promenade, North Wales in October 2018. Welsh Government's Coastal Risk Management Programme (CRMP) is funding the study. Barmouth North Promenade encompasses the northern extents of the developed frontage of the community of Barmouth, in North Wales.

This report sets out the economic appraisal of flood and coastal erosion risk management (FCERM) options, the methodology used to estimate the benefits of options and the findings.

The project is to be delivered under Welsh Government's CRMP. The business case is required to identify FCERM costs and benefits in line with industry guidance (FCERM Business Case Guidance, Appraisal Guidance, Accounting for Adaptive Capacity, Multi-Coloured Manual, and Treasury Green Book) and present the benefit cost ratio for the preferred option and short-listed options. Economic benefits to the nation have been estimated using the Flood Hazard Research Centre's Multi Coloured Manual (MCM) methodology¹ in **Section 2** (erosion risk management in **Section 2.3** and coastal flood risk management in **Section 2.4**).

In terms of economic benefits from coastal FCERM that are admissible by the MCM, the make-up of these benefits is summarised below. A precautionary and proportionate approach has been undertaken to ensure a robust business case is developed.

Table 1. Summary of economic appraisal baseline damages (in the absence of investment)

Component	(£k)	Key areas of uncertainty
<i>Flood Related Damages</i>		
Damage to people and property	£99,767	<i>Extents and severity of flooding</i>
<i>Erosion Related Damages</i>		
Loss of properties	[Excluded – up to 60 properties affected]	<i>High uncertainty associated with the rates of erosion.</i>
Cambrian Coastal Railway Loss	[Excluded - benefits of protecting this asset are likely to range in the £m's and safe-guarding of this asset is imperative]	<i>Significant cost uncertainties and lack of available data. Wider context/connectivity risks.</i>
Loss of Recreational Benefits	[Excluded - the loss of Barmouth North Promenade may reduce the appeal of Barmouth]	<i>North Promenade amenity interdependent on Barmouth South.</i>
Damage to utilities infrastructure (services replacement)	£100	<i>Cost of diversion works & replacement services, timing</i>
Total	£99,867	
Significant potential benefits are excluded from this assessment due to uncertainties in a quantitative figure. The damages could arguably increase significantly if implications of property erosion, loss of the Cambrian Coastal Railway function and recreational or wider benefits were included. Benefits are considered qualitatively.		

¹ Flood and Coastal Erosion Risk Management: A Manual for Economic Appraisal, 2013 Flood Hazard Research Centre

Table 2 summarises the number of properties likely to be affected by flooding for the options considered. The table illustrates the onset of predicted flooding to property is less than 1 in 1 annual chance. **Some 757 properties have greater than a 1 in 100 chance of coastal and/or surface water flooding in any year** (across Flood Cell 1 and 3 – refer to Appendix A).

Table 2. Property count for the epochs including climate change (worst case) for Baseline option²

	NCC (Present day, no climate change (CC))						CC2069						CC2119					
Return Period	1	10	50	100	200	1000	1	10	50	100	200	1000	1	10	50	100	200	1000
Baseline	14	300	322	757	760	761	261	261	538	>757	>760	>761	261	261	538	>757	>760	>761

Standard of protection

Within the economic assessment, each option assessed represents a different standard of protection (onset of flooding, with allowance for residual uncertainty or freeboard). The economic assessment focusses on demonstrating the relative benefit (damages avoided by providing a Standard of Protection compared to the Do Minimum) by providing a range of standards of protection to inform a cost-benefit analysis.

A further assessment was undertaken to define the benefits associated with a do-something option which involved managed realignment – i.e. setting the defence line further inland now and in the future Epochs to align with the SMP2 policy.

The resulting capped present value damages (PVD) associated with the options are shown in the table below.

Table 3. Summary of flood damages provided with each Standard of Protection²

Option & SOP	NPV (£k)	Present Value Benefits (£k)
Baseline	99,867	N/A
Option 1 – 1 in 200 yr (2019)	32,371	67,396
Option 2 – 1 in 100 yr (2019)	37,662	62,104
Option 3 – 1 in 50 yr (2019)	89,774	9,992
Option 4 – 1 in 200 year (2069)	16,604	83,162
Option 4b - 1 in 200 yr (2069) – Managed Realignment	16,194	68,896
Option 4c - 1 in 200 yr (2069) – Managed Realignment (North Only)	16,596	82,929
Option 5 – 1 in 100 year (2069)	12,855	86,912
Option 6 – 1 in 50 year (2069)	29,229	70,538

² Note that the number of properties incurring damage in the present day for the 1 in 200yr and 1 in 1000yr event greatly exceeds that of CC2069 and CC2119. This is due to the scenarios modelled, and the limitations encountered in assessing wave overtopping as discussed in both ABPmer's wave modelling report and Arup's Inundation modelling report. Due to limitations within the overtopping modelling for 2119 scenarios, as outlined in Appendix B Inundation Modelling Report, the 2119 Epoch was assessed by substituting model results that represented the worst case modelled for each return period.

Option 6b - 1 in 50 yr (2069) – Managed Realignment	26,681	58,409
Option 6c - 1 in 50 yr (2069) – Managed Realignment (North Only)	29,229	70,296

If options considered a ‘Baseline’ (i.e. Business As Usual) approach, with Managed Realignment implemented in Epoch 2, *as per the SMP2 Policy*, the flood damages in Table 4 are identified. The assessment illustrates damages within Year 0-20 are significant, supporting the justification of implementing a solution in Epoch 1.

Table 4. Summary of flood damages provided with each Standard of Protection for Managed Realignment in Epoch 2

Option & SOP	NPV Total NPV (£k)	Present Value Benefits (£k)
Option 7a - 1 in 200 yr (2069) – Managed Realignment from Epoch 2	Property damage <i>only</i> equates to £46,174	Property benefits <i>only</i> equates to £10,945
Option 7b - 1 in 200 yr (2069) – Managed Realignment (North Only) from Epoch 2	Property damage <i>only</i> equates to £55,256	Property benefits <i>only</i> equates to £10,985

Coastal Risk Management Option Appraisal

An adaptive pathway approach has been utilised within the economic assessment to consider different possible sequences of investment decisions associated with the Do-Something Options (i.e. different combination/temporal interventions).

Table 5. Do-Something Options

Option	SOP
2. Betterment of existing defences	1in50 + CC events up to 2069
3. Beach Management and Associated Structures (i.e. groynes/breakwaters)	1in200 year + CC SOP up to 2119
4a. New line of defence set back at the railway (i.e. Managed Realignment)	1in200 year + CC SOP up to 2119
4b. New line of defence set back at the railway (i.e. Managed Realignment) – Northern Extents Only	1in200 year + CC SOP up to 2119

An adaptive pathway approach has been utilised within the economic assessment to consider different possible sequences of investment decisions associated with the Do-Something Options (i.e. different combination/temporal interventions).

Table 6. Adaptive pathway scenarios considered for the economic assessment

	Epoch 1 0-20 years	Epoch 2 20-50 years	Epoch 3 50-100 years
Option A	Option 2: Betterment of defences <i>Precautionary SOP reducing to 1 in 50 by 2069</i>		Option 4: Managed Realignment (SMP2) <i>Adaptive SOP 1 in 200</i>
Option B	Option 2: Betterment of defences <i>SOP 1 in 200 in 2019</i>	Option 4: Managed Realignment (SMP2) <i>Adaptive SOP 1 in 200</i>	
Option C	Option 2: Betterment of defences <i>Precautionary SOP reducing to 1 in 50 by 2069</i>		Option 3: Beach Management <i>Adaptive SOP 1 in 200</i>
Option D	Option 2: Betterment of defences <i>SOP 1 in 200 in 2019</i>	Option 3: Beach Management <i>Adaptive SOP 1 in 200</i>	
Option E	Option 3: Beach Management <i>Adaptive SOP 1 in 200</i>		
Option F	Option 2 + Option 3 <i>Adaptive SOP 1 in 200</i>		
Option G	Option 2: Betterment of defences <i>Precautionary SOP reducing to 1 in 50 by 2069</i>		Option 4b: Managed Realignment (North Only) <i>Adaptive SOP 1 in 200</i>
Option H	Option 2: Betterment of defences <i>SOP 1 in 200 in 2019</i>	Option 4b: Managed Realignment (North Only) <i>Adaptive SOP 1 in 200</i>	

Capped PVD damages, the net benefit of implementing each of the options, and the project costs are used to calculate the benefit cost ratios. Recognising the SOP of each pathway varies throughout the scheme life-span and modelling limitations, a precautionary approach has been applied to the assessment.

Table 7. Estimate of benefit cost ratios for providing increasing Standards of Protection

Option	Flood Damages	Flood and Erosion Benefits	Preliminary Costs	Preliminary Benefit Cost Ratio	Incremental Benefit Cost Ratio
	(£k)	(£k)	(£k)		
Baseline	£99,867	£0			
Pathway G	£29,221	£70,304	£26,395	2.7	
Pathway A	£26,681	£58,409	£30,639	1.9	0.0
Pathway C	£29,229	£70,538	£31,384	2.2	0.0
Pathway H	£16,596	£82,929	£37,540	2.2	1.1
Pathway B	£16,194	£68,896	£46,949	1.5	0.0
Pathway D	£16,604	£83,163	£48,668	1.7	0.7
Pathway E	£16,604	£83,163	£62,453	1.3	0.0
Pathway F	£16,604	£83,163	£79,676	1.0	0.0

Conclusion

The economically preferred adaptive approach is Pathway G, which offers a precautionary Benefit Cost Ratio of 1.7. The BCR has the potential to increase when considering additional benefits (e.g. protection of Network Rail assets).

Table 8. Adaptive pathway scenario

	Epoch 1 0-20 years	Epoch 2 20-50 years	Epoch 3 50-100 years
Option G	Option 2: Betterment of defences <i>Precautionary SOP reducing to 1 in 50 by 2069</i>		Option 4b: Managed Realignment (North Only) <i>Adaptive SOP 1 in 200</i>

1 Introduction

Ymgynghoriaeth Gwynedd Consultancy (YGC) of Gwynedd Council (GC) have appointed Ove Arup and Partners (Arup) to review coastal flood and erosion risk at Barmouth North Promenade, North Wales. Welsh Government's Coastal Risk Management Programme (CRMP) is funding the study.

This report sets out the economic appraisal of flood and coastal erosion risk management (FCERM) options, the methodology used to estimate the benefits of options and the findings.

1.1 Scheme background

Barmouth is a town on the west coast of Snowdonia in Gwynedd (north-western Wales). The study extents are defined as 'Barmouth North Promenade' as indicated in Figure 1 below and encompass the northmost section of the Barmouth developed frontage. The study area comprises a mixture of hard defences, including a vertical sheet piled sea wall, a concrete platform, stone revetment and precast concrete wave recurve wall units, with secondary and tertiary setback walls. The existing coastal defences run parallel with the promenade adjacent to the Marine Parade.



Figure 1. Study extents and key features of note within Barmouth

The current Shoreline Management Plan 2 (SMP2) (2011) policy (epoch 1) for the frontage of Barmouth North Promenade³ is to continue to '*hold the line*'. Due to implications of climate change, the present alignment was considered likely to become increasingly difficult to sustain. As such, for the medium and long term the SMP2 recommends a change in approach to '*managed realignment*'. Neighbouring SMP2 Policy areas include:

- Barmouth South Promenade: 'Hold the Line'; lies adjacent to the centre of Barmouth and comprises the main amenity beach fronted by vegetated stabilised sand-dunes, Barmouth harbour and the access road to Barmouth.
- Llanaber: 'Hold the Line'; lies northwards comprising a managed shingle bank providing coastal protection to the railway.

All three sections are intrinsically linked - forming a single flood-cell and with interacting coastal processes. The SMP2 expresses (as outlined) that whilst the frontage at Barmouth is split over three areas, the policies should be considered and '*progressed as one overall area*'.

For further information in-relation to the SMP2 Policy Context for Barmouth, please refer to Appendix I.

1.2 Nature of the problem

Barmouth North Promenade experiences the following issues:

- **Poor Asset Condition:** The northern end of the promenade is fronted by a shingle berm with timber groynes. The beach levels significantly decrease, and the defences deteriorate in condition, moving towards the northern extent of the study area. The existing defences have a number of structural defects; and should drawdown continue (as is expected to continue), then structural failure and global stability of the structure from sheet pile toe exposure and wash-out of fines increasingly is a concern.
- **High Flood Risk:** Barmouth, and in particular, its north promenade is identified as at risk of coastal flooding and erosion. It is commonplace to see overtopping at the north-most end of the promenade in what could be described as relatively "normal" conditions i.e. median level tides, without surge, swell, low pressure or high winds. Recent winter storms have highlighted that wave overtopping can be significant along North Promenade; such as those experienced in the January 2014 storms, where a number of residents had to be evacuated.

NRW Flood Maps indicate a large extent of the study areas is at High Risk (<1 in 30 annual chance) of surface water flooding. Two watercourses (non-main river) flow into the study area from the east and discharge via a pumped surface water system with flap valve and a separate screened culvert. Effects of sea-level rise & climate change are expected to exacerbated the problems identified at Barmouth North Promenade.

- **Coastal Erosion:** The ABPmer Coastal Process Assessment (2019) indicates that although there is not a strong transport regime along the frontage, overall foreshore bed levels along North Promenade are lowering and this lowering is expected to continue. Based on the average SMP2 lateral erosion rates over a 100-year period, it is indicated that beach levels around Barmouth North Promenade are likely to decrease by up to 0.7m for northern end and 0.5m for the southern end of the study extents. The lack of credible groynes and coarser material in the upper foreshore along North Promenade is likely to have accelerated the rate

³ Barmouth North Promenade is located within the SMP2 Management area 24 (MA24) and Policy Unit 15 (Barmouth North) of SMP Sub Cell 9 and Policy Development Zone (PDZ) 11.

at which the foreshore has lowered with additional wave energy being reflected off the sea wall.

Future beach evolution is difficult to predict but assuming No Active Intervention (NAI), erosion is predicted to continue at North Promenade (at a rate of between 30 and 120 m (SMP2, 2011)). The rate of erosion is likely to increase with sea level rise which will result in larger waves reaching the promenade and in turn increasing beach lowering.

1.3 Economic appraisal approach

The project is to be delivered under Welsh Government's CRMP. The business case is required to identify FCERM costs and benefits in line with the standard guidance (FCERM Appraisal Guidance, Multi-Coloured Manual, and Treasury Green Book) and present the benefit cost ratio for the preferred option and short-listed schemes. Economic benefits to the nation have been estimated using the Flood Hazard Research Centre's Multi Coloured Manual (MCM) methodology⁴ in **Section 2** (erosion risk management in **Section 2.3** and coastal flood risk management in **Section 2.4**).

Whilst the prime motivation for investment in FCERM is to reduce damage costs to property both residential and commercial, building and other private property, there are other benefits from these investments which will help to improve the seafront environment and bring wider benefits. These go beyond the conventional economic assessment outlined in the multi-coloured manual. The assessment of wider benefits is reported in **Section 3**.

Welsh Government will be providing a revenue stream to reflect the prudential borrowing cost burden of 75% of capital costs. The CRMP gives flexibility to local authorities as to how they raise the residual capital and revenue costs. Potential opportunities for funding may come from the wider benefits of the scheme to current and future stakeholders.

⁴ Flood and Coastal Erosion Risk Management: A Manual for Economic Appraisal, 2013 Flood Hazard Research Centre

2 Coastal risk management economic appraisal

In order to undertake an appraisal of potential coastal improvement measures, it is necessary to compare the benefits of any ‘Do Something’ options to the baseline scenarios representing the ‘Walkaway’ (i.e. ‘Do Nothing’) and the ‘Business As Usual’ (i.e. ‘Do Minimum’).

