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East Rhyl Coastal Defence PAR Addendum

Final for WG review

14th August 2017

JBA Project Manager

Gary Deakin
Bank Quay House
Sankey St
Warrington
WA1 1NN

Revision History

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ER-JBA-00-00-RP-C-0003-S3-P02-EastRhyl_OptionsUpdate	1st draft, internal JBA review	DCC and BB via BC
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Contract

This report describes work commissioned by Balfour Beatty, on behalf of Denbighshire County Council, by a letter dated 14th of October 2016. Balfour Beatty's representative for the contract was Graham Manners and Denbighshire CC's representative was Wayne Hope. Sam Wingfield, Graham Kenn, Alec Dane, Matt Eliot, Johnny Coyle and Mark Cope of JBA Consulting carried out this work.

Prepared by ....Samuel Wingfield BSc MRes MCIWEM C.WEM CEnv

Principal Analyst

Reviewed by ....Marc Pinnell BSc MSc MCIWEM C.WEM

....Managing Director

Philip Bennett-Lloyd BSc Dip Mgmt CMLI MCIEEM MCIWEM C.WEM CEnv

Technical Director

Purpose

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Acknowledgements

This report was produced in collaboration with Denbighshire CC and Balfour Beatty. Conwy CBC also provided data to help inform this report.

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Executive Summary

Introduction

The Garford Road area of east Rhyl is at risk from coastal flooding. Recent flood events and the increase of risk due to climate change means that a scheme is needed now.

A Project Appraisal Report (PAR) was completed in 2016, this identified several 'do something options' to manage flood risk now and in the future. The most cost beneficial option was an offshore breakwater, but a new rock revetment also scored well. The list of options considered was:

Option 1 – No active intervention (Do nothing)

Option 2 – Do minimum – Regular maintenance and beach recharge

Option 3 – Do something – Beach Recharge scheme with a terminal groyne

Option 4 – Do something – Offshore breakwater with a beach recharge

Option 5 – Do something – Rock revetment with beach recharge

Option 6 – Do something – Beach recharge scheme with a sand engine

Due to uncertainties in the sediment transport regime and the resulting beach recharge costs, it was decided to undertake a sediment modelling stage before the preferred option was taken forward to detailed design. Following the modelling, the concept designs were developed further and costs updated by Balfour Beatty.

This report uses the findings from the sediment modelling stage to promote a preferred option taking into account economics, technical feasibility and the environmental impacts.

The project is currently at stage 3 (Pre-Construction, including design). JBA Consulting have been nominated by DCC and appointed by Balfour Beatty to provide consultancy services during this preconstruction stage.

If there is consensus and approval of this PAR addendum, then the future stages will be commissioned: 4 (Construction), and 5 (Post Construction).

The preconstruction is forecast to complete in September 2018 and the completion of construction is currently predicted to be September 2019.

Modelling

Coastal assessment and modelling identified key attributes of the Rhyl coastline, including onshore ridge-runnel dynamics and net eastward sediment transport along the beach face. An existing onshore delivery of approximately 20,000 m^3/yr occurs through the migration of sand ridges, which is balanced by alongshore loss.

Modelling identified that the offshore breakwater needs to be located further offshore and westward than its original position to operate effectively. The original position of the offshore breakwater was likely to result in the shoreline attaching to the rock structure. This would effectively block alongshore flow, acting more like a groyne than a breakwater. A recharge volume of approximately 156,000 m^3 would be required to infill the sheltered area behind the breakwater.

The existing rate of onshore supply is only capable of supporting a low beach. A higher beach, such as placed by recharge, is likely to experience rapid erosion. Secondary structures such as groynes are required to retain a recharge beach for a time scale in the order of 8-10 years.

Although both the offshore breakwater and groynes are theoretically capable of being designed for coastal stability, it is prudent to allow for potential ongoing loss of recharge. Allowances of 5,000 m^3/yr and 7,000 m^3/yr are recommended for the offshore breakwater and groynes respectively.

Options involving recharge will increase sediment supply to the downdrift coast. This effect will be dispersed by the intervening distance and effect of coastal protection works at Prestatyn. When looking at the potential environmental impacts of the scheme, the downdrift sediment supply is minor compared with existing year-to-year variation in beach volume occurring in the environmentally sensitive areas of Gronant and Talacre.

The full detailed modelling report can be found in Appendix A.1.

Engineering

The sediment modelling has influenced how the two original preferred options (Options 4 and 5 from the PAR) have been reappraised in this report. The main elements of the breakwater option remain but the engineering implications have changed.

The results of the modelling show that the breakwater (the original Option 4 from the PAR) needs to be positioned further offshore which requires a consequent increase in its size and hence cost. The findings from the modelling also mean it has been necessary to subdivide the original rock revetment with beach recharge (Option 5 above). The sub-options include a rock revetment with a beach recharge that maintains the existing minimal beach, and an option for a rock revetment and rock groynes with a much larger amenity beach.

This division of the rock revetment option (PAR Option 5) allows the costs of the amenity beach to be identified and a decision made that takes into consideration the value given to an enhanced beach.

The revised options for appraisal in this PAR addendum are therefore:

- Option 1 – No active intervention (Do Nothing)
- Option 2 – Do Minimum – regular maintenance through beach recharge
- Option 3 - Offshore breakwater
- Option 4 – Rock revetment with minimal recharge for 'status quo' beach
- Option 5 - Rock revetment with rock groynes for enhanced amenity beach

Further engineering design drawings have been developed to represent these options and are included within Appendix A.2

Economics

The offshore breakwater will cost significantly more than the two revetment options due to the high capital costs. An enhanced amenity beach at east Rhyl will cost an additional ~£12.4m over the 100 year design life compared to the revetment option with a status quo beach. The amenity beach will not provide any additional flood risk benefits.

The preferred economic option is therefore Option 4 – Rock revetment with minimal recharge for 'status quo' beach.

Environment

Initial coastal processes sediment modelling work has indicated that none of the options has potential for likely significant effects on habitats that support European protected species including a breeding population of little tern (Dee Estuary SPA designation, and Liverpool Bay SPA proposed extension).

Revetment Option 4, which does not include measures to significantly retain or recharge beach material, but largely retains the existing sediment dynamics, would, over time, potentially increase the risk of exposure of buried archaeology on the foreshore, along with associated heritage impacts. Any further reduction in beach material could potentially affect recreational amenity, but this is unlikely to give rise to significant effects on tourism and local businesses reliant on tourism.

Conversely, should the options include proposals to provide significant beach recharge, the potential disruption or modification of intertidal sand/mud flat habitat over an area of up to 25 ha, together with any inhabiting marine benthic invertebrates, has potential to have a likely significant environmental effect on overwintering bird species associated with the Liverpool Bay SPA designation.

Other potential impacts identified could be addressed through standard best practice for construction.

Conclusions

The sediment transport modelling and new engineering analysis has shown that Option 4 (revetment minimal recharge) provides the most cost beneficial option. This option provides a 1 in 200 year SoP up to the end of the design life, taking into account climate change.

Option 3, breakwater, is no longer cost beneficial based on the new beach recharge and the costs of placing the breakwater further off shore than originally estimated.

The only other option that has a positive cost benefit ratio is Option 5, revetment with groynes. This option provides an enhanced amenity beach through beach recharge and control structures. This beach is not needed for flood protection or to protect the toe of the new revetment from scour. Compared to Option 4, the amenity beach will cost ~£12.4m over the 100 year design life.