The following epochs, in line with Shoreline Management Planning Guidance have been considered:

- *Immediate term*: 0-5 years from present (i.e. 2019)
- *Short Term*: 5-20 years from present
- *Medium Term*: 20-50 years from present
- *Long term*: 50-100 years from present

2.1 Outcomes of Walkaway Scenario

The baseline for the investment case is a theoretical Walkaway scenario. The following impacts of this case have been identified:

The sea wall and revetment are in a poor condition. In the absence of maintenance, progressive structural failure of the sea-wall and revetment is reasonable to assume, with the northern most area at greatest risk. Washout of infill material from unsealed joints, cracks and openings through corroded piles would be the most likely cause. Over time the progressive failure of the sheet pile toe due to abrasion and corrosive section loss is likely.

It is expected there will be a continued reduction in beach levels over the next 10 year period, particularly. There is a slight southerly near-shore drift of material, however this is very limited. It is noted that the winter storms of 2013/2014 caused a rapid reduction in beach levels. Future storms are expected to exacerbate beach levels significantly. With on-going beach drawdown, the global stability of the structure from sheet pile toe exposure increasingly becomes a concern

Frequent overtopping will be experienced, increasing in frequency and severity due to climate change. This will increase flows along the promenade and associated wash-out of material from beneath the sea-wall and revetment structures. This will impact on the stability and performance of the highway and secondary and tertiary flood walls.

As such, **the residual life of the sea-wall and revetment is considered to be <10 years**. Note, there is a high degree of uncertainty associated with this figure⁵. On-going deterioration will lead to failure of the sea-wall and revetment, leading to a breach in the defences and associated risks of tidal and overtopping inundation. Existing highway drainage, culverts and outfalls (including flap-valves) associated with this section of the frontage will cease to operate effectively without maintenance and the decline of the frontage. This will exacerbate drainage issues and potentially cause flooding upstream.

Hence, failure of the sea wall and revetment at Barmouth North Promenade is expected to result in the following direct damages:

- Continued **erosion** of the frontage causing recession of the shoreline and:

⁵ Please refer to Barmouth OBC Appendix E: Arup, Existing Coastal Defence Assessment, 2019, for further information.

- Loss of aesthetic appeal and function of the North Promenade / Loss of safe access
- Decrease property life-span for adjacent residential and non-residential properties
- Damage to utility infrastructure and infrastructure, including pumped surface water system with flap valve and the separate screened culvert for the discharging watercourses.
- Loss or re-routing of the Network Rail Cambrian Railway
- Loss or re-routing of the Barmouth Promenade land train and All Wales Coastal Path
- Potential impacts on the Barmouth South (SMP2 Policy Unit 11.14) and Llanaber (SMP2 Policy Unit 11.16), which are both 'Hold the Line' policy units.
- **Flooding** associated with the breach of the defences, which is expected to affect:
 - Increase flood risk (including coastal, fluvial and surface water) – the secondary and tertiary flood walls are considered to provide limited flood protection. The loss of the watercourse outfalls (due to erosion above) is likely to exacerbate fluvial flood risk.
 - Flooding to the wider flood-cell of Barmouth North Promenade; including Barmouth South (SMP2 Policy Unit 11.14) and Llanaber (SMP2 Policy Unit 11.16).

The wider implications (including socio-economic, health & tourism) of increased erosion of the shoreline and flooding at Barmouth North Promenade are discussed further in **Section 3**.

2.2 Outcomes of Business As Usual Scenario

This scenario considers the continuation of the present beach management regime, with repairs to the existing defences as they become necessary (i.e. continuation of the 'status-quo') at an on-going cost to YGC. The present structure maintenance and beach management regime involves an 'as and when' programme of inspection and maintenance – including:

- Filling of voids, sealing of joints and mortar replacement along the promenade.
- Repairs to the secondary and tertiary flood defence walls following storm events.
- Maintenance of deployable flood barriers.

Measures to protect or replace the sheet pile section and arrest the abrasion/ corrosion are likely to be significant and are not considered a Business As Usual intervention. Continued loss of the structural section means there is an expected residual life of <20 years⁶.

In the absence of remedial works to address erosion at the toe of the defences, it is considered that **the status-quo Business As Usual scenario shares the Walkaway scenario's risk** posed by undermining of the defence structures through washout of infill material and/or progressive failure of the sheet pile toe due to abrasion and corrosive section loss and/or stability failure due to continued beach draw-down.

Due to the similarity between the baseline Walkaway and Business As Usual Scenarios, **the modelling and economic assessment approach taken has been, conservatively, to consider the Business As Usual as the baseline going forwards**, whilst testing sensitivity to features of the Walkaway scenario including:

- Not operating the tertiary flood wall gates/boards.

⁶ Please refer to Barmouth OBC Appendix E: Arup, Existing Coastal Defence Assessment, 2019, for further information.

- Measures to manage local flooding not functioning.
- Additional breaches of the primary wall.

2.3 Flood risk management economic appraisal

Economic losses from the predicted flood risk from tidal inundation and wave overtopping inundation, with consideration of fluvial and surface water inundation, have been estimated using the MCM methodology⁷ and are outlined in full in **Appendix A**. A summary of the results is provided in **Section 2.5**.

As status-quo Business As Usual scenario shares the Walkaway scenario's risk, the inundation modelling has considered the Business As Usual as the baseline, whilst testing the sensitivity to not operating the tertiary flood walls/gates, in-active measures managing local flood sources and additional breaches of the primary wall. Flood inundation modelling (see Barmouth OBC Appendix B: Inundation Modelling Report) identified overtopping risk as predominately from the northern extents of the promenade.

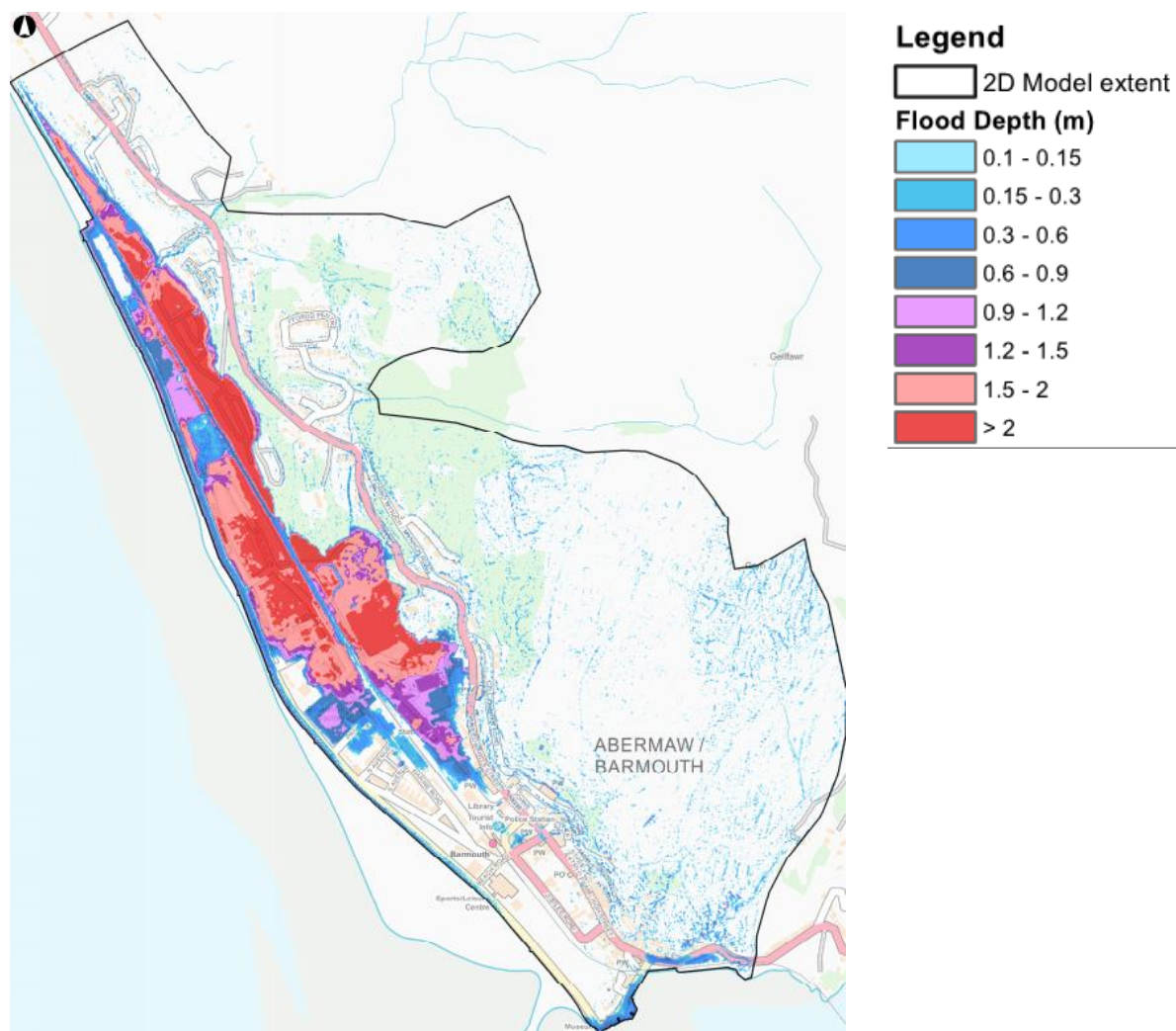


Figure 2. Baseline Flood Depths (2019) Combined 1 in 200 year event

⁷ Flood Hazard Research Centre, *Flood and Coastal Erosion Risk Management: A Manual for Economic Appraisal*, 2013,

Table 9. Summary of flood risk management economic appraisal over appraisal period 2019 to 2119

Category	Commentary	Capped Present Value (£k) Damages
		Baseline: Walkaway & Business As Usual
Damages to residential and non-residential properties	Predicted flood depths are estimated from the average ground level at each property, the assumed overtopping inundation flood water levels (utilising data from the ABPmer 2019 report and potential inundation analysis undertaken by Arup 2019) with an allowance for the property threshold height. MCM depth damage curves were used to derive property damages, based on analysis of water level predictions for the Baseline scenarios for the different climate change epochs.	£66,483
Vehicle damages	Economic losses associated with damage to vehicles are estimated for all residential properties.	£3,913
Intangible Benefits	Intangible health benefits reflect the long-term personal impact of flooding on the health and wellbeing of those affected; a reduction in flood risk is correlated with an approximate equivalent financial benefit.	[precautionarily excluded]
Emergency Services	Emergency service impact from flooding. No consideration of closure of promenade due to overtopping hazard.	£7,113
Risk to Life	Risk to life assesses the likely impact of floods of different severities. The analysis defines a value for the number of fatalities likely.	£15,609
Utilities damages	Excludes damages already accounted for within erosion	£6,648
YGC Surface Water Pumping Station	Two non-main river outfalls (and pumping station). The consequences of the prolonged flooding to the pumping stations would result in pump failure and potential risk to local properties.	[Excluded from damage calculations]
Inundation of Road	The tidal flood extents show that Marine Parade (highway adjacent to Barmouth North Promenade) would be inundated, and hence un-usable, during storm events. A diversion is not expected to be required, as alternative routes to properties are available.	[Excluded from damage calculations]
Net PV Damages	Minimum (Property Damage)	£66,483
	Maximum (Incorporating Property Damage, Emergency Services, Utilities, Vehicle Damage, Risk to Life)	£99,767

The table below summarises the number of properties likely to be affected by flooding for the options considered. The table illustrates the onset of flooding to property is less than 1 in 1 annual chance. **Some 757 properties have greater than a 1 in 100 chance of coastal and/or surface water flooding in any year** (across Flood Cell 1 and 3 – refer to Appendix A).

Table 10. Property count for the epochs including climate change for Baseline option⁸

	NCC (Present day, no climate change (CC))						CC2069						CC2119					
Return Period	1	10	50	100	200	1000	1	10	50	100	200	1000	1	10	50	100	200	1000
Baseline	14	300	322	757	760	761	261	300	538	>757	>760	>761	>261	>261	>538	>757	>760	>761

The rapid speed of onset and depth of predicted flooding presents a considerable risk to life. **High risk to life damage values are substantial contributors** to the overall damages. This is due to the high proportion of residential properties in the study area in addition to predicted deep flood water.

2.3.1 Inundation prediction limitations

Hydraulic modelling has attempted to represent the baseline scenario. Representation of the baseline is sensitive to assumptions regarding:

- Topography (LiDAR)
- Structure geometry (culverts)
- Geometry and state of wave walls
- Approach to hydrological calculations
- Geometry and operation of flood risk management infrastructure
- Locations of overtopping, and
- Limitations associated with the modelling of wave events (i.e. NNT software and EurOtop guidance)

2.3.2 Standards of protection

Within the economic assessment, each option assessed represents a different standard of protection (onset of flooding, with allowance for residual uncertainty or freeboard). There are many engineering solutions to providing each standard of protection. The economic assessment focusses on demonstrating the relative benefit (damages avoided by providing a Standard of Protection compared to the Do Minimum) by providing a range of standards of protection to inform a cost-benefit analysis. Residual annual average damages of these options are calculated by assuming zero damages are associated with any flood events of a lesser magnitude. This is in line with FCERM-AG's requirement for proportionality.

In some instances (Options 4 – 6) defences will follow a 'Precautionary' approach i.e. constructed to a given level at the start of the scheme's life, already incorporating allowances for dealing with climate change. For instance, "1 in 50 years with 100 years' climate change" describes a defence constructed in 2019 to a height that will protect against the 50yr return period event that might be expected in 2119. The alternative is a "Managed Adaptive" approach, in which flood defences are raised to respond to climate change as required.

⁸ Note that the number of properties incurring damage in the present day for the 1 in 200yr and 1 in 1000yr event greatly exceeds that of CC2069 and CC2119. This is due to the scenarios modelled, and the limitations encountered in assessing wave overtopping as discussed in both ABPmer's wave modelling report and Arup's Inundation modelling report.

The scenarios in Table 33 were assessed for the 1 in 1, 1 in 10, 1 in 50, 1 in 100, 1 in 200 and 1 in 1000 annual chance events, and the corresponding damages combined to produce the Annual Average Damage (AAD) figure for present day and future epochs.

It is noted that a 2119 epoch has not been modelled within this assessment. This results from limitations within the overtopping modelling - primarily the scale of impact was beyond the limits of the overtopping analysis, please refer to Appendix B Inundation Modelling Report for further details.

Table 11. Options assessed.

Option		Standard of Protection	
		Return Period	Climate Change Allowance
Baseline	Combination of Do Minimum and Do Nothing (see Inundation Modelling report for details)	Baseline (No SoP)	
Do Something Residual Risk	1	1 in 200yr	2019
	2	1 in 100yr	
	3	1 in 50yr	
	4	1 in 200yr	2069
	5	1 in 100yr	
	6	1 in 50yr	

The resulting capped present value damages (PVD) associated with the options are shown in the table below. Please refer to **Appendix A** for further information outlining the assumptions and limitations of the results provided.

Table 12. Summary of flood damages provided with each Standard of Protection

Option	NPV Total NPV (Property Damage, Emergency Services, Utilities, Vehicle Damage, Risk to Life) (£k)	Present Value Benefits Present Value Benefits (£k)
Baseline	99,767	N/A
Option 1	32,371	67,396
Option 2	37,662	62,104
Option 3	89,774	9,992
Option 4	16,604	83,162
Option 5	12,855	86,912
Option 6	29,229	70,538

2.3.2.1 Managed Realignment

A further assessment was undertaken to define the benefits associated with a do-something option which involved managed realignment – i.e. setting the define line further inland now and in the future Epochs to align with the SMP2 policy. The following additional scenarios were considered to support the economic assessment of the options in **Section 4**:

Table 13. Managed realignment options assessed.

Option	Standard of Protection
--------	------------------------

			Return Period	Climate Change Allowance
Do Something Residual Risk	4b 6b	Managed Realignment (Year 0): Full extents (as per SMP2 (2011)). <i>Involves the loss of properties (assumed FC3⁹) associated with setting back the defence line. The flood damages/benefits with these properties have been excluded from the benefit calculations.</i>	1 in 200 yr 1 in 50 yr	2069
	4c 6c	Managed Realignment (Year 0): Northern extents only. <i>Only involves the loss of two commercial properties. These have been excluded from the benefits calculations.</i>		
	7a	Managed Realignment: Full extents – as above. Implemented in Epoch 2 (Year 20). <i>Baseline damages included up to Year 20.</i>	1 in 200yr	2069
	7b	Managed Realignment: Northern extents only – as above. Implemented in Epoch 2 (Year 20). <i>Baseline damages included up to Year 20.</i>		

The resulting capped present value damages (PVD) associated with the options are shown in the table below.