The potential range of environmental impacts of the options are broadly similar, with an anticipated lower likelihood of negative impacts from Option 4.

Option 4, revetment with minimal recharge, is the recommended option on technical, economic and environmental grounds, but a value for money judgement needs to be made on the amenity beach that is provided by Option 5.

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1 Introduction

1.1 Project introduction

The East Rhyl Coastal Defence project is a proposed new coastal defence scheme to be constructed to protect the east of Rhyl primarily from flooding caused by wave overtopping of the existing seawall. The scheme will be designed to protect the Garford Road area of East Rhyl, from Splash Point to the Rhyl Golf Course as shown in Figure 1-1.

Rhyl is a seaside resort town on the coast of Denbighshire, North Wales. The town has been protected from coastal flooding in the past by a range of defence structures, the performance standards of these defences are now being exceeded. In east Rhyl, the existing defences have overtopped, most recently in 2013, causing significant damage and disruption to residential and commercial properties. The East Rhyl Coastal Defence project is a proposed flood defence scheme to prevent these coastal flood events by improving the standard of protection.

Figure 1-1: Location map of East Rhyl

1.2 Background

The East Rhyl Coastal Defence Project is a key Denbighshire County Council (DCC) flood defence scheme, of great significance to the residential and commercial stakeholders in Rhyl currently at risk of flooding.

A Project Appraisal Report (PAR) was produced by JBA Consulting in May 2016 on behalf of DCC to investigate potential options for the required form of coastal defence and justify further investment in the project.

Subsequent to the submission of the PAR, DCC engaged Balfour Beatty through the Scape National Civil Engineering and Infrastructure Framework to progress the project through a Feasibility Study into the cost, and programme for delivery of the Pre-construction and Construction stages of this project.

Balfour Beatty have subsequently been commissioned by DCC to deliver the Pre-construction stage of the project again through the Scape Civil National Civil Engineering and Infrastructure Framework.

The project is currently at stage 3 (Pre-Construction, including design). JBA Consulting have been nominated by DCC and appointed by Balfour Beatty to provide consultancy services during this preconstruction stage .

If there is consensus and approval of this PAR addendum, then the future stages will be commissioned: 4 (Construction), and 5 (Post Construction).

The preconstruction is forecast to complete in September 2018 and the completion of construction is currently predicted to be September 2019.

1.2.1 The PAR and preferred option

The PAR completed in 2016 identified six options:

- Option 1 – No active intervention (do nothing)
- Option 2 – Do minimum – regular maintenance through beach recharge
- Option 3 – Do something – Beach Recharge scheme with a terminal groyne
- Option 4 – Do something – Offshore breakwater with a beach recharge
- Option 5 – Do something – Rock revetment with beach recharge
- Option 6 – Do something – Beach recharge scheme with a sand engine

Option 4 – Do Something – Offshore Breakwater with a beach recharge, with a cost benefit ratio of 1.7 was selected as the preferred option in the PAR. This option provides a 1 in 200-year standard of Protection (including climate change impacts to the year 2116) for the Garford Road area of East Rhyl. This option is described in the PAR as an offshore breakwater, however, the assumption made at PAR stage is that it would not truly be an offshore breakwater but one that is located in the intertidal zone and will therefore dry out around low tide.

Although Option 4 was identified within the PAR as the preferred solution, the selection of this option is subject to approval by Welsh Government. In particular,, Welsh government queried the potential use of Option 5, re-facing the existing structures with rock armour which has a similar cost benefit ratio to Option 4. There were concerns over how accurate the costs could be estimated at this stage due to the lack of sediment modelling which would determine retention rates of sand on the beach and hence recharge requirements. This report has been produced as an addendum to the 2016 PAR to answer these questions and satisfy Welsh Government on the preferred option. The requirements and objectives of the study are described below.

1.3 Objectives

Welsh Government (WG) requested this study as an addendum to the PAR to enable confirmation of a preferred option from those remaining in the PAR to be taken forward into detailed design.

The main issue over selecting the preferred option was uncertainty over the sediment recharge volumes both during construction and ongoing maintenance over the design life and how these will differ.

Sediment modelling had not been undertaken at PAR stage so the recharge volumes were estimated. As the volume and frequency of recharge has such a significant impact on the whole life scheme costs, it was decided to undertake sediment transport modelling before the preferred option was chosen.

This sediment modelling would also allow more understanding on where to position the breakwater option. This option had been costed based on assumptions on the breakwater position that would allow for land based construction. If the breakwater had to be positioned further out, it could significantly increase the construction cost.

JBA produced a methodology to deliver this aim by undertaking a coastal impact assessment for the two preferred coastal defence options. This coastal assessment has included numerical modelling to assess the relative impact of each option on sediment transport erosion and accretion patterns.

The primary objective of this study was to get a better understanding of the scheme costs, but the potential impacts on the environment have also been reported on. The impacts on the environment are initial results to enable early engagement and do not constitute a full environmental assessment. In summary, the objectives of the report are to:

- To provide more accuracy on the up front and long term costs of the preferred options to update the economic appraisal and identify the preferred economic option.
- With the available data provide an overview of the potential environmental impacts of each option for early environmental engagement.
- With the available data identify any environmental show stoppers or clear benefits of one over the other.

1.4 Summary

The Garford Road area of east Rhyl is at risk from coastal flooding, recent flood events and the increase of risk due to climate change means that a scheme is needed now.

A Project Appraisal Report was completed in 2016, this identified several 'do something options' to manage flood risk now and in the future. The most cost beneficial option was an offshore breakwater, but a new rock revetment also scored well.

Due to uncertainties in the sediment transport regime and the resulting beach recharge costs, it was decided to undertake a sediment modelling stage before the preferred option was taken forward to detailed design.

This report uses the findings from the sediment modelling stage to promote a preferred option taking into account economics, technical feasibility and the environmental impacts.

2 Main findings of the modelling

2.1 Introduction

A coastal process assessment has been undertaken to refine the understanding of potential sediment management issues related to two coastal defence options for East Rhyl. Specific objectives were to:

- Refine estimates of sediment recharge volume and timing;
- Evaluate the effects of each option upon the physical distribution of sediment;
- Refine offshore breakwater position with regards to coastal stability; and
- Characterise impacts of the defence options on areas of environmental significance located to downdrift (further east).

A layered evaluation was undertaken, combining review of existing literature, analysis of coastal monitoring and application of numerical modelling. Key findings of the evaluation include:

- The offshore breakwater needs to be located further offshore and westward to operate effectively. Relocation approximately 70m offshore from the original position is required;
- The additional recharge placed in conjunction with the revetment option will be rapidly transported eastward, unless controlled by secondary structures such as groynes;
- Options involving recharge will increase sediment supply to the downdrift coast. This effect will be dispersed by the intervening distance and effect of coastal protection works at Prestatyn. The sediment supply is volumetrically minor compared with existing year-to-year variation in beach volume occurring in the environmentally sensitive areas of Gronant and Talacre.