Table 14. Summary of flood damages provided with each Standard of Protection

Option	NPV Total NPV (Incorporating Property Damage, Emergency Services, Utilities, Vehicle Damage, Risk to Life) (£k)	Present Value Benefits Present Value Benefits (£k)
Option 4b (1 in 200 yr)	16,194	68,896
Option 6b (1 in 50 yr)	26,681	58,409
Option 4c (1 in 200 yr)	16,596	82,929
Option 6c (1 in 50 yr)	29,221	70,304
Option 7a (1 in 200 yr)	Property damage <u>only</u> equates to £46,174	Property benefits <u>only</u> equates to £10,945
Option 7b (1 in 200 yr)	Property damage <u>only</u> equates to £55,256	Property benefits <u>only</u> equates to £10,985

If options considered a 'Baseline' (i.e. Business As Usual) approach, with Managed Realignment implemented in Epoch 2, as per the SMP2 Policy, significant flood damages were identified.

⁹ Properties located in Flood Cell 3 (FC3) are excluded – please refer to Appendix A Section 1.1 for extents of FC3.

2.4 Assessment of erosion risk management benefits

The following estimates of damages have been calculated to reflect if recession of the shoreline occurs within the baseline scenario.

As indicated within **Section 2.1** it is estimated that without the significant works to the sea-wall to refurbish the sheet-pile, the sea wall and revetment will fail in Year 10 - 20. Following this, based on guidance within the Barmouth North Promenade Coastal Process Study (ABPmer, 2019) and Geotechnical Desk Study (Arup, 2019), the following scenario is envisioned:

- Year 10-20

As the flood wall fails due to washout of infill material and corrosion to its exposed sheet piled toe, there would be immediate impacts on the North Promenade, the adjacent road and the Welsh coastal path located immediately behind the sea wall. These would become unsafe for use and would therefore be closed in the first instance.

The granular material (sand) supporting the promenade would be at considerable risk of erosion as it becomes exposed to wave action and would be drawn out rapidly. This would lead to the rapid loss of the secondary and tertiary flood defences, watercourse outfalls/pumping station and Marine Parade road adjacent to the sea wall. The northern extents of the frontage would become inaccessible.

- Year 20 onwards to 100 years.

Beyond the initial loss of the promenade, the potential erosion rates for Barmouth North Promenade have been estimated in the SMP2 by Royal Haskoning, assuming no active intervention (NAI) at Barmouth and the surrounding areas. As indicated in the table below, the rate of erosion is predicted to be between 30 and 120m. This is likely to increase with sea-level rise, suggesting it could increase by a factor of 1.7 to 2.5 times the existing base rate over the next 100 years. Based upon this, and noting the general uncertainty behind these figures, diagrams below indicate the possible erosion extents that could be experienced over a 50 to 100 year period¹⁰. The adjacent frontages of Barmouth South and Llanaber are considered to be nominally unchanged.

Table 15. Potential erosion rates at Barmouth and surrounding areas (Royal Haskoning, 2011)

Location	NAI Base Rate (m/yr)	Notes	100 yr. Erosion Range (m)
Barmouth S	0.05	<i>Defended area recently accreting</i>	20-40
Barmouth N	0.2-0.4	Defended but historically reducing beach levels	30-120
Llanaber	0.2	<i>Heavily defended with no longer term record</i>	40-100

¹⁰ For further information, please refer to the Barmouth North Promenade Coastal Process Study (ABPmer, 2019)

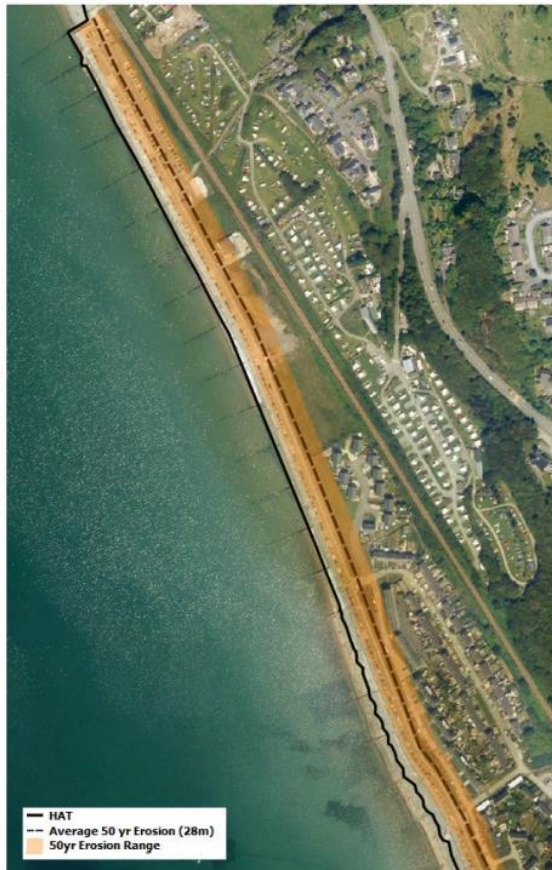


Figure 3. Potential erosion over 50-year period based on SMP2 NAI scenario

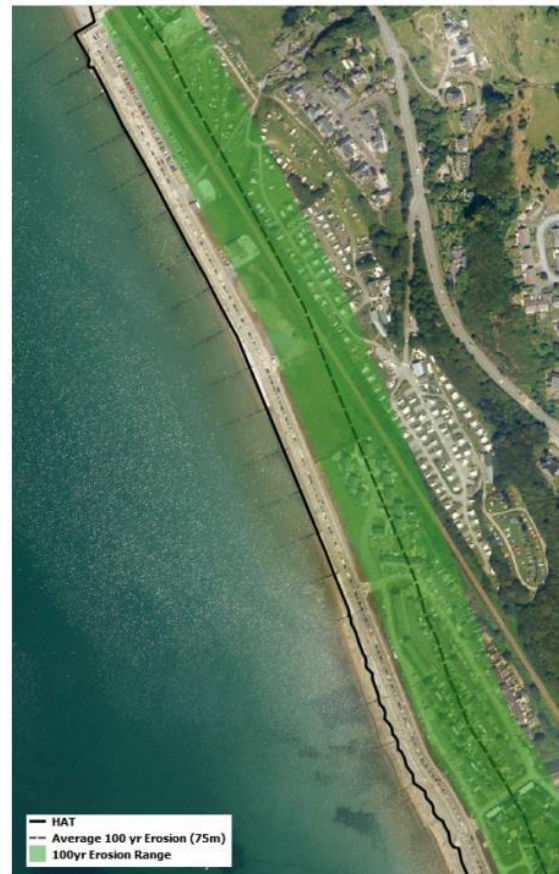


Figure 4. Potential erosion over 100-year period based on SMP2 NAI scenario

The SMP rates are based on NAI, however in practice the debris of failed structures would in practice be likely to reduce the pace of erosion. It is therefore assumed the final erosion rates are likely to be in the lower to mid-range of the estimates. Hence, from Figure 3 and Figure 4, it is evident that, the following assets are at risk of erosion including:

- The Promenade Café, local skatepark, Pen-y-Gogledd Car Park and Hoel-Y-Llan Housing Estate (includes a number of residential properties)
- The Network Rail Cambrian Railway Line (located 50m in-shore of the existing defences)
- Recreational value of Barmouth North Promenade and adjacent policy units
- The Marine Parade Highway and associated utilities infrastructure
- The Hendre Myanach Caravan & Camping Park & Hydragea House Holidays (located beyond the Cambrian Railway Line).

Throughout the 100-year appraisal period described above, the areas of transition from Barmouth North to the neighbouring policy areas (i.e. South Barmouth and Llanaber both 'Hold the Line' Policy Units) would be put at risk from coastal erosion and flooding without significant interventions. Most likely, the coastal protection authority (GC) and Network Rail would collaboratively undertake works to maintain the railway and safe public access. This is considered outside of the scope of this baseline scenario.

2.4.1 Loss of properties due to erosion

Several residential properties have been identified to be proximity to the existing Barmouth shoreline and at potential risk to the implications of erosion. It should be noted that there is substantial uncertainty within the exact timescales and extents to which erosion of the shoreline would occur.

For the purposes of this assessment, the properties at risk have been grouped into which epoch they are expected to experience damages as a result from the projected erosion extents – as shown on **Figure 3** and **Figure 4** (Year 20-50 and Year 50-100). Flood Cell 3 in **Figure 9** in **Appendix A** defines the extents of the area considered to be affected by a mid-range 50-100 year erosion scenario in this assessment. A count of the properties likely to be affected are outlined in **Table 16**.

Table 16. Count of properties estimated to be affected by erosion

Property Type	Properties affected by erosion (20-50yr epoch)	Properties affected by erosion (50-100yr epoch)
Detached	0	2
Semi-Detached	0	21
Terrace	0	12
Flat / Bungalow	0	22
Other	0	3
Total	0	60

A summary of projected damages expected to occur due to erosion is provided in **Table 17**. The calculated write-off value of these properties (as described in the MCM methodology) is taken to be the current market value occurring in the year the property is assumed to be lost based on estimated erosion rates. This value is discounted to give present value erosion damages, which can be taken as an approximate value of the benefit of delaying erosion.

There are 60 properties within the anticipated erosion band over the next 100 years. Most of the properties affected are residential; the values of these properties have been estimated based on house type and local Land Registry data¹¹ (refer to **Table 30** in **Appendix A** for further information). The values of non-residential facilities (i.e. 'other') have been estimated by use of rental yield and rateable value information, coupled with footprint area to calculate property value.

Table 17. Summary of property damages expected to occur due to erosion

Assumed Property Value (in 2019)	Number of properties	Year when assets are expected to be lost	Expected Damages (Do-Nothing)
£350,317	2	75	£1,130k
£217,986	21	75	
£188,131	12	75	
£202,663	22	75	
Other	3	75	

¹¹ <http://landregistry.data.gov.uk/app/ukhpi/explore>

Total PV erosion damages to residential properties	£1,130k
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It is clear that this estimate is sensitive to the assumed timing of erosion. Sensitivity analysis accelerated and delayed the erosion dates above by 15 years, the impact of this on projected damages is summarised below.

Table 18: Sensitivity of timing on projected erosion damages

	Expected Damages (Do-Nothing)	Percentage change
Accelerated by 15 years (Year 60)	£1,761	+56%
Delayed by 15 years (Year 90)	£780	-31%

Please note, due to the high level of uncertainty associated with the rates of erosion, whilst recognising the effects of discounting in epoch three minimises the resulting damages (i.e. 10% of capped property PvD), the assessment provided is intended to provide a sense of scale of the erosion implications only. To support a precautionary approach and avoid double counting, the PV erosion damages are excluded from the final benefits.

2.4.2 Cambrian Coast Railway

The Cambrian Line is a railway that runs from Shrewsbury to Aberystwyth and Pwllheli, both on the west coast of Wales. It spans 120 miles of *'unspoilt natural beauty and is one of the most scenic rail routes in Britain'*¹². In 2017, the UK national newspaper The Guardian described the Cambrian Coast Railway *'as one of the world's most spectacular railway trips'*.

Whilst boasting scenic views, the Cambrian Line also provides a strategic public transport link to coastal towns in west Wales, including Barmouth, for both tourists, residents and businesses. The Anglesey and Gwynedd Joint Local Development Plan (JLDP) (2016-2026) recognises, as part of Strategic Policy 4: Sustainable transport, Development and Accessibility, that *'transport has an important role to play in the lives of residents and visitors'* and *'the movement of people and goods depend on good sustainable transport links of all types'*. It further recognises the positive benefits of sustainable transport on wider policy areas such as tourism, the economy and climate change.

The Cambrian Coast Railway is located within the SMP2 erosion extents and considered likely to be at risk of coastal erosion, and flooding inundation (see **Section 2.4**), between a 50-100 year appraisal period. Recognising the importance of this strategic transport link, it is considered that disruptions to this asset would have heavy economic and social implications to the wider county of Gwynedd. Impacts include:

- Loss of railway service beyond Barmouth (affecting 17 stations): This will impact on the economies and recreational benefits of a series of coastal towns including Talybont, Llaneddwyn, Llanbedr, Minffordd, Porthmadog and Pwllheli, amongst others. It is notable that the railway is the only public transport link for many of these towns; the loss of which would reduce the ability of residents, tourists and businesses to travel via sustainable transport and decrease connectivity between local towns and the wider regions of Wales

¹² Cambrian Railway Partnership: <https://www.walesonrails.com/>

and England. Such actions would work against the aims of the JLDP Strategy Policy 4 and the wider interests of Welsh Government.

- **Social well-being, health and community cohesion:** Reducing public transport links will limit residents and communities, particularly those most vulnerable (e.g. elderly / unwell who are unable or can't afford to drive), from traveling beyond Barmouth via the Cambrian Line. This may reduce ability to access local services, access recreational facilities or visit friends and family beyond their immediate location. The JLDP notes there are already a number of challenges faced by Gwynedd including an elderly population, high levels of deprivation and issues accessing community, leisure and healthcare services (see Table 23 on page 28). Disruption would exacerbate the issues experienced. Such implications would have significant negative impacts on the health and social well-being of the local communities within Gwynedd.

To provide a scale to the value of these assets, following the unprecedented storm damage in 2014, Network Rail undertook a programme to repair the section of the line from Barmouth to Pwllheli. The anticipated final cost for the full works to re-open the Cambrian coast railway was estimated to be in the region of £10m¹³.

Although damages associated with this loss of the network are considered to range in the £m's, due to significant uncertainties associated and lack of available data, the impacts have therefore been considered qualitatively. It is considered that the safe-guarding of this asset is imperative. Significant works would need to be undertaken to either divert the route (requiring UK Parliamentary Approval) or afford protection via alternative defences, which are outside the scope of the baseline scenario.

2.4.3 Loss of recreational value of Barmouth North Promenade

Barmouth is a popular seaside resort and has been awarded the Blue Flag and Seaside Awards (2014). As well as being hailed as the third best beach in Wales, Barmouth also made it into the Top 25 beaches across the UK in TripAdvisor's 2017 Annual Traveller's Choice Awards for Beaches¹⁴. The town attracts around 280,000 visitors annually¹⁵ and tourism provides an important source of income to the community (estimated to be £42.7 million annually¹⁶) in the form of visitor spending and local business supply chains and wholesalers.



Figure 5. Barmouth Beach¹⁷

¹³ <https://www.networkrailmediacentre.co.uk/news/cambrian-coast-railway-update>

¹⁴ <https://www.dailypost.co.uk/news/north-wales-news/barmouth-beach-only-one-north-10912948>

¹⁵ Barmouth Tourism Estimates - Global Tourism Solutions (UK) Ltd, October 2018

¹⁶ Barmouth Tourism Estimates - Global Tourism Solutions (UK) Ltd, October 2018

¹⁷ <http://www.visitmidwales.co.uk/Barmouth-Barmouth-Beach/details/?dms=3&venue=1162790>

In recreational terms, Barmouth is considered to support:

- Barmouth promenade and beach, which is a mixture of sand and fine shingle, with disabled access.
- A land train runs along the promenade and there are traditional donkey rides and swing boats. The town itself hosts shops, cafés and restaurants, good parking, amusements arcades and entertainment facilities.
- Water sports (with an access to the sea via a slipway on the beach) and hosts Route 8 of the National Cycle Network.

Continued erosion of the foreshore at Barmouth North Promenade would result in the immediate loss of the Wales Coastal Path and the National Cycle route which run directly parallel to the promenade. Such action would also result in the loss of aesthetic appeal to northern extents of the frontage, reducing amenity value of the full promenade and safe access to the beach beyond South Barmouth. The car-parking facilities, Promenade Café and local stake-board park would become inaccessible and un-safe.

It is recognised that whilst Barmouth as a whole supports significant recreational value and ‘value of enjoyment’, Barmouth North and Barmouth South host differing levels of recreational benefit. Whilst Barmouth South is considered to support a considerable proportion of existing recreational users, the loss of Barmouth North Promenade would reduce the appeal of Barmouth as a whole due to the unsightly nature of the northern extents, loss of car-parking facilities and lack of full promenade or beach access. Any health benefits that the existing North Promenade and beach promoted would also be affected. However, there is insufficient data to assess Barmouth North separately from Barmouth South Promenade and therefore this aspect has been considered qualitatively. In summary, the baseline at Barmouth North Promenade is considered to have negative implications on the existing recreational value supported, and further negatively impact on the neighbouring Barmouth South.

Barmouth Promenade Land-train

A land train runs along the length of the promenade (between North and South Barmouth Promenade) and is considered a popular local attraction. It is practically assumed that with the loss of North Promenade would confine the land-train to the extents of South Barmouth, and render the use of land-train unavailing. This would result in significant reduction in “Value of Enjoyment” associated with the recreational value of Barmouth North Promenade – since the attraction of the land-train is typically to enjoy the sea front experience. There is insufficient data to assess this separately and is therefore considered qualitatively along with the loss of aesthetic appeal and recreational value of North Promenade.

2.4.4 Damages to highways and utilities infrastructure

Marine Parade and Heol-Y-Llan Highways

The Marine Parade highway runs parallel to the public defences at Penrhyn Bay, whilst the Heol-Y-Llan Highway provides access from this point into the Heo-Y-Llan housing estate. In the baseline scenarios, failure of the sea wall is likely to result in tension cracks developing in the pavement and, as a minimum, the safe usage of the road will no longer be guaranteed.

In this instance, a value of traffic disruption has not been assessed, as it considered that minimal disruption to traffic flows would be incurred. Marine Parade Road is considered to have minimal volumes of traffic, whilst entrances from south Barmouth would still provide a close diversion route to access the Heol-Y-Llan housing estate.

Utilities and infrastructure

The seawall, promenade and adjacent highways retains infrastructure including:

- OpenReach Fibre
- Two non-main river outfalls – including a pumping station and outfall and screened culvert, discharging via the beach

Utilities infrastructure related to Wales and West Utilities (gas) and SP Energy (electricity) were considered to have assets beyond the erosion extents to a point which works to safe-guard or divert them are considered to be negligible or minimal. No information related to Water and Wastewater infrastructure was available at the time of writing.

The MCM recommends that three alternative strategies are considered, and the least cost option adopted:

- Abandon properties served by service
- Invest in alternative service
- Accept disruption

By reference to Figure 7.5 of the MCM, it appears likely that the most appropriate approach to assessment of the benefit of erosion protection is to:

- BT OpenReach – Accept disruption - in this instance it is considered that the properties being served by BT OpenReach would have to be abandoned due to erosion. The services affected are not considered to affect assets beyond the extents of Barmouth North Promenade.

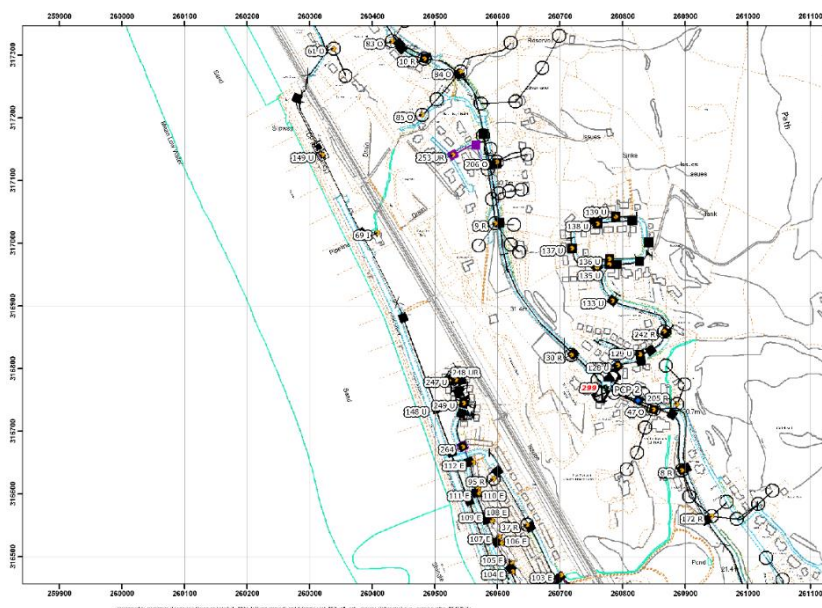


Figure 6. BT OpenReach Assets at Barmouth North Promenade

- Two non-main river outfalls (and pumping station) - Assess the costs of investing in replacements for these once they have failed – It is not considered that accepting the

disruption is an acceptable option for failure, without appropriate action fluvial and surface water flooding may be experienced upstream (particularly adjacent to the east of the Cambrian Railway Line) or within the wider flood cell of Barmouth South. Therefore the benefit of the erosion protection measures are considered to be the net present value of any diversion works for these services.

The most likely location in which to construct the replacement assets is considered to be upstream of the present outfalls, beyond areas significantly affected by erosion. It is estimate that the cost of replacing the assets is between £250 - £350k. The timing of the realignment may not be known exactly, but reasonable estimates can be made of how this might impact on the present value benefit of works. The benefit to the scheme can be estimated, assuming extension of the promenade life by 100 years. This indicates in broad terms that the economic benefit of extending the frontage's life may be of the order of £0.1m.

Table 19: Estimated benefit of scheme in terms of difference present value costs (£m)

	Cost	Assumed timing		
	(£m)	2029	2034	2039
Assumed value of works	£2.5	0.1	0.1	0.1
	£3.0	0.1	0.1	0.1
	£3.5	0.2	0.1	0.1

2.5 Economic appraisal damages summary

In terms of economic damages from coastal flood and erosion risk management that are admissible by the MCM, the make-up of these damages is summarised below. A precautionary and proportionate approach has been undertaken to ensure a robust business case is developed.

Table 20. Summary of damages economic appraisal

Component	(£k)	Key areas of uncertainty
Flood Related Damages		
Damage to people and property	£99,767	<i>Extents and severity of flooding</i>
Erosion Related Damages		
Loss of properties	[Excluded – up to 60 properties affected]	<i>High uncertainty associated with the rates of erosion.</i>
Cambrian Coastal Railway Loss	[Excluded - benefits of protecting this asset are likely to range in the £m's and safe-guarding of this asset is imperative]	<i>Significant cost uncertainties and lack of available data. Wider context/connectivity risks.</i>
Loss of Recreational Benefits	[Excluded - the loss of Barmouth North Promenade may reduce the appeal of Barmouth]	<i>North Promenade amenity interdependent on Barmouth South.</i>
Damage to utilities infrastructure (services replacement)	£100	<i>Cost of diversion works & replacement services, timing</i>
Total	£99,867	
Significant potential benefits are excluded from this assessment due to uncertainties in a quantitative figure. The damages could arguably increase significantly if implications of property erosion, loss of the Cambrian Coastal Railway function and recreational or wider benefits were included. Benefits are considered qualitatively.		

2.5.1 Additional comments

In addition to the economic benefits identified above, it is recognised that a critical aim of the scheme is the incorporation of wider benefits and added amenity value in the project design and construction (including consideration of the Welsh Government's Community Benefits policy and Well-Being of Future Generations Act). To ensure any proposal adheres to these values, a full qualitative review of the wider benefits and context of Barmouth North Promenade within the local area is undertaken in **Section 4**.

3 Wider impacts

Coastal risk management schemes although primarily about reducing coastal flooding and erosion risk, can also safeguard and enhance the economic function of tourism, and facilitate or accelerate regeneration of the coastal community.

The schematic below illustrates the all-encompassing best practice approach from inception to delivery of coastal risk management projects. The detailed FCERM option appraisal process (shown in blue) is undertaken and through engagement with stakeholders has been seeking to understand how the scheme can deliver wider outcomes such as enhancements to the promenade and facilitate development (shown in green).

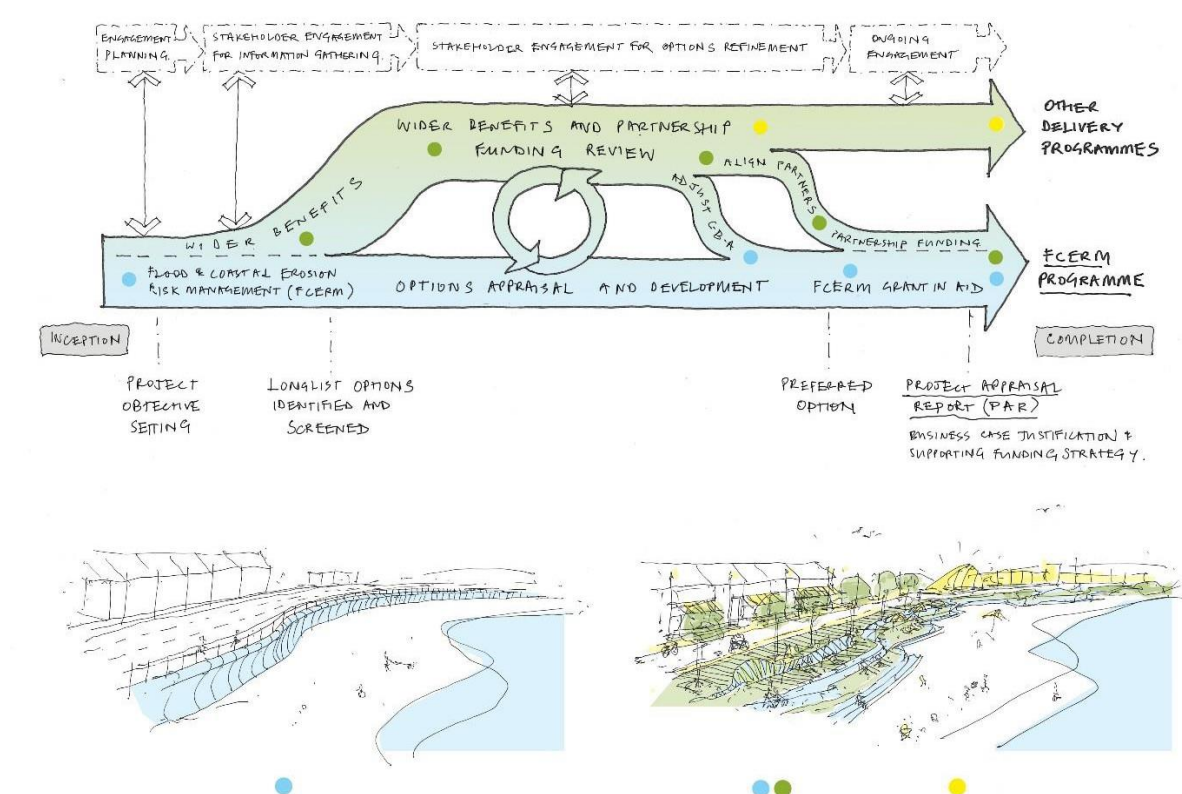


Figure 7: Framework for aligning coastal risk schemes with wider programmes to regenerate coastal communities

This section outlines the policy and socio-economic context and the wider impact that

3.1 Policy Context

Coastal risk management schemes that are primarily about reducing coastal flooding and erosion risk can have wider benefits not captured in as part of the main quantified economic appraisal. These benefits help to provide a further rational for intervention and demonstrate that the scheme is aligned to wider policy aspirations.

The development of the scheme has been conducted in partnership with local stakeholders in order to make sure the scheme's objectives match their aspirations. The scheme design seeks to provide opportunities to allow future long term evolution of the seafront area while taking account of its existing unique natural beauty

3.1.1 Well Being of Future Generations Act

The Well-being of Future Generations Act (WBFGA) was introduced in 2016 to ensure Welsh public policy and spending is sustainable and safeguards the interests of today's and future generations. This Act is about improving the social, economic, environmental and cultural well-being of Wales and features a series of overarching Well Being Goals¹⁸.



Figure 8. Well Being of Future Generations Goals

The Act features more focussed ‘well-being’ objectives, which are based on the biggest issues identified to be facing Wales today. These objectives are as follows:

- Create conditions to give every child the best start in life
- Improve education outcomes for all and reduce the gap in outcomes for different groups
- Help people live healthy and independent lives and support a healthy workplace
- Improve prosperity for all across Wales, helping people into employment and sustaining jobs.
- Create the conditions for people to learn and use the Welsh language with their families, in their communities in the workplace
- Support the transition to a low carbon and climate resilient economy
- Connect communities through sustainable and resilient infrastructure
- Support safe, cohesive and resilient communities
- Improve access to secure, safe, efficient and affordable homes
- Foster conditions for sustainable economic development and employment whilst stimulating innovation and growth for a modern low carbon economy
- Promote and enhance the culture and heritage of Wales
- Facilitate high quality, responsive and better integrated public services, to those that need them most, enabling citizens to be an equal partner and
- Position Wales as an internationally-focussed, ambitious country engaged and connected to the wider world.
- Improve conditions for sustainable economic development and employment while stimulating innovation and growth for a modern low carbon economy.

¹⁸ The Wales We Want. Well Being of Future Generations Act 2015 Available at: <http://thewaleswewant.co.uk/about/well-being-future-generations-wales-act-2015>

3.1.1.1 The Five Ways of Working

The Act identifies ‘Ways of Working’ which are

- Long term – a clear vision of the future potential if the goals are met.
- Integration – public bodies working together and understanding their role in contributing to the goals.
- Prevention – early interventions are important to improving the lives of the people of Wales and provide the best long term value
- Collaboration – an understanding of how this can lead to better solutions and better outcomes for the people of Wales.
- Involvement – only by involving the community and individuals in public services can the needs of current and future generations be met.

3.1.2 Local Development Plan

Anglesey and Gwynedd Joint Local Development Plan (JLDP) (2016-2026): The Plan sets out the strategy and aims for development and land use in the area covered by the Anglesey and Gwynedd Planning Authorities and includes policies to implement the strategy and aims over a period of 15 years (2011 to 2026). This vision for the JLDP is “*Strengthen communities in Gwynedd and Anglesey*”. Of particular note is the following policy area:

POLICY ARNA 1: COASTAL CHANGE MANAGEMENT AREA:

A Coastal Change Management Area (CChMA) is identified in Appendix 6 (see Table 21) of which Barmouth North Promenade is identified within. Key extracts of the policy are outlined below:

- *New Residential Development* - Proposals for new dwellings, replacement dwellings, subdivisions of existing buildings to residential use or conversion of existing buildings to residential use will be refused in the CChMA.
- *Relocation of Existing Permanent Dwellings in the Countryside:* Proposals for the relocation of existing permanent dwellings in the countryside located in the CChMA predicted to be affected by coastal erosion and/or flood risk will be permitted provided they conform to the associated criteria.
- *New or Existing Non-Residential Buildings:* Proposals for the following types of new non-residential development (e.g. beach huts, cafes, leisure activities, campsites etc.) will be permitted on sites within the CChMA predicted as being at risk from coastal change during the second indicative policy epoch (2026 – 2055), subject to a compliant Flood Consequence Assessment or a Stability Assessment.
- *New or Replacement Coastal Defence Scheme:* Proposals for new or replacement coastal defence schemes will only be permitted where it can be demonstrated that the works are consistent with the management approach for the frontage presented in the Shoreline Management Plan, and there will be no material adverse impact on the environment.
- *Managing Development:* Planning conditions will be applied or a planning obligation will be secured where there is a need to: limit the planned life of a development or seasonal use; remove a time-limited development or existing dwellings on cessation of use; review relevant planning permissions; manage the occupancy of a relocated dwelling.

Please refer to the JLP for full details of the associated policy.