2.2 Coastal process analysis

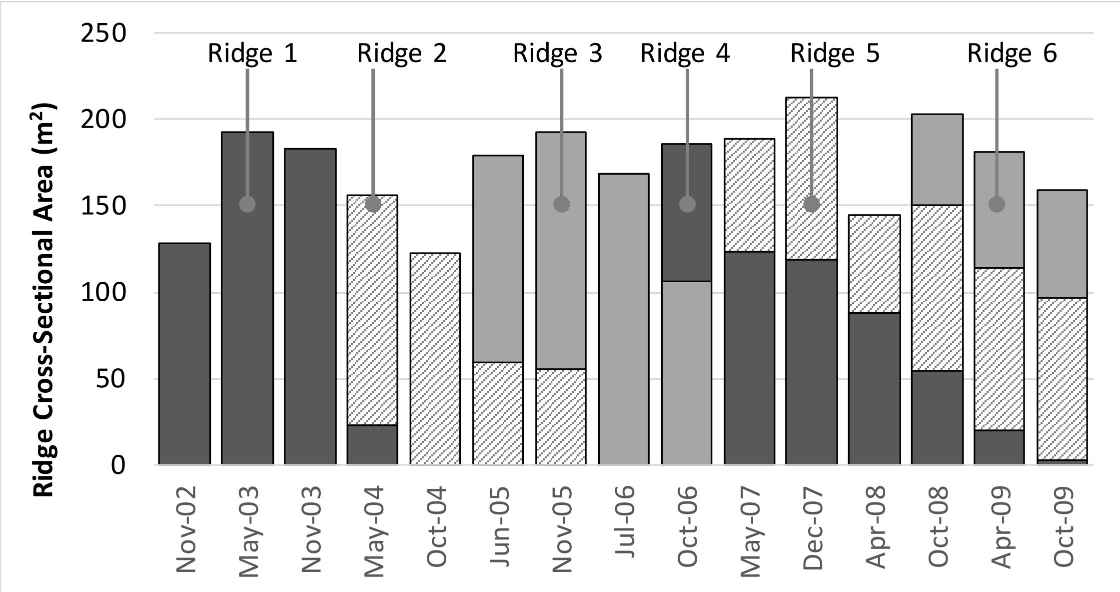
Evaluation of active coastal processes was undertaken to support model selection, quantitative validation and interpretation. The evaluation included site visits, review of available literature and quantitative analysis of Denbighshire County Council coastal monitoring data.

East Rhyl has a tidally dominated coastline, with a relatively wide sandy shore that has been subject to progressive beach lowering over the 20th Century (see Figure 2.1). Wave conditions are low to moderate, but are predominantly from the west-northwest. The high wave angle relative to the coast generates potentially high alongshore sediment transport, from west to east.

Figure 2-1: Rhyl Aerial Image, the difference between shore and nearshore ridge orientation

Coastal sediment transport is strongly modified by the formation of ridges and runnels in the intertidal zone, aligned in a direction that substantially reduces alongshore transport. Due to the low wave climate, which is comprised almost entirely of spilling breaker waves, these features are not characteristic of storm erosion-recovery cycles (i.e. storm bars), but behave more like coastal spits. The ridges are subject to frequent overwash, and therefore migrate landward and onshore, with a new spit being resolved each year, and taking 3-4 years to migrate onshore (Figure 2.2). There is some evidence of secondary geomorphic features developed through tidal flow within the runnels, particularly where they interact with coastal structures.

Figure 2-2: Cross-sectional Area of Beach Ridges, showing time sequence of onshore sediment delivery



Material that is deposited onshore due to ridge migration is subject to a greater alongshore stress due to the shoreline aspect, resulting in an approximate balance between the onshore supply and the alongshore transport. For the existing delivery rate, estimated at 20,000m^3/yr (mean supply over 2002-2009, derived from monitoring profile DCC07), this is equivalent to an alongshore transport rate of 60 m^3/m along a length of 300m, from the section of coast between Splash Point and the beach access ramp. This transport rate corresponds to a beach level of approximately +2.5m OD, and a higher beach, such as placed by a recharge scheme, will experience higher rates of alongshore sediment transport.

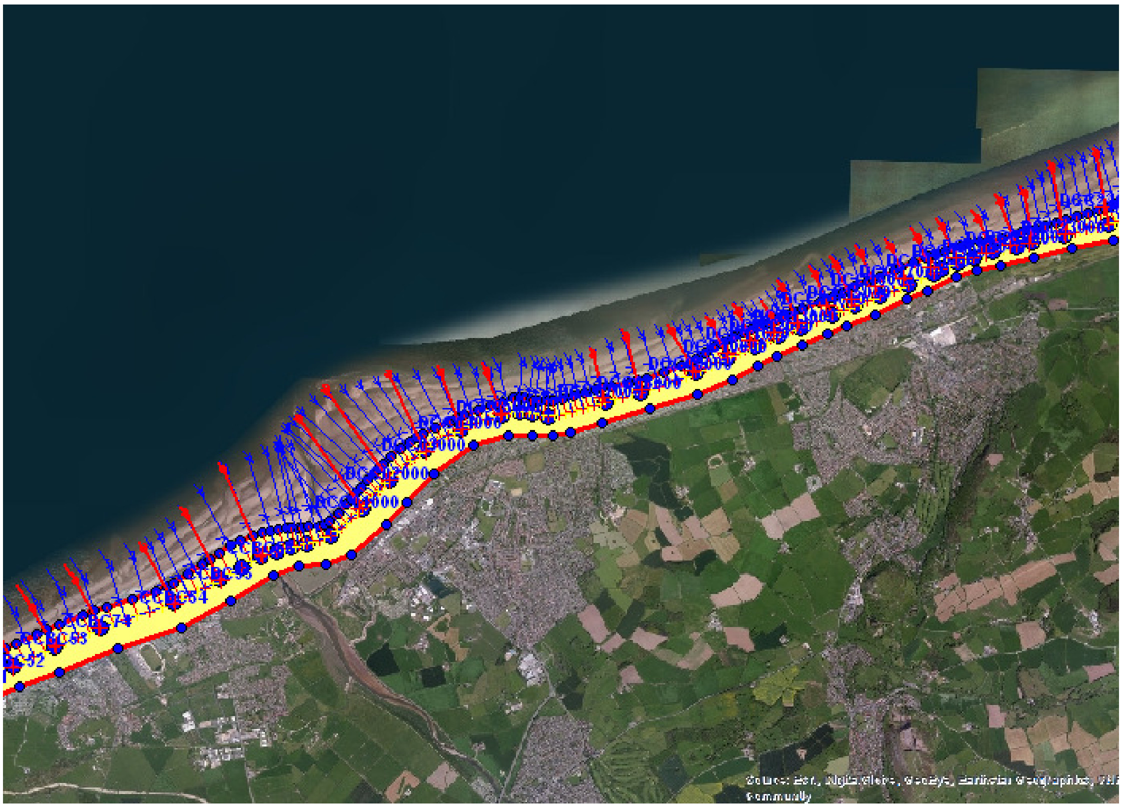
Long-term observations of beach lowering and narrowing of the intertidal zone along the Rhyl-Prestatyn shore suggest that there was a net tendency for erosion over the 20th Century. Much of this change is directly attributable to coastal works, including material excavation, a substantial training wall for the River Clwyd and coastal revetments. Modern observations from the Denbighshire County Council coastal monitoring programme since 2002 indicate a relative cessation of the historic erosion trend. However, due to the comparatively short duration of the monitoring program, it is not wholly certain that the coast has reached a degree of relative stability.