Table 21. Appendix 6: Coastal Change Management Area of the JLD

SMP2 Policy Boundaries			Preferred Policies			
PDZ	Man	PU	Policy Name	Policy Comments	2025	2055
11	24	PU11.15	Barmouth North	This many include the relocation of properties	HTL	MR

Key further policies relevant to the scheme include:

Table 22. Key policies relevant to the scheme

Policy Details	Project Alignment
STRATEGIC POLICY PS 4: SUSTAINABLE TRANSPORT, DEVELOPMENT AND ACCESSIBILITY: Development will be located so as to minimise the need to travel. The Councils will support improvements that maximise accessibility for all modes of transport, but particularly by foot, cycle and public transport. This will be achieved by securing convenient access via footways, cycle infrastructure and public transport where appropriate.	The frontage at North Promenade promotes active travel and further accommodates the Wales Coastal Cycle Path. The scheme will look to promote activity travel throughout.
STRATEGIC POLICY PS 5: SUSTAINABLE DEVELOPMENT: Development will be supported where it is demonstrated that they are consistent with the principles of sustainable development.	The scheme will be aligned to the principles of sustainable development.
STRATEGIC POLICY PS 6: ALLEVIATING AND ADAPTING TO THE EFFECTS OF CLIMATE CHANGE: In order to alleviate the effects of climate change, proposals will only be permitted where it is demonstrated that they have fully taken account of and responded to the energy hierarchy and reducing greenhouse gas emissions.	The scheme is assessed across a 100-year time-frame – with consideration made to the alleviation/ adaption to climate change and rising sea levels.
STRATEGIC POLICY PS 14: THE VISITOR ECONOMY: Whilst ensuring compatibility with the local economy and communities and ensuring the protection of the natural, built and historic environment the Councils will support the development of a year-round local tourism industry.	The scheme will consider opportunities to protect, and where possible enhance, the visitor economy in Barmouth (see Project Objective 2)
STRATEGIC POLICY PS 19: CONSERVING AND WHERE APPROPRIATE ENHANCING THE NATURAL ENVIRONMENT: The Councils will manage development so as to conserve and where appropriate enhance the Plan area's distinctive natural environment, countryside and coastline, and proposals that have a significant adverse effect on them will be refused unless the need for and benefits of the development in that location clearly outweighs their value.	The scheme will maintain, and where possible enhance, natural and historic environments – with consideration of the this Strategic Policy (see Project Objective 3).

The JLDP further notes a number of key challenges for the Gwynedd as a whole, as identified below. It is recognising that if the Baseline Scenario was to occur it would negatively impact on the key challenges already faced by the county, particularly in terms of health and well-being and economic factors.

Table 23. Key challenges faced by the county of Gwynedd

Key challenges for the region:			
Demographic	Social	Economic	Environmental
An aging population, impact of holiday/secondary homes on communities and housing market, losing young residents who are economically active, insufficient supply of housing (with current houses old or of poor design), limited capacity of settlements to deal with additional housing.	Promoting opportunities for people to live healthy lives and have reasonable access to health care, areas with high levels of various types of deprivation, access to facilities and community services, leisure facilities and formal/ informal entertainment including access to the countryside.	Responding to business development and employment needs of existing / new employers, declines in the prosperity and vitality of town centres; improving and managing the 'all year' tourist provision in the area in a sustainable way.	Mitigate and adapt to the effects of climate change, need to protect and whenever possible, improve the natural environment, habitats and species of the area, make the best use of the comparatively low levels of brownfield sites.

3.2 Wider benefit opportunities

A review of the wider benefits associated with Barmouth North Promenade has been undertaken. Please refer to **OBC Appendix K** to review the plan mapping the Wider Benefit opportunities; a summary is provided below.

Table 24. Wider benefits and opportunities

Area	Opportunities
Existing	- Amenity and recreational value of the promenade (cycling and walking) local stake park, Promenade Café and Wine Bar - Erosion control of the frontage
Economic	- Reducing YGC operation and maintenance activities - Impact on, or improve, tourism and the recreational value the North Promenade affords and the wide town of Barmouth itself - Implications on, or opportunities associated with local property and employment (GVA)
Social	- Improve amenity value of the northern extents of the shorefront and promenade - Improve or promote health and well-being - Implications on crime and safety (should the defences be left fail and pose a public health risk or un-slightly area) - Opportunities to maintain or improve community cohesion and civil pride
Environmental	- Improving bio-diversity (planting and habitat improvements) - Opportunities for geomorphological features installed on the beach - Improve WFD status of culverted watercourses - Consideration of carbon depending on the scale of new construction activities - Rain scaping and surface water separation - Enhance bio-diversity of dune system to the south of the study area
Political	Political implications of implementing SMP2 policies
Stakeholders	Impacts on local businesses and tourism at Barmouth

3.2.1 Health and Well-Being

Intangible health benefits reflect the longer-term personal impact of flooding on the health and wellbeing of those affected; a reduction in flood risk is correlated with an approximate equivalent financial benefit.

However, wider health and well-being benefits should be also recognised. Beaches and promenades can play an important part in facilitating physical activity.

A report by public health Wales found that the cost of conditions associated with physical inactivity in Wales was £314m each year and increasing cycling and walking could save NHS Wales £0.9bn over 20 years¹⁹. Research by the Active Healthy Kids Global Alliance, a network of researchers and health workers worldwide, found that children in Wales rank among the worst for physical activity.

Recent research in England found that beaches encourage families to be physically active²⁰. Another study found that coastal proximity was associated with a greater probability of meeting physical activity guidelines²¹.

3.2.2 Impacts During construction

Benefits

During construction the scheme is likely to generate approximately 13.3 jobs per £1million spend. Training and apprenticeships will help to make sure that young people living in Penrhyn and indeed other parts of Conwy are able to benefit directly from the scheme. Local procurement where possible will help to ensure that wider supply chain benefits are remain within North Wales where possible and help to support local businesses and jobs.

Recent transport infrastructure targets are for 2.5% of construction jobs to be apprenticeships²².

Welsh Government expect projects over £2 million in value should have a clear plan for achieving community benefits and that this should be factored into any consideration of procurement options.

Disruption

Disruption to businesses during construction works would be limited, there will have to be some encroachment onto the promenade which will require temporary diversions although should not bring about any disruption in trading to existing businesses.

¹⁹ Public Health Wales (2016) *Making a Difference: Investing in Sustainable Health and Well-Being for the People of Wales* Available at: http://www.wales.nhs.uk/sitesplus/documents/888/PHW%20Making%20a%20difference%20ES%28Web_2%29.pdf

²⁰ Ashbullby et al (2013). *The beach as a setting for families health promotion: A qualitative Study with parents and children living in coastal regions in Southwest England*

²¹ White et al (2014). *Coastal proximity and physical activity: Is the coast an under-appreciated public health resource.*

²² https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/495900/transport-infrastructure-strategy-building-sustainable-skills.pdf

4 Coastal Risk Management Option Appraisal

4.1 Short List Options Scheme Costs

The cost of increasing the Standard of Protection (SOP) at Barmouth North Promenade was calculated. The shortlisted options comprised:

Table 25. Do-Something Options

Option	Description	SOP
2. Betterment of existing defences	A series of works to extend the life-span of the existing structure and improvements to the standard of protection of the defences.	1in50 + CC events up to 2069
3. Beach Management and Associated Structures (i.e. groynes/breakwaters)	Combination of rock breakwaters offshore and/or shore-linked groynes (rocks or refurbish existing) to hold the placement of beach material and reduce overtopping.	1in200 year + CC SOP up to 2119
4a. New line of defence set back at the railway (i.e. Managed Realignment)	The option will replace the existing defences and set them back further in-land (managed realignment) to protect the Railway Line	1in200 year + CC SOP up to 2119
4b. New line of defence set back at the railway (i.e. Managed Realignment) – Northern Extents Only	As above, but option considers managed realignment to the northern extents of the promenade only (protecting existing residential properties).	1in200 year + CC SOP up to 2119
<i>Due to modelling limitations, for the economic assessment of benefits associated with Options 3 and 4 a 1in200 year + CC up to 2069 have been conservatively considered.</i>		

A breakdown of these preliminary costs are described below. The impact of phasing construction is to be considered once the preferred option had been selected and developed.

	Option 2	Option 3	Option 4a	Option 4b	Notes - assumptions, source(s) and dates
	Business As Usual ++	Breakwaters and Beach Recharge	Managed Full Realignment	Managed Realignment North only	
OBC to construction:					
Staff costs (YGC)	£73	£73	£146	£146	Project management costs (YGC, 2019)
Site investigation and surveys	£60	£40	£5,021	£3,351	Option 4: Managed Realignment - EA: SC080039 Cost Estimation for Managed Realignment; suggests that although highly variable, the average pre-implementation costs associated with design, surveys, modelling and consultation are 17% of the total cost.
Consultants' fees (Outline and Detail Design)	£502	£1,765	£865	£961	Assume 5% of capital construction cost for detailed design stage
Early Contractor Involvement	£25	£25	£25	£25	One off cost
Other costs (specify)	£32	£32	£120	£120	Includes marine licence, consent, monitoring and stakeholder engagement
Optimism Bias	207	£581	£1,853	£1,381	30% applied to 'OBC to Construction' costs due to uncertainty pending ongoing study and further survey.
Subtotal	£899	£2,516	£8,029	£5,983	
Construction:					
Construction costs	£10,035	£35,307	£17,291	£19,212	PV Capital cost, based on estimates from YGC Twynn Scheme (2011). Includes: - Preliminaries, overheads and profit: 25% - Contingency (including inflation): 15% Option 4: New line of defence estimated from: EA - SC080039 Cost Estimation for Coastal Protection (2007). Includes decommissioning costs.
Utility diversions	-	-	-	-	No diversions anticipated as part of the scheme, based on initial review
Land purchase & compensation	-	-	£12,244	£500	Option 4: Managed Realignment - Assume 57 properties (Option 4a) and 1 property (Option 4b) compensated at value of property in 2019. Assumption subject to further review at detailed design. - £250,000 land purchase costs (YGC, 2019)
Optimism Bias	£6,021	£21,184	£17,722	£11,827	60% applied – due to uncertainty pending ongoing study and further survey.
Subtotal	£16,055	£56,492	£47,257	£31,539	
Future costs (scheme implemented at Year 0):					
Maintenance (PV)	£38	£1,790	£45	£45	
Future construction (PV)	-	-	-	-	
Optimism Bias	£23	£1,074	£27	£27	60% applied – as detailed above
Subtotal	£62	£2,864	£72	£72	
Total	£17,016	£61,872	£55,359	£37,594	

Table 26: Proposed scheme preliminary costs (£k)

4.2 Adaptive pathways

Adaptive pathways are defined by best-practice guidance²³ as:

Adopting a managed adaptive approach to Flood and Coastal Erosion Risk Management (FCERM) involves investing now in actions that manage today's risks, monitoring the change in risk over time and managing these changes. The managed adaptive approach, therefore, involves planning for multiple interventions and investments in the future, although the future choices and the timing of these interventions will be uncertain.

It is recognised that:

- The SMP2 Policy for Barmouth North Promenade recommends moving towards a policy of 'Managed Realignment' in Epoch 2 (from Year 20).
- Overtopping is significant at Barmouth, therefore the Do-Something Options' focus is to reduce flood risk to property, as opposed to alleviating overtopping. On-going climate change and sea-level rise will look to exacerbate risks further; whilst adding uncertainty around the future implications or performance of the options over the 100-year appraisal period.
- A combination of Do-Something options may offer additional or enhanced benefits. Noting that Option 2 (Betterment of the existing defences) has an anticipated life-span to Epoch 3 (Year 50 onwards).

As such, an adaptive pathway approach has been utilised within the economic assessment to consider different possible sequences of investment decisions associated with the Do-Something Options (i.e. different combination/temporal interventions). The aim of this approach is to introduce flexibility into the 100-year appraisal period, to account for the uncertainties highlighted above. The following pathways have been considered:

²³ Accounting for adaptive capacity in FCERM options appraisal, User Guide SC110001/R1, Environment Agency 2018.

Table 27. Adaptive pathway scenarios considered for the economic assessment

	Epoch 1 0-20 years	Epoch 2 20-50 years	Epoch 3 50-100 years
Option A	Option 2: Betterment of defences <i>Precautionary SOP reducing to 1 in 50 by 2069</i>		Option 4: Managed Realignment (SMP2) <i>Adaptive SOP 1 in 200</i>
Option B	Option 2: Betterment of defences <i>SOP 1 in 200 in 2019</i>	Option 4: Managed Realignment (SMP2) <i>Adaptive SOP 1 in 200</i>	
Option C	Option 2: Betterment of defences <i>Precautionary SOP reducing to 1 in 50 by 2069</i>		Option 3: Beach Management <i>Adaptive SOP 1 in 200</i>
Option D	Option 2: Betterment of defences <i>SOP 1 in 200 in 2019</i>	Option 3: Beach Management <i>Adaptive SOP 1 in 200</i>	
Option E	Option 3: Beach Management <i>Adaptive SOP 1 in 200</i>		
Option F	Option 2 + Option 3 <i>Adaptive SOP 1 in 200</i>		
Option G	Option 2: Betterment of defences <i>Precautionary SOP reducing to 1 in 50 by 2069</i>		Option 4b: Managed Realignment (North Only) <i>Adaptive SOP 1 in 200</i>
Option H	Option 2: Betterment of defences <i>SOP 1 in 200 in 2019</i>	Option 4b: Managed Realignment (North Only) <i>Adaptive SOP 1 in 200</i>	

Options which included a Business As Usual approach in Epoch 1 and implementing Option 4a and 4b (i.e. Managed Realignment) in the second epoch (as per the SMP2 policy) were discounted. As the promenade is at significant risk of failure (i.e. considered 10-20 year life-span remaining) and there is an early on-set of flood risk, there is a need to undertake significant works now.

It is recommended that this process is developed further at the next stage to define detailed pathways which include monitoring and evaluation processes, key milestones or trigger points and associated downstream pathways.

4.3 Benefit cost ratios

Capped PVD damages, the net benefit of implementing each of the options, and the project costs are used to calculate the benefit cost ratios. Recognising the SOP of each pathway varies throughout the scheme life-span, a precautionary approach has been applied to the assessment. The lower 1 in 50 year 2069 SOP has been considered for Option 2 in Epoch 2 (i.e. Option A, C and G), with 1 in 200 year 2069 considered for the remaining options.

An estimate of the benefit-cost ratios has been provided below in Table 28.

Table 28. Estimate of benefit cost ratios for providing increasing Standards of Protection

Option	Flood Damages	Flood and Erosion Benefits	Preliminary Costs	Preliminary Benefit Cost Ratio	Incremental Benefit Cost Ratio
	(£k)	(£k)	(£k)		
Baseline	£99,867	£0			
Pathway G	£29,221	£70,304	£26,395	2.7	
Pathway A	£26,681	£58,409	£30,639	1.9	N/A
Pathway C	£29,229	£70,538	£31,384	2.2	0.0
Pathway H	£16,596	£82,929	£37,540	2.2	1.1
Pathway B	£16,194	£68,896	£46,949	1.5	N/A
Pathway D	£16,604	£83,163	£48,668	1.7	0.7
Pathway E	£16,604	£83,163	£62,453	1.3	0.0
Pathway F	£16,604	£83,163	£79,676	1.0	0.0

4.3.1 Limitations

It is recognised that there are a number of limitations within the economic assessment undertaken; e.g. the 2119 scenario has not been modelled due to modelling limitations and there are varying SOPs associated with the adaptive pathways. As such, a precautionary and conservative approach has been applied to the assessment. Capping of properties' values is significant at Barmouth North Promenade, due to the early onset of flooding. As such the approaches applied are not expected to significantly affect the results.

5 Conclusions

The economic appraisal of costs and benefits of FCERM for North Promenade Barmouth has been completed, in line with industry guidance (FCERM Business Case Guidance, Appraisal Guidance, Accounting for Adaptive Capacity, Multi-Coloured Manual, and Treasury Green Book). Present value the benefit cost ratio for the preferred option and short-listed schemes.

The case for investment is compelling. In the absence of investment, FCERM damages over the 100-year appraisal period have been conservatively estimated between £66.6m and £99.9m. Some 757 properties have greater than a 1 in 100 chance of coastal and/or surface water flooding in any year.

Adopting a managed adaptive approach to FCERM involves investing now in actions that manage today's risks, monitoring the change in risk over time and managing these changes. An adaptive pathway approach considers different possible sequences of investment decisions associated with the Do-Something Options (i.e. different combination/temporal interventions).

The economically preferred adaptive approach is Option G, which offers a precautionary Benefit Cost Ratio of 1.7. The BCR has the potential to increase when considering additional benefits (e.g. protection of Network Rail assets).

Table 29. Adaptive pathway scenario

	Epoch 1 0-20 years	Epoch 2 20-50 years	Epoch 3 50-100 years
Option G	Option 2: Betterment of defences <i>Precautionary SOP reducing to 1 in 50 by 2069</i>		Option 4b: Managed Realignment (North Only) <i>Adaptive SOP 1 in 200</i>

Appendix A

Flood Inundation Economic Appraisal

A1 Methodology

The economic case for the project has been appraised in accordance with Welsh Government's requirement for Flood and Coastal Erosion Risk Management (FCERM) projects.

Economic losses caused by the predicted flood risk have been estimated using the Flood Hazard Research Centre's Multi Coloured Manual (MCM) methodology²⁴.

The avoidance of damage from flooding to residential and non-residential property fabric and contents is the principal benefit for the purposes of the economic assessment.

The following other direct sources of economic damage as a result of predicted flood risk have also been considered:

- Emergency Services
- Utilities damages
- Costs of evacuation
- Intangible Benefits
- Vehicle damages
- Risks to Life

A1.1 Flood Cells

The site has been split into three Flood Cells as shown in Figure 9. Residual risk of surface water flooding is also included across the entire study area as described in the Inundation Modelling Report. **This appendix focuses on the inundation flood damages associated with FC1+FC3.**

- Properties within FC1 are impacted by coastal flooding due to overtopping along Northern Promenade but are unaffected by erosion.
- Properties within FC2 are impacted by coastal flooding due to overtopping of defences around Viaduct Gardens. Risk to these properties is not reduced as a result of the proposed works at Northern Promenade and they are therefore omitted from this report.
- Properties within FC3 are at risk of erosion during a Baseline (i.e. Walkaway / Business As Usual) scenario. During the baseline scenarios, they are at risk of residual coastal flooding due to overtopping along Northern Promenade. Quantification of the benefits resulting from avoided erosion damages are presented in Section 2.3 of the above report.

²⁴ Flood and Coastal Erosion Risk Management: A Manual for Economic Appraisal, 2013 Flood Hazard Research Centre

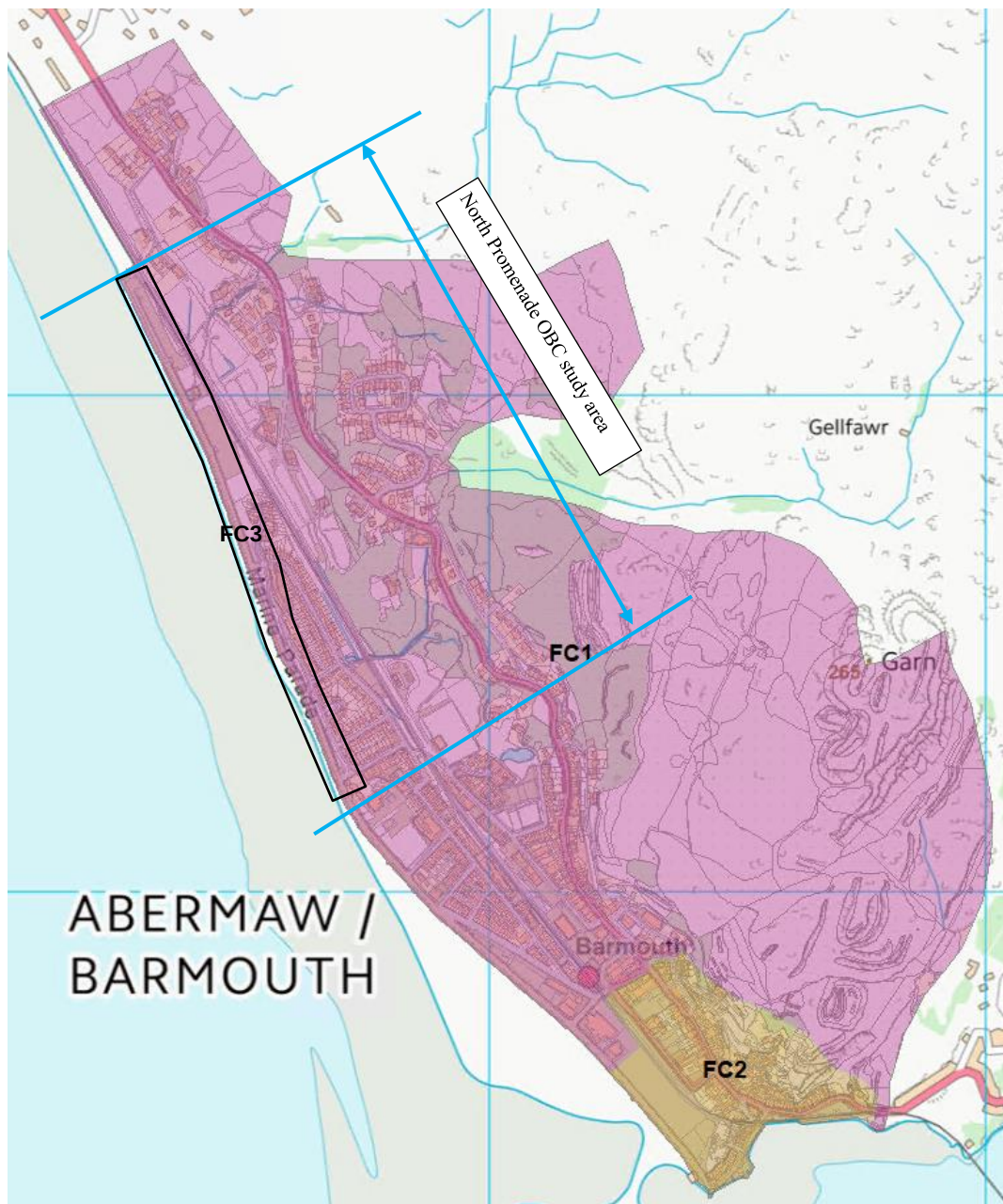


Figure 9 Flood Cell distribution: FC1, FC2 and FC3 represent Flood Cells 1, 2 and 3 respectively.

A1.2 Property Damages

MCM depth damage curves were used to derive property damages, based on hydraulic model outputs of flood hazard, velocity and depths with an allowance for property threshold height, for the modelled scenarios of the project phases.

The study area includes both residential and non-residential properties (NRP). The MCM values flood damage to NRP building fabric and contents on the basis of various NRP categories and ground floor areas estimated from OS Mastermap (OSMM) data. The area attributed to each property is based on the floor area of the building polygon. Where multiple NRD points fall within the same building polygon the floor area of the building is divided evenly between them. This approach is best practice but nonetheless has limitations – for example an industrial factory may have a small ancillary office function.

Property damages are calculated for a range of different event probabilities and integrated to find the annual average damage (AAD) over the appraisal period.

Climate change means that the relationship between probability and event magnitude changes over time, and this means that the AAD value also changes against time. AAD has been calculated for three different climate change epochs, present day (2019), 2060s and the 2110s, which is proportionate for this study.

Net Present Value (NPV) damages accrued over the proposals' lifetime have been calculated by interpolating between the values of AAD in each epoch and discounting into present day values based on the Treasury Green Book discount rates. Finally, the NPV damages are capped so that they do not exceed the market value of that property in total.

Benefits, represented by damages avoided, are then calculated by comparison of the damages observed during the baseline option with the damages observed during each of the Do Something options.

A1.3 Risk to Life

Risk to life assesses the likely impact of floods of different severities on the properties affected. The analysis defines a value for the number of fatalities likely, taking into account the severity of flooding defined by the depth of flooding and hazard, as well as the demographics and characteristics of the area at risk. This value is multiplied by the valuation of a life listed in Table 30.

A1.4 Intangible health benefits

Intangible health benefits reflect the longer-term personal impact of flooding on the health and wellbeing of those affected. Flooding of residential properties causes stress, disruption, illness and other losses that are not assigned a value in the main economic assessment. The MCM 2013 methodology typically estimates these intangible benefits at a property level as an additional benefit of flood risk reduction to be added to the 'damages avoided' by each option. The magnitude of the benefit is dependent on the number of residential properties benefitting (i.e. with a reduced threshold of flooding), and the size of the change in threshold of flooding at each property. At Barmouth, a proportionate approach has been adopted which excludes calculation of intangible benefits. This represents a conservative approach.

A1.5 Vehicle damages

Economic losses associated with damage to vehicles are estimated for all residential properties. Guidance suggests that flood depths of greater than 35cm are almost certain to lead to a vehicle being written off (FCERM-AG, 2013)²⁵. Damage equal to the write-off value of all vehicles at the property are therefore assumed for all properties where flood depth exceeds this threshold.

A1.6 Assumptions

Present value damages have been estimated for a 100-year appraisal period, based on the assumed design life of the proposed works. The base date of the assessment is Q1 2019.

²⁵ FCERM: A Manual for Economic Appraisal, 2013 Flood Hazard Research Centre and Environment Agency

The National Receptor Dataset (NRD) was supplemented with the OS Mastermap Topographic Area data to maximise the available information on each property, and then ‘cleaned’ to exclude those property points with no land-use categories or floor areas. Properties where the NRD and OSMM MCM codes didn’t match were checked against available mapping and aerial photography in order to assign the correct MCM code.

Many properties were initially coded as “Unknown” with MCM code 999. Some of these were identified as garages, sheds or erroneous residential polygons and removed from the dataset so that damages would not be accrued from them. Several were also identified as residential properties; these were updated to the relevant MCM code based on information from OSMM and aerial photography.

Hydraulic modelling undertaken for this study adopted a method of increasing Manning’s roughness in order to represent flood flow pathways. This method set a Manning’s value of 1 to each polygon in a ‘buildings’ layer derived from OSMM data. Model outputs of flood depth were used to calculate damages which included this representation of buildings therefore additional property threshold allowances were not required for the damage assessment.

Many residential buildings were listed within the NRD with an MCM code of “1”. Since this was insufficient information for quantifying damages, the codes were updated to match the category of the housing; detached, semi-detached, terraced, flat or bungalow. Limited information about the age of the buildings was available, therefore historical maps, Google Street View and information from the Consumer Data Research Centre (CDRC)²⁶ were used to estimate the general age of buildings. Data from the CDRC indicated that the average age of buildings within the study area was pre 1900, however on Google Street View numerous post First and Second World War properties were identified in addition to several newly built residential properties. A range of MCM codes were therefore assigned to groups of housing based on multiple sources of information.

Only properties with ground level occupancy are included in the dataset. These are classified as dG (definitely ground) or pG (possible ground) in the NRD dataset; the classifications dU and pU denote definitely upper and possible upper level respectively. Upper floor properties have been removed from the assessment. This is a conservative approach since it does not capture costs associated with relocating residents from upper floor properties. Cellars and basement properties, defined as dB or pB, were not included in the damage assessment.

Non-commercial NRPs, including PO Boxes and telephone boxes, were excluded from the assessment. The assessment also does not value the impact of flooding to agricultural or amenity land. The assessment assumptions are summarised in the below table.

²⁶ <https://maps.cdrc.ac.uk/#/metrics/dwellingage/default/BTTTTFTT/8/-3.8615/51.5733/>

Table 30 Key Assumptions

Parameter	Assumed Value		
Properties			
Property Threshold	Residential	300 mm	Nominal assumed
	NRP	300 mm	Nominal assumed
Residential Property Value	Detached	£350,317	Residential property values obtained October 2018 from: http://landregistry.data.gov.uk/app/ukhpi/explore
	Semi-Detached	£217,986	
	Terraced	£188,131	
	Bungalow	£202,663	Assumed same as Maisonette
	Flat	£202,663	Assumed same as Maisonette
NRP Rateable Value (£/m²)	Factory	20.63	Commercial property values and rental yield approximated from properties on https://www.tax.service.gov.uk/view-my-valuation/search
	Retail	73.16	
	Office	69.54	
	Warehouse	7.34	
	Other	69.83	
NRP Rental Yield	Factory	6.7	Retail rateable value and rental yield set to a default value as insufficient data was available on which to base an estimate.
	Retail	6.7	
	Office	6.7	
	Warehouse	8.09	
	Other	8.09	
CPI (Consumer Price Index)	107.1	CPI in December 2018 used	
Flood Characteristics			
Flood Type	Wave		
Flood Duration	More than 12 hours		
Flood Warning	None	None for Baseline and over 8 hours for Do Something.	
Risk to Life Parameters			
Average number of people per property	2.44		
Percentage elderly (> 75 yr)	0.48		
Percentage disabled or infirm	1.95		
Reference value of a life	£1,877,675	Treasury Green Book	
Flood warning	Wales - 2.23		
Speed of Onset	3 - Rapid		
Nature of area	2 – typical residential area, industrial and commercial areas		
Nature of catchment	Pasture or arable		
ZeroPoint Events (These define the threshold frequency of flooding)			
No Climate Change	1 in 1yr	Lowest modelled event.	
Climate Change to 2069	1 in 1yr	Lowest modelled event.	
Climate Change to 2119	1 in 1yr	Lowest modelled event.	
Vehicle Damage			

Parameter	Assumed Value	
Vehicles Per Household	1.16	National Average Assumed
Threshold for vehicle write-off	350mm	As recommended by the Multi-Coloured Manual.
Average Value Per Vehicle	£3,100	Average Assumed
Additional Assumptions		
Susceptibility	Indicative	Average Assumed
Social Class Distribution	Class AB	13%
	Class C1	24%
	Class C2	52%
	Class DE	11%
Emergency Service allowance	10.7% of direct property damages ²⁷	
Utilities damage allowance	10% of direct property damages ²⁸	
Green Book Discount Rates	0-30 years	3.5%
	31-75 years	3.0%
	76-100 years	2.5%

A1.7 Treatment of climate change

Current Welsh Government guidance²⁹ on the impact of climate change is to build on the assessment of current risk, and to incorporate resilience and flexibility based on an assessment of potential future sensitivities. The ‘Central Estimate’ for Wales has been adopted to account for the predicted change in rainfall as a result of climate change as quoted in Table 31.

Table 31 Change to extreme rainfall intensity compared to a 1961-90 baseline. As with river flood flows, it is recommended that the 2080s changes are used when considering any time beyond 2115. The peak rainfall intensity ranges should be used for small catchments and urban/local drainage sites. For river catchments over 5km², the peak flow ranges should be used.

Applies across all of Wales	Total potential change anticipated for 2020s (2015-2039)	Total potential change anticipated for 2050s (2040-2069)	Total potential change anticipated for 2080s (2070-2115)
Upper estimate	10%	20%	40%
Central estimate	5%	10%	20%

Allowances for climate change were also applied to the 2019 baseline tidal data using uplift values in the model boundary condition database to account for the anticipated rise in sea level due to the effects of climate change. The changes to relative mean sea level were adopted as per Welsh Government guidance²⁹ and interpolated to provide increases specific to the years of the epochs modelled in this study as shown in Table 32.

Table 32 Sea level rise (SLR) increases to apply to tidal water levels. Based on 2008 base year.

Modelled year	Allowance applied
2019	0.039
2069	0.422

²⁷ FCERM: A Manual for Economic Appraisal, 2013 Flood Hazard Research Centre and Environment Agency

²⁸ “Learning Lessons from the 2007 Floods”, M. Pitt, 2008

²⁹ Adapting to Climate Change: Guidance for Flood and Coastal Risk Management Authorities in Wales. Welsh Government, December 2017.

2119	1.099
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A1.8 Options Assessed: Standards of Protection

Within the economic assessment, each option assessed represents a different standard of protection. There are many engineering solutions to providing each standard of protection. The economic assessment focusses on demonstrating the relative benefit (damages avoided by providing a Standard of Protection compared to the Do Minimum) by providing a range of standards of protection to inform a cost-benefit analysis. Residual annual average damages of these options are calculated by assuming zero damages are associated with any flood events of a lesser magnitude. This is in line with FCERM-AG's requirement for proportionality.