Analysis of coastal profiles from the east Rhyl site has indicated that the sandy material comprising the migratory ridges moves over a stable planar bed, including the occasionally exposed clay under-layer. The under-layer was not subject to measurable erosion during the monitoring period. Year-to-year variation in the volume of sediment in the ridges, and their relative movement, explains most of the previously reported volume changes on east Rhyl beach.

2.3 Regional transport modelling

Alongshore coastal sediment transport was assessed from Abergele to the Point of Ayr using the range of assessment techniques available within the Unibest coastal model (Figure 2.3). These techniques vary from bulk littoral transport formulae that are purely based on wave climate and shore aspect through to 1+1D modelling that has greater consideration of coastal profile structure, sediment size and spatial connectivity. In all cases, the modelling indicated a predominant west to east sediment transport, with a wide range of transport rates derived, from 2,500 m^3/yr to 115,000 m^3/yr. The highest estimated rate of transport was associated with the simplest bulk littoral transport rate, using the CERC formula. Previous application of this formula, based on a wave climate from further offshore, gave transport estimates of 330,000 m^3/yr to 465,000 m^3/yr (Halcrow 2008).

Figure 2-3:Illustration of Unibest profile density (blue lines), with comparison against measured profiles (red lines)



A key benefit of using the Unibest suite of assessment techniques is that it supports evaluation of the effect of physical attributes associated with each additional model refinement. In this case, most of the “additional physics” corresponds to morphological features that are present on the Rhyl foreshore. Consequently, there is a degree of confidence accepting the consequent reduction in projected alongshore sediment transport rates. The high rates of alongshore transport suggested by the simpler models are not supported by either the rates of erosion observed further updrift along the north Wales coast, or on the depositional features located further downdrift at Talacre and Gronant.

The best estimate range for mean littoral transport is 30,000 to 45,000 m^3/yr. This is based upon 1+1D modelling that accounts for variation of the profile grade, and truncation of the profile due to the existing revetment. However, the modelling is not capable of resolving the difference between the shore aspect and alignment of the intertidal ridges, and therefore can be expected to provide an overestimate of the alongshore transport rate. In effect, the modelling is consistent with the observational estimate of approximately 20,000 m_3/yr being delivered through onshore ridge migration, and subsequently removed by alongshore transport.

A higher resolution hydrodynamic and geomorphic model was applied to assess alongshore sediment transport for the defence options. The Delft3D modelling suite was used in both 2D and 3D modes.

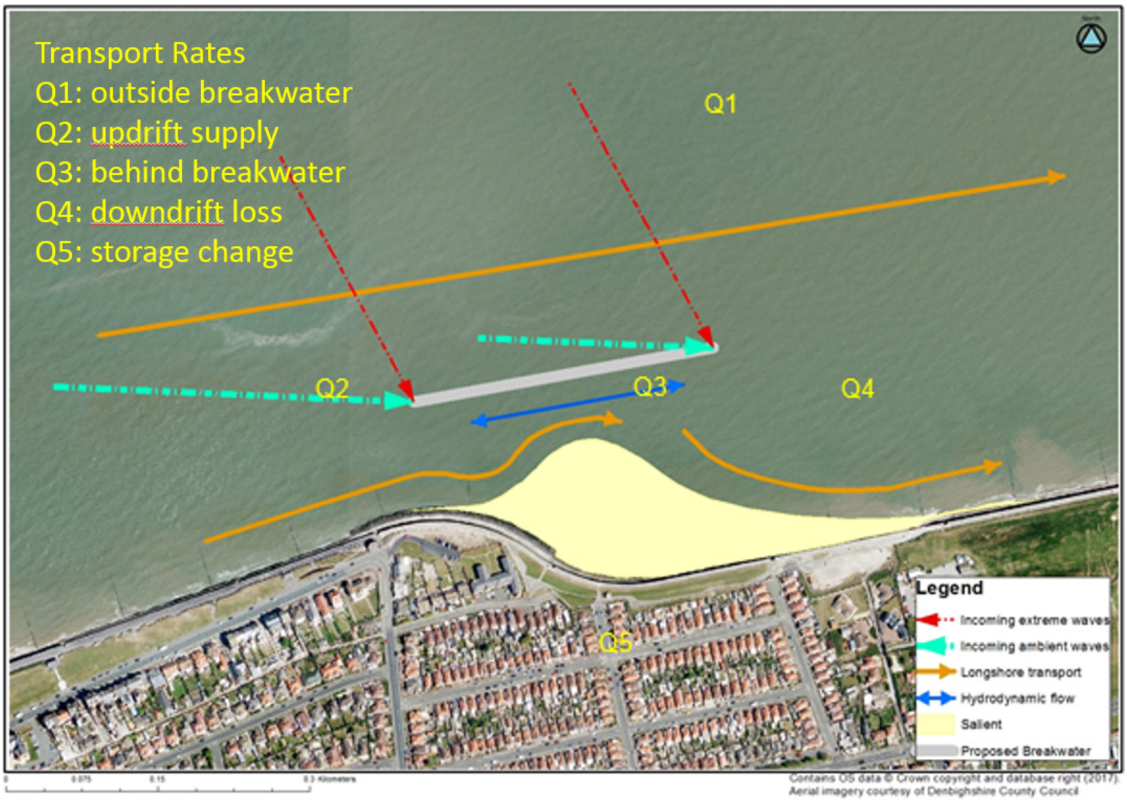
2.4 Modelling of East Rhyl defence options

Two defence options were evaluated for the east Rhyl foreshore between Splash Point and the beach access ramp (to the east):

A rock offshore breakwater 350m long, was initially modelled for a location approximately 115m offshore and slightly east from Splash Point. Two subsequent iterations were also modelled, first moved westward to ensure protection of Splash Point from the prevailing waves, then subsequently moved offshore to reduce the potential for the shoreline behind to connect to the breakwater.

The anticipated result of constructing an offshore breakwater is formation of a sediment body in the sheltered area behind the breakwater (Figure 2.4). This required assessment using the empirical model developed by Silvester & Hsu (1996). A volume of recharge is required to infill the expected feature, rather than cause near-field erosion if the feature were to draw material from the adjacent beach. The required volume of recharge was estimated as 156,000 m^3 for the breakwater option located furthest offshore.

Figure 2-4 Transport Components Associated with the Offshore Breakwater Option and Associated Salient



A large volume of beach recharge was modelled, to investigate the recharge volume and rates potentially associated with revetment redesign. The “maximum” amount of sediment that could practically be placed on the beach (~200,000 m^3) was modelled, with the understanding that the loss rate would progressively decline over time as the amount of “excess” fill on the beach reduced.

Sediment loss rates for the two options were determined using both the 1+1D modelling approaches used for regional transport modelling and higher resolution hydrodynamic and geomorphic modelling using the Delft3D modelling suite. As with the regional transport modelling, a layered assessment approach was used, including implementation of the high-resolution modelling in both 2D and 3D modes.

The 2D and 3D modelling replicated geomorphic attributes associated with the East Rhyl foreshore, including ridge and runnel migration. It also supported understanding of the sediment feature behind the offshore breakwater (Figure 2.4) suggesting the need for locating the structure further offshore. However, the modelling also demonstrated relative biases and instabilities of each model (Figure 2.5), with the 2D mode causing higher rates of onshore sediment movement than are supported by observations. The 3D mode suggested slightly lower stability of the beach recharge for both options, but created hydrodynamic features that were not considered realistic.