In some instances (Options 4 – 6) this means that defences will be constructed to a given level at the start of the scheme's life, already incorporating allowances for dealing with climate change. For instance, "1 in 50 years with 100 years' climate change" describes a defence constructed in 2019 to a height that will protect against the 50yr return period event that might be expected in 2119. The alternative is a "Managed Adaptive" approach, in which flood defences are raised to respond to climate change as required.

The scenarios in Table 33 were assessed for the 1 in 1, 1 in 10, 1 in 50, 1 in 100, 1 in 200 and 1 in 1000 annual chance events, and the corresponding damages combined to produce the Annual Average Damage (AAD) figure for present day and future epochs.

Table 33 Options assessed.

Option		Standard of Protection	
		Return Period	Climate Change Allowance
Baseline	Combination of Do Minimum and Do Nothing (see Inundation Modelling report for details)	Baseline (No SoP)	
Do Something Residual Risk	1	1 in 200yr	None
	2	1 in 100yr	None
	3	1 in 50yr	None
	4	1 in 200yr	50 years
	5	1 in 100yr	50 years
	6	1 in 50yr	50 years

The 1 in 100yr standard of protection assumes that no damage occurs for events of a smaller return period. In order to maintain a proportionate approach to the assessment, residual damages for each of the above the standard of protection for each option were represented using the Baseline damages (see Appendix B Inundation modelling report).

The calculation is shown for the No Climate Change Annual Average Damage curve in the figure below.

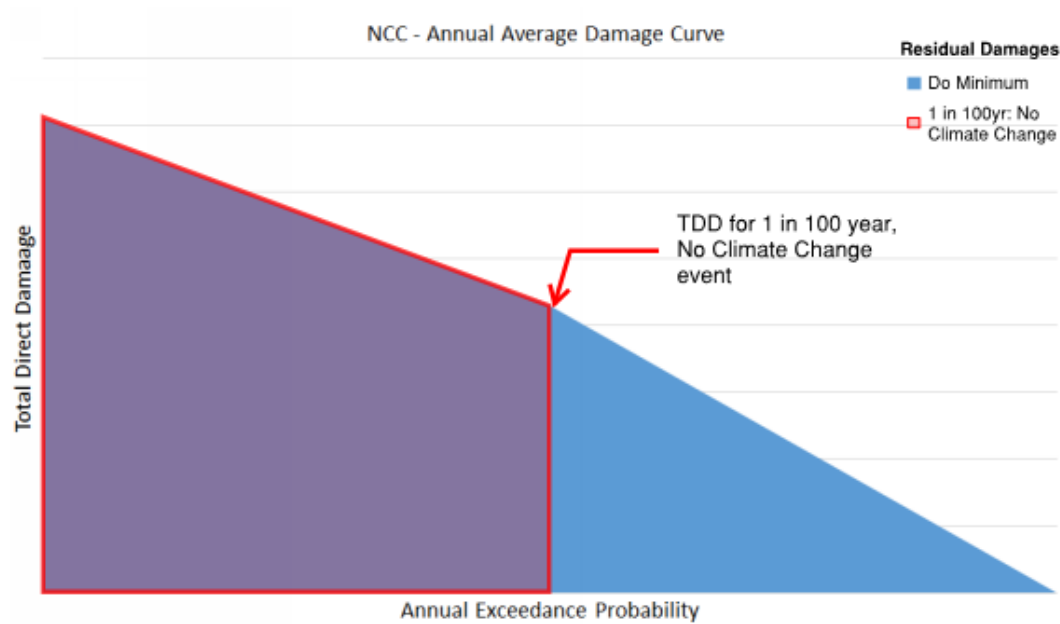


Figure 10: Annual Average Damages are represented by the area under the curve shown above. Residual damages for providing a Standard of Protection of 1 in 100 years with No Climate Change are highlighted.

The range of Annual Average Damages were then applied over the 100-year appraisal period from 2019 to 2119 and discounted to give the Net Present Value (NPV) of damages for each standard of protection. The potential benefits of the Baseline standards of protection are presented in Table 34 as a comparison of the number of properties incurring flood damages for each option, epoch and return period against the baseline scenario.

Table 34 Predicted numbers of properties incurring damage

	Epoch			NCC (Present day, no climate change)						CC2069						CC2119					
Option	Standard of Protection		Return Period Flood cell	1	10	50	100	200	1000	1	10	50	100	200	1000	1	10	50	100	200	1000
	Return Period	Climate Change Allowance																			
DoM	None		FC1	14	300	322	757	760	761	261	261	538	541	541	541	261	261	538	541	541	541
Op1	1 in 200yr	None	FC1	0	0	0	311	760	761	0	0	538	541	541	541	261	261	538	541	541	541
Op2	1 in 100yr	None	FC1	0	0	0	757	760	761	0	0	538	541	541	541	261	261	538	541	541	541
Op3	1 in 50yr	None	FC1	0	0	322	757	760	761	0	261	538	541	541	541	261	261	538	541	541	541
Op4	1 in 200yr	50 years	FC1	0	0	0	311	313	317	0	0	310	313	541	541	261	261	538	541	541	541
Op5	1 in 100yr	50 years	FC1	0	0	0	311	313	761	0	0	0	541	541	541	261	261	538	541	541	541
Op6	1 in 50yr	50 years	FC1	0	0	0	311	313	761	0	0	538	541	541	541	261	261	538	541	541	541

Note that the number of properties incurring damage in the present day for the 1 in 200yr and 1 in 1000yr event greatly exceeds that of CC2069 and CC2119. This is due to the scenarios modelled, and the limitations encountered in assessing wave overtopping as discussed in both ABPmer's wave modelling report and Arup's Inundation modelling report.

A1.9 Summary of checking process

An initial assessment of flood damages was completed and subjected to a prioritised checking process. Those properties with the highest damages were analysed to understand their impact on the total damages in the study area.

The key contributing properties to the Baseline present value damages were identified from this process included a property classed as an hotel on the A496, Homes for the Elderly assisted living residences on Marine Road, the Min-Y-Mor Hotel and Ysgol Y Traeth. These properties were found to be appropriately capped and an indicator that the damages estimated are plausible.

A2 Flood damages results

The MCM approach to assessing property flood damage, incorporating the valuation of property fabric and content, provides reasonable confidence in the estimated Total Annual Average Damage (AAD) and Capped Net Present Value (NPV) Damage for property damage. It is therefore assumed that the total AAD (incorporating relocation costs) and total NPV relating to property damages represents the *minimum* damage associated with each flood cell, option and epoch. Emergency services and utilities AADs are derived by multiplying the Property Damages by the factors listed in Table 30 and Total AAD is then summed and values capped to provide NPV. Given the level of uncertainty associated with these factors in Table 18, there is less confidence associated with the damages relating Emergency Services, Utilities, Vehicle Damage and Risk to Life. These have therefore been combined with property damage to represent the estimated *maximum* total AAD and NPV associated with each flood cell, option and epoch.

A2.1 Annual Average Damages

Total AAD for the Baseline scenario for each epoch are shown in the table below.

Table 35 Annual Average Damages for the Baseline scenario for each epoch and flood cell

Epoch	Flood Cell	Minimum Total AAD (Property Damage) (£k)	Maximum Total AAD (Incorporating Property Damage, Emergency Services, Utilities, Vehicle Damage, Risk to Life) (£k)
Present Day (2019)	FC1 + 3	28,262	36,588
	FC2	462	578
2069	FC1 + 3	27,079	35,706
	FC2	1,091	1,360
2119	FC1 + 3	27,079	35,534
	FC2	1,107	1,379

Table 35 indicates that the Total AAD in the present day exceeds that of CC2069 and CC2119 for flood cell FC1. This is due to the limitations encountered in assessing wave overtopping as discussed in both ABPmer's wave modelling report and Arup's Inundation modelling report which resulted in different maximum coastally dominated scenarios modelled for each epoch: 1 in 1000yr for the present day, 1 in 100yr for 2069 and 1 in 1yr in 2119. The 'missing' return periods (1 in 200yr and 1 in 1000yr in 2069 and all return periods greater than 1 in 1yr for 2119) were assessed by substituting model results that represented the worst case modelled for each return period as shown in Table 36. Alternatively, the damages could have been extrapolated along the AAD damage curve; however this would have resulted in an unreasonably large damage value at the upper end. **It was therefore considered that the method used represented a more conservative approach.** The effect of substitution versus extrapolation on the damage calculations is shown in Figure 11 AAD damage curves for Present Day (2019) and future epoch 2069 demonstrating the different end points of adopting a substitution approach (flatline) versus an extrapolated value.

Table 36 Results used to assess damages for each Baseline epoch and return period.

Epoch	1 in 1 yr	1 in 10yr	1 in 50yr	1 in 100yr	1 in 200yr	1 in 1000yr
2019	2019 1yr	2019 10yr	2019 50yr	2019 100yr	2019 200yr	2019 1000yr
2069	2069 1yr	2069 10yr	2069 50yr	2069 100yr	2069 100yr	2069 100yr
2119	2119 1yr	2069 10yr	2069 50yr	2069 100yr	2069 100yr	2069 100yr

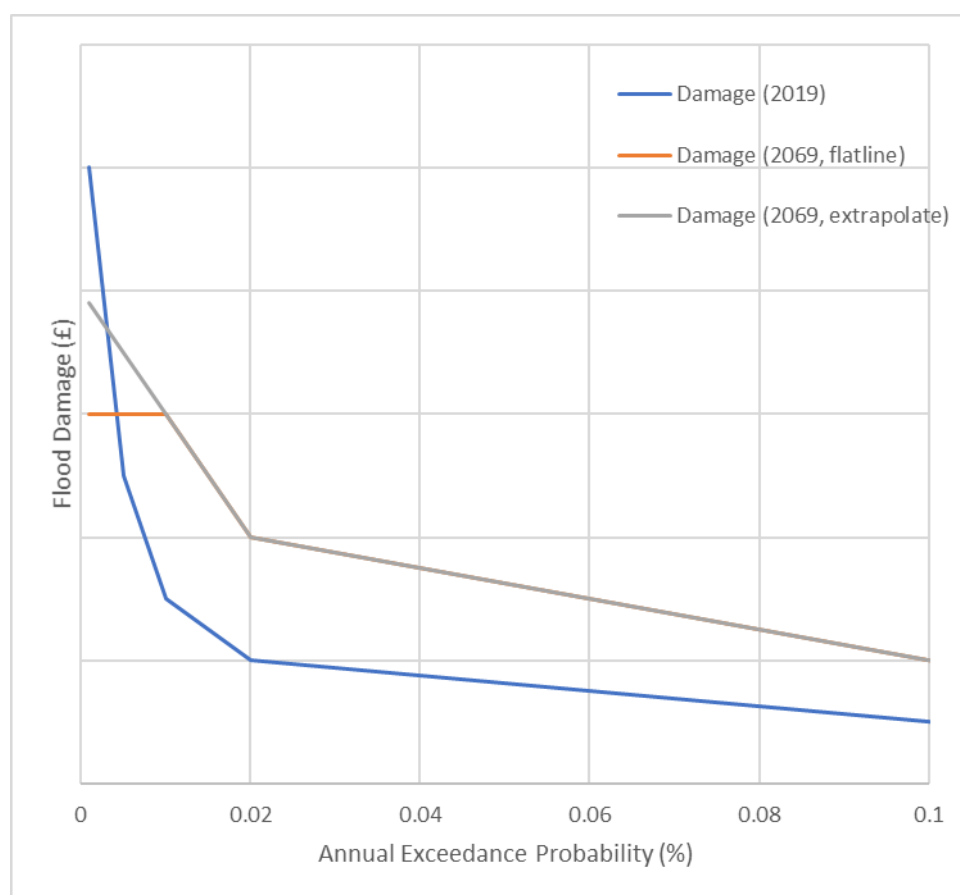


Figure 11 AAD damage curves for Present Day (2019) and future epoch 2069 demonstrating the different end points of adopting a substitution approach (flatline) versus an extrapolated value.

Annual Average Damages associated with each epoch and option are shown in the tables below.

Table 37. Annual Average Damages for 2019 (present day) associated with each option

Option	Minimum Total AAD (Property Damage) (£k)	Maximum Total AAD (Incorporating Property Damage, Emergency Services, Utilities, Vehicle Damage, Risk to Life) (£k)
Baseline	28,262	36,588
Option 1	2,029	2,508
Option 2	3,480	4,307
Option 3	5,694	7,205
Option 4	568	696
Option 5	1,180	1,455
Option 6	1,180	1,455

Table 38. Annual Average Damages for 2069 associated with each option

Option	Minimum Total AAD (Property Damage) (£k)	Maximum Total AAD (Incorporating Property Damage, Emergency Services, Utilities, Vehicle Damage, Risk to Life) (£k)
Baseline	27,079	35,706
Option 1	4,201	5,305
Option 2	4,201	5,305
Option 3	16,126	21,056
Option 4	2,513	3,097
Option 5	1,053	1,330
Option 6	4,201	5,305

Table 39. Annual Average Damages for 2119 associated with each option

Option	Minimum Total AAD (Property Damage) (£k)	Maximum Total AAD (Incorporating Property Damage, Emergency Services, Utilities, Vehicle Damage, Risk to Life) (£k)
Baseline	27,079	35,534
Option 1	27,079	35,534
Option 2	27,079	35,534
Option 3	27,079	35,534
Option 4	27,079	35,534
Option 5	27,079	35,534
Option 6	27,079	35,534

A2.2 Present Value Damages

Capped present value damages (PVD) associated with the options are shown in Table 40. The benefits presented here do not incorporate erosion benefits within FC3. Please refer to Section 2.4 for the final NPV values considered.

Table 40. Capped PVD for FC1+3 associated with providing each Standard of Protection

Option	NPV		Present Value Benefits	
	Minimum Total Capped NPV (Property Damage) (£k)	Maximum Total NPV (Incorporating Property Damage, Emergency Services, Utilities, Vehicle Damage, Risk to Life) (£k)	Minimum Present Value Benefits (£k)	Maximum Present Value Benefits (£k)
Baseline	66,483	99,767	N/A	N/A
Option 1	23,195	32,371	43,288	67,396
Option 2	26,953	37,662	39,530	62,104
Option 3	60,386	89,774	6,096	9,992
Option 4	12,766	16,604	53,716	83,162
Option 5	9,433	12,855	57,050	86,912
Option 6	20,962	29,229	45,521	70,538

A3 Conclusion

An economic appraisal has been conducted to assess the benefits of a range of shortlisted options to reduce the risk of flooding to properties in the town of Barmouth.

The key outcomes from the assessment are:

- Flood risk predictions show that today there is a significant risk of flooding to properties within the community. The onset of flooding to property is less than 1 in 1 annual chance. Despite current operation/maintenance activities **some 757 properties have greater than a 1 in 100 chance of coastal and/or surface water flooding in any year** across the entire modelled extent.
- The rapid speed of onset and depth of predicted flooding presents a considerable risk to life. **High risk to life damage values are substantial contributors** to the overall damages. This is due to the high proportion of residential properties in the study area in addition to predicted deep flood water.