Figure 2-5 Sedimentation & erosion associated with offshore breakwater, showing salient

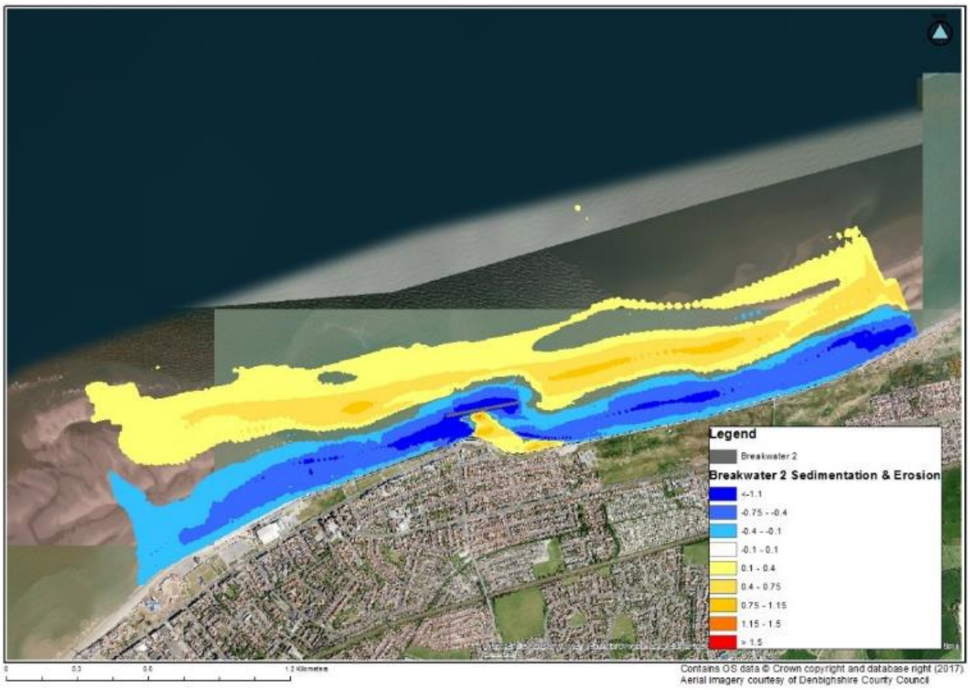
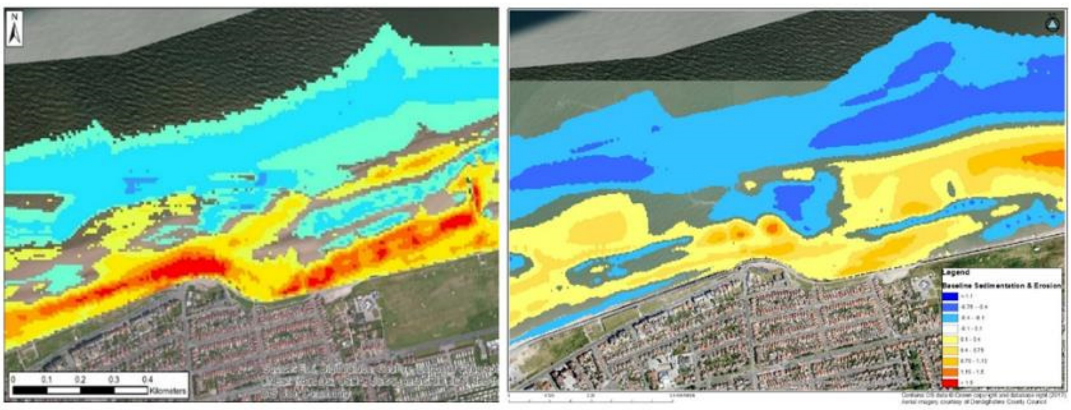


Figure 2-6: Comparison of 2D and 3D model outcomes for existing case simulation



2D modelling simulates high rates of onshore sediment transport

Improved representation of shoreline processes in 3D modelling

In all cases, the sediment size modelled was derived from the median particle size distribution of in situ sand. This represented fine-medium sand, with a median diameter of 0.26 mm. The effect of placing differently sized material will be to modify the required recharge rates, with coarser material typically requiring slightly less recharge (sediment with almost 50% larger mean diameter reduces the ongoing recharge rate by approximately 15%), but finer material may require a far higher rate of recharge (sediment with 40% smaller mean diameter increases the ongoing recharge rate by approximately 30%).

2.5 Key outcomes of the modelling

The required volumes and rates of sediment recharge volumes are large, due to the high potential for alongshore sediment transport. Material placed without constraint on East Rhyl beach will be rapidly transported eastward, and therefore any beach restoration associated with the revetment option should also include installation of groynes to slow the rate of sediment loss;

The original position of the offshore breakwater was determined likely to result in the shoreline attaching to the rock structure. This would effectively block alongshore flow, acting more like a groyne than a breakwater, with consequent downdrift erosion stresses likely to occur on the east side of the breakwater's wave shadow. The ability for the sediment feature to act as a sand source during periods of erosion stress would also be reduced, limiting its intended functionality.

The offshore breakwater needs to be located further offshore and westward to operate effectively. Relocation approximately 70m offshore from the original position is required.

Further to this analysis, the impracticality of maintaining a large volume recharge on the beach as part of the revetment option was recognised. The option of using groynes to provide partial retention of sand on the east Rhyl beach has been subsequently evaluated and included within cost-estimates. Comparison of the estimated recharge requirements (capital and ongoing) of the three options is summarised in Table 2.1 below. An upper limit allowance for ongoing recharge has been presented, to illustrate the uncertainty associated with modelled transport rates.

Table 2-1 Recharge estimates associated with defence options

Option	Capital Recharge Volume	Recommended (costed) Allowance for Ongoing Recharge	Upper allowance for Ongoing Recharge
3 - Offshore Breakwater	156,000 m^3	5,000 m^3/yr *	15,000 m^3/yr
4 - Revetment Rebuild with minimal recharge	20,000m^3	0m^3/yr	20,000 m^3/yr (i.e. total loss each year)
5 - Revetment Rebuild, Recharge and Groynes	56,000 m^3	7,000 m^3/yr *	20,000 m^3/yr
* Both the offshore breakwater and groynes have been designed for overall net stability. However, it is prudent to allow for potential ongoing loss.			

2.6 Summary

Coastal assessment and modelling identified key attributes of the Rhyl coastline, including onshore ridge-runnel dynamics and net eastward sediment transport along the beach face. An existing onshore delivery of approximately 20,000 m3/yr occurs through the migration of sand ridges, which is balanced by alongshore loss.

Modelling identified that the offshore breakwater needs to be located further offshore and westward than its original position to operate effectively. A recharge volume of approximately 156,000 m3 would be required to infill the sheltered area behind the breakwater.

The existing rate of onshore supply is capable of supporting only a low beach, with a higher beach, such as placed by recharge, likely to experience rapid erosion. Secondary structures such as groynes will be required to retain a beach for a time scale in the order of 8-10 years.

Although both the offshore breakwater and groynes are theoretically capable of being designed for coastal stability, it is prudent to allow for potential ongoing loss of recharge. Allowances of 5,000 m3/yr and 7,000 m3/yr are recommended for the offshore

breakwater and groynes respectively.

Options involving recharge will increase sediment supply to the downdrift coast. This effect will be dispersed by the intervening distance and effect of coastal protection works at Prestatyn. The sediment supply is minor compared with existing year-to-year variation in beach volume occurring in the environmentally sensitive areas of Gronant and Talacre.

3 Engineering

3.1 Introduction

This chapter describes the options that have been considered in the updated appraisal following the findings from the sediment modelling. This includes revising the original options from the PAR.

All of the 'do something' options from the PAR and this addendum provide a 1in 200-year SoP with 100 years climate change taken into account. This standard has been chosen for all options as the height of the existing sea wall exceeds this still water level (SWL). The options being considered maintain the existing sea wall and provide measures to reduce wave overtopping to the same standard.

The 2016 PAR appraised four ‘do something’ options in addition to the ‘do nothing’ and ‘do minimum’ baseline.

Option 1 – No active intervention (Do nothing)

Option 2 – Do minimum – Regular maintenance and beach recharge

Option 3 – Do something – Beach Recharge scheme with a terminal groyne

Option 4 – Do something – Offshore breakwater with a beach recharge

Option 5 – Do something – Rock revetment with beach recharge

Option 6 – Do something – Beach recharge scheme with a sand engine

Option 4 was identified as the preferred solution as it had the highest cost benefit ratio. However, Option 5 also scored well and had a similar cost benefit ratio. Due to the uncertainties over the costs of beach recharge (volume and frequency) and positioning of the breakwater, sediment transport modelling has been undertaken to understand the impact both options may have on the sediment transport regime. This new understanding allows for better certainty of estimates of the volume and regularity of beach recharge and therefore the whole life scheme costs.

The modelling has also influenced how the two preferred options (Options 4 and 5 from the PAR) have been reappraised in this report. The main elements of the breakwater option remain but the engineering implications have changed, this will be discussed later in the chapter. The findings from the modelling mean it has been necessary to subdivide Option 5 (Rock revetment with beach recharge). The sub-options include a rock revetment with a beach recharge that maintains the existing minimal beach, and an option for a rock revetment and rock groynes with a much larger amenity beach.

This division of Option 5 will allow the costs of the amenity beach to be identified and a decision made that takes into consideration the value given to an enhanced beach.

The revised options for appraisal in this PAR addendum are therefore:

Option 1 – No active intervention (Do Nothing)

Option 2 – Do Minimum – regular maintenance through beach recharge

Option 3 – Offshore breakwater

Option 4 – Rock revetment with minimal recharge for ‘status quo’ beach

Option 5 – Rock revetment with rock groynes for enhanced amenity beach

3.2 Description of the options

3.2.1 Option1 - Do Nothing

Under this option no improvement works would be undertaken and all maintenance activities would cease. The modelling for this option assumes a 50m wide breach in the sea wall between year 20 and year 35 and a complete failure of the wall and revetment from year 50 onwards.

3.2.2 Option 2 - Do Minimum

This consists of implementation of a regular 'maintenance' beach recharge scheme to ensure beach levels to not continue to lower. It is based on the average rate of sand loss, which is replaced over a ten-yearly cycle. This will continue to provide protection to the toe of the existing coastal defences, ensuring they are not undermined. This option therefore includes minor-scale capital recharge (~20,000 m^3 every seven years) of the beach for structural protection of the existing defences, preventing an immediate breach due to ongoing toe scour, and would not prevent wave overtopping of the defences. The recently completed storage basin within the Golf Course is included in this option.

This option assumes that in years 1 to 35 the existing coastal defences in Rhyl continue to be maintained to their present standard. This would include both routine maintenance and reactive repairs as required. However, there will be a critical point when 'repairs' will become larger scale capital works in order to maintain the current SoP. FCERM AG state that capital works should not be included in a Do Minimum scenario so this option assumes that maintenance works will stop and there will be a 50m wide breach by year 50 and complete revetment failure by year 99.

This option is not considered viable as it does not result in a suitable SoP at Garford Road. However, it aims to protect and prolong a catastrophic failure of the coastal defence due to continued beach lowering. Natural processes will tend to continue to strip sand from the beach and regular beach recharge would be required.

3.2.3 Option 3 – Offshore breakwater

This option is similar to the previous offshore breakwater option, a concept drawing of this option is included in Appendix A.2.

The offshore breakwater works on the principles of reducing wave energy in the lee of the structure, so that the wave overtopping over the existing defences is reduced. This option does not include any works to the existing stepped revetment and recurve wall which will be reliant of regular maintenance to keep them functioning for the full 100 year design life.

Since the original PAR, sediment transport models have been run to assess the impact of the breakwater on the sediment transport regime. The use of sediment transport models at PAR stage is not considered standard practice as the level of detail is considered to far exceed the level of detail of the other design elements. However, given the potential impacts on scheme cost, sediment transport modelling has been undertaken in this supplementary report.

As described in Chapter 2, in order to minimise the impacts of the breakwater on the sediment transport and avoid causing downdrift problems, the offshore breakwater has been moved 70m further offshore than the original PAR position. This reduces the sediment trapping effect of the breakwater, allowing a volume of sediment to naturally move through the sediment cell.

With option 3, 156,000m^3 of beach recharge is placed in year 0 to protect the toe and fabric of the existing sea wall. Based on results of sediment transport modelling, this frontage would lose 5,000m^3/yr and therefore requires 50,00m^3 to be placed back on the beach in ten yearly intervals.

However, moving the breakwater further offshore introduces the following issues, explained in more detail below:

- Change to breakwater geometry and hence material volumes
- Change rock armour grading
- Change to construction accessibility

3.2.3.1 Breakwater geometry

With the new location of the breakwater, the sheltering effect is likely to be reduced. This is due to waves being able to potentially bypass around the roundheads of the breakwater or being allowed to reform in the lee of the structure. For these reasons, the latest concept drawings show the breakwater as significantly longer with a higher crest and increased crest width as a result of moving the breakwater offshore. The current cost estimates of the breakwater are significantly greater than the original PAR budgetary estimate. This would be subject to further detailed numerical modelling during detailed design to determine the exact breakwater geometry and cost.

3.2.3.2 Rock armour grading

By moving the breakwater 70m offshore, the breakwater will be situated in deeper water. With deeper water depths at the structure, wave heights are likely to be considerably larger. To ensure stability of the rock armour, the rock armour grading mass will have to be increased. A minimum 6 to 10 tonne rock armour grading would be required, which is not readily available from UK based quaries. The rock armour source would therefore likely be from Norway, delivered by marine based plant and inheriting the risks of marine based delivery. This factor has also increased the latest estimate of the schemes cost.

3.2.3.3 Construction accessibility

Due to the new location of the offshore breakwater, the tidal windows for construction will be reduced. While the breakwater will dry out at low tide, due to the short working window, it may require amphibious or marine based plant to construct the breakwater. The PAR breakwater costs were produced on the assumption that the breakwater would be constructed using land based plant as is typical for an intertidal breakwater. Due to the increased risks and alternate construction methodology, the latest cost estimate for construction is significantly higher.

3.2.4 Option 4 – Rock revetment with minimal recharge for 'status quo' beach

Option 4 seeks to place rock armour over the existing concrete stepped structure to dissipate wave energy arriving at the structure. Allowance for a small beach recharge of 20,000m^3 has been made to maintain the beach at the existing levels. This would provide sufficient beach for an intertidal amenity beach e.g. suitable for dog walking.