Appendix B

Shortlisting Costs and Adaptive Pathway

ARUP		Job No.		Sheet No.		Rev.	
		264326					
		Member/Location					
		Drg. Ref.					
		Made by		RJ	Date	06/08/19	Chd.
Job Title		Barmouth North Promenade OBC					
Calculation		Shortlised Option Capital Costs					

Option & Activity	Cross-Section (m2)	Length (m)	Quantity		Rate (£)	Rate (£) (2019)	Cost	Comments
Do-something: Business As Usual (++) - Tertiary Wall 6.4m								
Raise wave wall crest rom (5.8mOD to 6.25mOD)								
Concrete walls	0.27	1170	315.9	m3	145.95	149	£47,220	Rates from Mumbles (2017); Uplifted to 2019 (CPI Index)
Formwork walls	0.45	1170	526.5	m2	49.45	51	£26,665	Rates from Mumbles (2017)
Rebar 150kg/m3 walls	47.385	1	47.385	t	946.47	969	£45,933	Rates from Mumbles (2017)
Structural connection -included in additional 20% to final cost			£119,818	%	20	20	£23,964	Rates from Mumbles (2017)
New total to include cost of anchors							£143,782	
2A: Rebuild tertiary flood wall (5.6mOD to 6.4mOD)								
Concrete walls	0.42	1100	462	m3	145.95	149	£69,059	Rates from Mumbles (2017)
Formwork walls	0.7	1100	770	m2	49.45	51	£38,997	Rates from Mumbles (2017)
Rebar 150kg/m3 walls	69.3	1	69.3	t	946.47	969	£67,176	Rates from Mumbles (2017)
Masonry cladding	2	1100	2200	m2	175	179	£394,309	Rates from Mumbles (2017)
Structural connection -included in additional 20% to final cost			£175,233	%	20	20	£35,047	Rates from Mumbles (2017)
New total to include cost of anchors							£604,588	
RC new wall at toe of defence								
Reinforced concrete wall	0.8	515	412	m3	145.95	149	£61,585	Rates from Mumbles (2017)
Formwork walls	2	515	1030	m2	49.45	51	£52,165	Rates from Mumbles (2017)
Rebar 150kg/m3 walls	61.8	1	61.8	t	946.47	969	£59,906	Rates from Mumbles (2017)
Excavation	8	515	4120	m3	17	18	£73,657	exc rate from Aberavon PAR (2016)
Total direct cost							£247,313	
Consistent level of promenade								
Type 1	1.25	1170	1462.5	m3	38.61	40	£57,832	Rates from Mumbles (2017)
Tarmac reinstatement 100mm	5	1170	5850	m2	49.01	50	£293,641	Rates from Mumbles (2017)
Total direct cost							£351,473	
Outfall extension								
Concrete pipe installation with protection, diam. 750	1	10	10	m	120	120	£1,200	CPM price list (2019)
Flap valve			1	No	1200	1200	£1,200	Supplier for 750mm diam
Total direct cost							£2,400	
Beach recharge								
Supply, transport and placement of material (shingle) by road for distance up to 20 miles.	140	560	78400	m3	£ 55	£ 62	£4,854,420	Rate from Tywyn (2011)
Rock Armour toe								
Rock armour - allow 2m3/m	18.3	400	12444	t	£ 53	£ 60	£742,720	Rate from Tywyn (2011); Includes Includes 100m extra for northern extents (SMP2 Policy Llanaber) Quantity obtained from measurements on section, assuming 1.7 t/m3 of revetment (2.6t/m3 rock and 35% voids)
Total direct cost							£6,946,695	
Preliminaries+overheads+profit			20%				£1,389,339	
Contingency (including inflation)			15%				£1,042,004	
Total							£9,378,038	
Do-something: Business As Usual (++) - Tertiary Wall 6.8m								
Construcion activities identified above, except:								
Rebuild tertiary flood wall (5.6mOD to 7mOD)								
Concrete walls	0.84	1100	924	m3	145.95	149	£138,118	Rates from Mumbles (2017)
Formwork walls	1.4	1100	1540	m2	49.45	51	£77,994	Rates from Mumbles (2017)
Rebar 150kg/m3 walls	138.6	1	138.6	t	946.47	969	£134,352	Rates from Mumbles (2017)
Masonry cladding	3.4	1100	3740	m2	175	179	£670,324	Rates from Mumbles (2017)
Structural connection -included in additional 20% to final cost			£350,465	%	20	20	£70,093	Rates from Mumbles (2017)
New total to include cost of anchors							£1,090,883	£604,587 to 0.7m height £1,229,824 to 1.6m height
Total direct cost							£7,432,990	
Preliminaries+overheads+profit			20%				£1,486,598	
Contingency (including inflation)			15%				£1,114,948	
Total							£10,034,536	

Do-something: Offshore Rock Breakwaters and Beach Recharge								
<u>RC new wall at toe of defence</u>								
Reinforced concrete wall	0.8	515	412	m3	145.95	149	£61,585	Rates from Mumbles (2017)
Formwork walls	2	515	1030	m2	49.45	51	£52,165	Rates from Mumbles (2017)
Rebar 150kg/m3 walls	61.8	1	61.8	t	946.47	969	£59,906	Rates from Mumbles (2017)
Excavation	8	515	4120	m3	17	17	£71,733	exc rate from Aberavon PAR (2016)
Total direct cost							£245,390	
<u>Rock armour</u>								
Gryone 1: Supply, transport and placement of 100-300kg size rock by barge for distance up to 20 miles. Floating plant or jack-up barge for rock placement.	129.2	130	16796	m3		£ 32.01	£537,608	Rate from Tywyn (2011)
Gryone 2: Supply, transport and placement of 100-300kg size rock by barge for distance up to 20 miles. Floating plant or jack-up barge for rock placement.	129.2	150	19380	m3		£ 32.01	£620,317	Rate from Tywyn (2011)
Breakwater 1: Supply, transport and placement of 3-6t size rock by barge for distance up to 20 miles. Floating plant or jack-up barge for rock placement.	138.32	120	16598.4	m3		£ 59.68	£990,675	Rate from Tywyn (2011)
Breakwater 2: Supply, transport and placement of 3-6t size rock by barge for distance up to 20 miles. Floating plant or jack-up barge for rock placement.	138.32	120	16598.4	m3		£ 59.68	£990,675	Rate from Tywyn (2011)
<u>Beach recharge</u>								
Gryone Bay 1: Supply, transport and placement of material (shingle) by road for distance up to 20 miles.	390.5	400	156200	m3		£ 62	£9,671,688	Rate from Tywyn (2011)
Gryone Bay 2: Supply, transport and placement of material (shingle) by road for distance up to 20 miles.	270.5	390	105495	m3		£ 62	£6,532,105	Rate from Tywyn (2011)
Gryone Bay 3: Supply, transport and placement of material (shingle) by road for distance up to 20 miles.	230.5	460	106030	m3		£ 62	£6,565,231	Rate from Tywyn (2011)
Total direct cost							£26,153,689	
Preliminaries+overheads+profit			20%				£5,230,738	
Contingency (including inflation)			15%				£3,923,053	
Total							£35,307,480	
Do-something: Managed Realignment - Full realignment to SMP2	Rates from Penrhyn							
<u>Construction of new defence line</u>								
Impermeable revetment and sea-wall		1150	1150	m	5400	6991	£8,039,597	EA - SC080039 Cost Estimation for Coastal Protection (2007)
Beach nourishment							£0	
Other: Standing time of plant/team during high tide			15	%			£1,205,939	
<u>Removal or decomissioning of existing defences</u>								
Decommissioning of existing defences; includes: primary sea-wall and reventment, and timber groynes		1150	1.15	km	162,714	220,633	£253,728	EA - SC080039 Cost Estimation for Managed Realignment; costs associated with removal of hard engineering is £70,000-120,000 per KM (SNIFFER, 2005)
Waste Disposal Costs	31.5	1150	36,225	t	91.35	91.35	£3,309,154	Source: https://gov.wales/landfill-disposals-tax-rates (2019) Assuming 1t/m3 of demolition debris
Total direct cost							£12,808,418	
Preliminaries+overheads+profit			20%				£2,561,684	
Contingency (including inflation)			15%				£1,921,263	
Total							£17,291,364	
Additional Costs								
Land purchase costs								EA - SC080039 Cost Estimation for Managed Realignment; notes Mixed (£/ha) for £12,525 for Wales Mixed Landuseage (2009)
Compensation costs							£11,994,498	Assume a maximum of 57 properties affected, and compensation provided at the cost of the value of the property (in 2019). From FC3.
Total							£11,994,498	
Do-something: Managed Realignment - Realignment to North only	Rates from Penrhyn							
<u>Construction of new defence line</u>								
Impermeable revetment and sea-wall		520	520	m	5400	6991	£3,635,296	EA - SC080039 Cost Estimation for Coastal Protection (2007)
Beach nourishment							£0	
Other: Standing time of plant/team during high tide			15	%			£545,294	
<u>Removal or decomissioning of existing defences</u>								

Decommissioning of existing defences; includes: primary sea-wall and reventment, and timber groynes		520	0.52	km	162,714	220,633	£114,729	EA - SC080039 Cost Estimation for Managed Realignment; costs associated with removal of hard engineering is £70,000-120,000 per KM (SNIFFER, 2005) Source: https://gov.wales/landfill-disposals-tax-rates (2019) Assuming 1t/m3 of demolition debris
Waste Disposal Costs	31.5	520	16,380	t	91.35	91.35	£1,496,313	
Rock armour & beach recharge								
Gryone 3: Supply, transport and placement of 100-300kg size rock by barge for distance up to 20 miles. Floating plant or jack-up barge for rock placement.	129.2	50	6460	m3		£ 32.01	£206,772	
As above, 1 in 8 sloping crest:	260	17.9	4654	m3		£ 32.01	£148,966	
Gryone 4: Supply, transport and placement of 100-300kg size rock by barge for distance up to 20 miles. Floating plant or jack-up barge for rock placement.	129.2	55	7106	m3		£ 32.01	£227,450	
As above, 1 in 8 sloping crest:	260	17.9	4654	m3		£ 32.01	£148,966	
Gryone Bay 3: Supply, transport and placement of material (shingle) by road for distance up to 20 miles.	230.5	540	124470	m3		£ 62	£7,707,010	
Total direct cost							£14,230,796	
Preliminaries+overheads+profit			20%				£2,846,159	
Contingency (including inflation)			15%				£2,134,619	
Total							£19,211,575	
Additional Costs								
Land purchase costs								
Compensation costs							£250,000	
Total							£250,000	
Notes								
No allowances for dealing with DCWW / Stats etc								
No allowances for landscaping / tree protection								
No allowances for land ownership issues								
No allowances for stepped or ramp access - details required								
Marine Licence - not allowed								
Planning application- not allowed								
Crown Estates application- not allowed								
HRA- not allowed								

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Option G					TOTALS:					Option H					TOTALS:				
Capital	Maint.	Other	Negative costs		Cash	Capital	Maint	Other	Negative costs	Capital	Maint.	Other	Negative costs		Cash	Capital	Maint	Other	Negative costs
£	29,746,111	£	140,000	£	5,293,673	£	-			£	29,746,111	£	140,000	£	5,293,673	£	-		
£	29,746	£	140	£	5,294	£	-			£	29,746	£	140	£	5,294	£	-		
£10,034,536	£500	£691,527			£10,726,563	£10,034,536	£500	£691,527		£10,034,536	£500	£691,527			£10,726,563	£10,034,536	£500	£691,527	
£500					£500	£0	£483	£0		£500					£500	£0	£483	£0	
£500					£500	£0	£467	£0		£500					£500	£0	£467	£0	
£500					£500	£0	£451	£0		£500					£500	£0	£451	£0	
£500					£500	£0	£436	£0		£500					£500	£0	£436	£0	
£5,500					£5,500	£0	£4,631	£0		£5,500					£5,500	£0	£4,631	£0	
£500					£500	£0	£407	£0		£500					£500	£0	£407	£0	
£500					£500	£0	£393	£0		£500					£500	£0	£393	£0	
£500					£500	£0	£380	£0		£500					£500	£0	£380	£0	
£500					£500	£0	£367	£0		£500					£500	£0	£367	£0	
£5,500					£5,500	£0	£3,899	£0		£5,500	£2,301,073				£2,306,573	£0	£3,899	£1,631,274	
£500					£500	£0	£342	£0		£500					£500	£0	£342	£0	
£500					£500	£0	£331	£0		£500					£500	£0	£331	£0	
£500					£500	£0	£320	£0		£500					£500	£0	£320	£0	
£500					£500	£0	£309	£0		£500					£500	£0	£309	£0	
£5,500					£5,500	£0	£3,283	£0		£5,500					£5,500	£0	£3,283	£0	
£500					£500	£0	£288	£0		£500					£500	£0	£288	£0	
£500					£500	£0	£279	£0		£500					£500	£0	£279	£0	
£500					£500	£0	£269	£0		£500					£500	£0	£269	£0	
£500					£500	£0	£260	£0		£500					£500	£0	£260	£0	
£5,500					£5,500	£0	£2,764	£0		£19,711,575	£500	£2,301,073			£22,013,148	£9,906,365	£251	£1,156,441	
£500					£500	£0	£243	£0		£500					£500	£0	£243	£0	
£500					£500	£0	£235	£0		£500					£500	£0	£235	£0	
£500					£500	£0	£227	£0		£500					£500	£0	£227	£0	
£500					£500	£0	£219	£0		£500					£500	£0	£219	£0	
£5,500					£5,500	£0	£2,327	£0		£5,500					£5,500	£0	£2,327	£0	
£500					£500	£0	£204	£0		£500					£500	£0	£204	£0	
£500					£500	£0	£198	£0		£500					£500	£0	£198	£0	
£500					£500	£0	£191	£0		£500					£500	£0	£191	£0	
£500					£500	£0	£184	£0		£500					£500	£0	£184	£0	
£5,500					£5,500	£0	£1,960	£0		£5,500					£5,500	£0	£1,960	£0	
£500					£500	£0	£200	£0		£500					£500	£0	£200	£0	
£500					£500	£0	£194	£0		£500					£500	£0	£194	£0	
£500					£500	£0	£189	£0		£500					£500	£0	£189	£0	
£500					£500	£0	£183	£0		£500					£500	£0	£183	£0	
£5,500					£5,500	£0	£1,955	£0		£5,500					£5,500	£0	£1,955	£0	
£500					£500	£0	£173	£0		£500					£500	£0	£173	£0	
£500					£500	£0	£167	£0		£500					£500	£0	£167	£0	
£500					£500	£0	£163	£0		£500					£500	£0	£163	£0	
£500					£500	£0	£158	£0		£500					£500	£0	£158	£0	
£5,500	£2,301,073				£2,306,573	£0	£1,686	£705,410		£5,500					£5,500	£0	£1,686	£0	
£500					£500	£0	£149	£0		£500					£500	£0	£149	£0	
£500					£500	£0	£144	£0		£500					£500	£0	£144	£0	
£500					£500	£0	£140	£0		£500					£500	£0	£140	£0	
£500					£500	£0	£136	£0		£500					£500	£0	£136	£0	
£5,500					£5,500	£0	£1,454	£0		£5,500					£5,500	£0	£1,454	£0	
£500					£500	£0	£128	£0		£500					£500	£0	£128	£0	
£500					£500	£0	£125	£0		£500					£500	£0	£125	£0	
£500					£500	£0	£121	£0		£500					£500	£0	£121	£0	
£500					£500	£0	£117	£0		£500					£500	£0	£117	£0	
£19,711,575	£500	£2,301,073			£22,013,148	£4,496,350	£114	£524,891		£0	£5,500	£0			£5,500	£0	£1,255	£0	
£500					£500	£0	£111	£0		£500					£500	£0	£111	£0	
£500					£500	£0	£108	£0		£500					£500	£0	£108	£0	
£500					£500	£0	£104	£0		£500					£500	£0	£104	£0	
£500					£500	£0	£101	£0		£500					£500	£0	£101	£0	
£5,500					£5,500	£0	£1,082	£0		£5,500					£5,500	£0	£1,082	£0	
£500					£500	£0	£96	£0		£500					£500	£0	£96	£0	
£500					£500	£0	£93	£0		£500					£500	£0	£93	£0	
£500					£500	£0	£90	£0		£500					£500	£0	£90	£0	
£500					£500	£0	£87	£0		£500					£500	£0	£87	£0	
£5,500					£5,500	£0	£934	£0		£5,500					£5,500	£0	£934	£0	
£500					£500	£0	£82	£0		£500					£500	£0	£82	£0	
£500					£500	£0	£80	£0		£500					£500	£0	£80	£0	
£500					£500	£0	£78	£0		£500					£500	£0	£78	£0	
£500					£500	£0	£75	£0		£500					£500	£0	£75	£0	
£5,500					£5,500	£0	£805	£0		£5,500					£5,500	£0	£805	£0	
£500					£500	£0	£71	£0		£500					£500	£0	£71	£0	
£500					£500	£0	£69	£0		£500					£500	£0	£69	£0	
£500					£500	£0	£67	£0		£500					£500	£0	£67	£0	
£500					£500	£0	£65	£0		£500					£500	£0	£65	£0	
£5,500					£5,500	£0	£695	£0		£5,500					£5,500	£0	£695	£0	
£500					£500	£0	£61	£0		£500					£500	£0	£		