With this option, no allowance for future maintenance recharge has been made as it has been developed on the assumption that the placement of permeable slope rock armour will reduce the reflection coefficient and therefore the structure induced losses of beach sediments.

A concept drawing of this option is included in Appendix A.2.

The existing sea wall is considered to be in fair condition, but further analysis is required to estimate the residual life. Deterioration in the existing stepped revetment profile through the design life of the structure can be accommodated by the rock revetment due to is natural adaptability. However, the upstand recurve wall is necessary to offer protection from wave overtopping. As it is not clear what condition the recurve wall is in, this appraisal (and costs) include its replacement along with the new revetment. If the condition assessment shows that it is in a good condition and could last many years, then this element can be delayed until e.g. year 40. If the recurve wall is delayed then adaptability will be built into the rock revetment so a new wall can easily be replaced and designed in line with climate change.

3.2.5 Option 5 – Rock revetment with rock groynes for enhanced amenity beach

Option 5 is similar to Option 4, however it seeks to create an amenity beach. 56,000m3 of material would be placed, with further 56,000m3 placed on 8 yearly intervals (based on a loss of 7,000m3/yr from sediment transport modelling).

The amenity beach would be wider and higher than the minimal beach and therefore provide access to dry sand for a much larger percentage of the tidal cycle hence increasing the duration of accessibility and potential for amenity usage. Due to the volume of material placed to create this beach, and the orientation of the coastline with respect to the typical wave directions, longshore control structures (rock groynes) are required to retain the sediment. A concept drawing of this option is included in Appendix A.2.

Due to the design life required for this scheme, rock groynes have been presented as the most viable groyne type, as timber groynes can typically expect design lives of less than 25 years, requiring regular maintenance. The groynes are placed at 100m centres, creating 4 no. groynes between 60 and 80m long.

This option also includes then replacement of the existing recurve wall as described in Option 4.

3.3 The existing sea wall

During the development of the original PAR it was considered appropriate to assume that the existing sea wall would be suitable to provide an element of protection over the scheme design life of 100 years. This was based on a visual inspection of the wall that considered it to be in a fair to good condition, and with the assumption that with regular maintenance it's life could be extended. It will not be possible to confirm a definitive residual life for the wall but destructive testing during detailed design will improve understanding. The function of the wall in relation to the proposed options is described below.

Option 3 – Offshore breakwater

The functionality of the offshore breakwater option is dependent on the ongoing presence of the existing sea wall as this provides the still water level flooding protection. The breakwater breaks up wave energy and reduces wave height in its lee. However, with this option the existing seawall structure will still be exposed to small waves and can therefore be expected to degrade over time and hence regular ongoing maintenance will be critical. With this option the full sea wall and concrete steps are exposed and therefore if degradation occurs to the point at which the sea wall cannot perform its function then the whole structure may need to be replaced. However, within this appraisal it has been assumed that the wall and revetment will remain in a good condition for the full 100-year design life. Adding in the revetment and wall replacement in say year 40 would negate the need for the breakwater option as this could have been done in year 0 without building a breakwater in the first place.

Option 4 and 5 – Rock revetment

For both options 4 and 5 a rock revetment will be placed over the existing sea wall structure with only part of the wave return wall exposed. This has the benefit of providing protection to the majority of the existing structure. Further degradation will be prevented and it would be reasonable to assume that the part of the wall that is beneath the rock armour revetment will be suitable for the full 100 year design life. The wave return wall part of the structure will still be exposed to wave impacts and therefore this section is likely to degrade more quickly and therefore would require more extensive maintenance over the 100 year design life and possible replacement at some point. However, at the appraisal stage to take account of this risk before the condition survey, this PAR addendum has costed the replacement of the recurve wall in year 0, along with the new revetment. At the design stage, following the condition assessment, a decision could be made to delay this replacement.

3.4 Summary

The sediment modelling has influenced how the two original preferred options (Options 4 and 5 from the PAR) have been reappraised in this report. The main elements of the breakwater option remain but the engineering implications have changed. The results of the modelling suggest the breakwater needs to be positioned further offshore which requires a consequent increase in its size and hence cost. The findings from the modelling mean it has been necessary to subdivide Option 5 (Rock revetment with beach recharge). The sub-options include a rock revetment with a beach recharge that maintains the existing minimal beach, and an option for a rock revetment and rock groynes with a much larger amenity beach.

This division of Option 5 allows the costs of the amenity beach to be identified and a decision made that takes into consideration the value given to an enhanced beach.

The revised options for appraisal in this PAR addendum are therefore:

Option 1 – No active intervention (Do Nothing)

Option 2 – Do Minimum – regular maintenance through beach recharge

Option 3 - Offshore breakwater

Option 4 – Rock revetment with minimal recharge for 'status quo' beach

Option 5 - Rock revetment with rock groynes for enhanced amenity beach

A summary of the beach recharge requirements with the three options are presented below:

Option	Capital recharge allowance (m3)	Justification	Maintenance recharge (m3)	Assumptions
Option 3	156,000	Sediment transport modelling	50,000 every ten years.	Sediment transport modelling indicating 5,000m3/yr losses
Option 4	20,000	Sediment transport modelling of required volume to top up beach	0	Based on assumption that lower reflection coefficient will reduce natural losses.
Option 5	56,000	Sediment transport modelling of required volume to create amenity beach	56,000 every 8 years	Sediment transport modelling indicating 7,000m3/yr losses

Further engineering design drawings have been developed to represent these options and are included within Appendix A.2

4 Economics

4.1 Introduction

This chapter shows the economic implications of revising the options following the findings of the sediment modelling. New variations to the preferred options have been costed for the economic appraisal.

The outcome of this section is a revision of the economic appraisal tables from the original PAR, including updates to scheme and staff costs. The updated costs show the preferred economic option (i.e. the option with the highest benefit/cost ratio). This information is added to the technical and environmental issues to provide an overall preferred option in Chapter 6.

4.2 Flood damages and benefits

Joint probability coastal flood modelling was used at the PAR stage to calculate the Do Nothing damages and flood benefits of the options. The following return periods were modelling for four climate change epochs.

Return periods - 1 in 2, 5, 20, 50, 100, 200, 1000 years.

Epochs

- Year 0 – 2015
- Year 20 – 2035
- Year 50 – 2065
- Year 99 – 2115

No additional flood modelling has been undertaken for the PAR addendum. Flood extent maps for the Do Nothing epochs can be found in Appendix A.3.

4.3 Basis of the cost estimates

4.3.1 Capital costs

Balfour Beatty have developed the capital costs based on the Conceptual Design Proposals submitted in this PAR addendum. In pricing the conceptual design proposals they have made use of current local supply chain costs (dredging using Liverpool bay sources, local rock placement plant capabilities etc) and recent experience on similar Coastal Defence Projects (in particular Fylde Coastal Defence works). Potential sources in variation in capital costs between now and construction include:

- design development (ie length of defence structures, extents of beach recharge, extents of landscaping works etc)
- unknown impacts of the UK leaving the EU (please note the marine delivery of rock required for the offshore breakwater structure)
- unexpected impact of inflation
- unexpected restrictions on working practice (for example road delivery of rock considered for revetment works, should this not be possible marine delivery may be required)
- discovery of different topographical or bathymetric information which result in a revision to working practice
- discovery of ecological, archaeological or other such concerns which result in a revision to construction practice beyond that which have been identified in the design services to date.

4.3.2 Beach recharge costs

Balfour Beatty have provided sediment recharge costs based on the supply of material from the Liverpool Bay Area. Boskalis Westminster own and operate vessels suitable of abstracting and supplying a beach recharge scheme from one of the two sources, the other being operated by Tarmac Marine, who own and operate vessels for supply of extracted aggregate to Docks in Liverpool for use by aggregate suppliers.

Due to the locality and availability of plant from Boskalis Westminster they have been consulted with to advise over beach recharge costs. The rates supplied by Boskalis reflect the use of appropriate plant based on the quantities required. A causeway type trailer dredger supplying around 35,000m^3/week has been considered for the supply of the offshore breakwater, supply to beach using pipes, and a smaller Trailer Dredger has been considered for both revetment designs, supply to beach by rainbowing in of materials. This is based on their best current understanding of the site, however a formal review of the site will be required. Potential sources in variation in capital costs between now and construction include:

- Design development (change of requirements)
- Availability of dredging resource
- Availability of dredging sources (maintenance of licence etc)
- Development of design requirements with respect to sediment grading and biological performance beyond that which has been covered previously (ecological engineering requirements)
- Access to the beach and working windows
- Significant change to fuel costs, exchange rates, crown estate royalties, management fee.
- Unknown impacts of the UK leaving the EU

In the Do Minimum option, the upfront beach recharge is required to prevent the existing structure toe from undermining. Based on analysis of beach profile data collected by DCC, the expected lifetime of this volume of material over this frontage would be 7 years. Therefore allowance for 20,000m^3 to be placed every 7 years has been made to prevent the existing structure from undermining.

4.3.3 Maintenance costs

Maintenance costs have been estimated for the new structures proposed in the options and the existing sea wall. The Environment Agency report 'Cost estimation for coastal protection'[1] states the following on the maintenance of coastal protection measures discussed in this report:

- Revetments - there are no records of any readily available cost information associated with the intermittent costs for revetment protection measures.
- Rock groynes - are unlikely to require annual maintenance costs, but may require intermittent maintenance as for other rock structures.
- Breakwaters - the design and evaluation procedure for breakwaters typically attempts to minimise whole life costs by the selection of design conditions that balance the initial capital costs and any longer term O&M costs.
- And in general, substantial schemes, which are likely to have much higher initial construction costs, may require a much lower level of long-term maintenance commitment.

From this it has been concluded that new coastal structures will require a minimum maintenance allowance and the design life maintenance costs have been estimated to reflect this. However, the existing wall will require more maintenance over the 100 year design life. The following maintenance costs have been included for each option.

Option 2 – Do Minimum. Costs for maintenance and reactive minor repairs of the existing sea wall have been included. The existing sea wall will be fully exposed to the storms but scour to the toe will be protected by the beach recharge. The PAR damages eventually predict a

1 Cost estimation for coastal protection – summary of evidence Report –SC080039/R7, Environment Agency, 2015

significant breach between year 50 (2067) and year 99 (2117) which would not be repaired as it would constitute significant capital construction, not the 'do minimum'.

Option 3 – Breakwater. Moderate maintenance will be required to the existing sea wall as it will only be exposed to small wave action during a storm. No maintenance has been included for the breakwater itself.

For Options 4 and 5 – Rock revetment with/without rock groynes. The existing wall will have a new rock revetment designed to a high standard, so no maintenance has been included for this or the new rock groynes. The only remaining feature is the upstanding wall, costs have been included to replace this along with regular ongoing maintenance to the existing wall.

4.3.4 Staff costs

Staff costs include all of JBA, DCC and BB's costs from the PAR stage to the completion of construction. These costs are itemised as either consultant/contractor fees, cost consultant fees or site supervision. JBA's fees have been taken directly from the agreed SCAPE contract allowance and BB have also estimated their costs within this contract. DCC costs have been estimated by Wayne Hope (Denbighshire Flood Risk Manager).

4.3.5 Risk and optimism bias

A 60% optimism bias has been adopted as is standard practice for schemes at appraisal stage (Defra, 2010)2.

4.4 Option costs

Table 4.1 shows the PV costs for all the options considered for comparison in the economic appraisal.

The top half of Table 4.1 shows the costs from the submission of the PAR up to the start of construction. These costs are the same for the Do Something options.

The construction costs are the year one capital costs for each option. In Appendix A.4, Beach recharge is shown in year 1 of the Do Minimum, but this has been included separately as 'beach recharge' as it is seen as the minimum required to maintain the status quo, not a capital construction cost. For the Do Minimum, continuing with beach recharge and reactive repairs will still cost 4.6 million over the 100 year design life and the flood risk will still be high, especially after a breach in the sea wall.

The three Do Something options show that the offshore breakwater will cost significantly more than the two revetment options due to the high capital costs. For the revetment options, Option 5 will cost ~ £12.4m more than option 4 as it includes much more beach recharge to provide an amenity beach and rock groynes to control sediment movement. It can be summarised that an enhance amenity beach at east Rhyl will cost an additional ~£12.4m over the 100 year design life.

2 Flood and Coastal Erosion Risk Management appraisal guidance, Environment Agency, March 2010

Table 4-1: Summary of options - present-value costs

Cost for economic appraisal (PV)	Do-minimum	Offshore Breakwater	Revetment minmal recharge	Revetment with groynes
	Option 2	Option 3	Option 4	Option 5
DCC staff costs		£36,000	£36,000	£36,000
BB staff costs		£387,689	£387,689	£387,689
Site investigation and survey		£195,531	£195,531	£195,531
JBA design fees		£665,264	£665,264	£665,264
Physical basin testing		£128,704	£128,704	£128,704
Construction:				
Construction costs	£0	£15,987,669	£7,575,184	£9,278,758
Inflation allowance for months		does not apply	does not apply	does not apply
Environmental enhancement and mitigation		£90,000	£90,000	£90,000
BB/contractor staff and site supervison costs		£3,882,596	£2,435,070	£2,814,393
DCC staff costs		£20,000	£20,000	£20,000
Cost consultant fees		£20,000	£20,000	£20,000
JBA and DCC Site supervision		£302,813	£302,813	£302,813
Subtotal (total PV capital)	£0	£21,716,266	£11,856,256	£13,939,152
Maintenance and future wall	£516,008	£13,776	£13,776	£13,776
Future beach recharge	£2,384,272	£3,023,955	£0	£5,621,222
Optimism bias/risk	£1,740,168	£14,852,398	£7,122,019	£11,744,490
Total present-value cost	**£4,640,448**	**£39,606,395**	**£18,992,051**	**£31,318,640**

4.5 Options benefits (Damages avoided)

The economic benefits of each option are shown in Table 4.2 below. As there has been no new flood modelling since the PAR, these benefits have stayed the same. The benefits assessment was completed in 2016 and the base year for this economic appraisal update is 2017.

Table 4-2: Summary of present-value damages (PVd) and benefits

	Damage (PVd)	Damage avoided	Benefits (PVb)	Key non-monetarised benefits Ignore this column if not needed.
Option 2 – Do Minimum – regular maintenance through beach recharge	£31,660,599	£7,834,401	£7,834,401	
Option 3 - Offshore breakwater	£1,332,970	£38,162,030	£38,162,030	Sustained amenity beach
Option 4 – Rock revetment with minimal recharge for 'status quo' beach	£1,332,970	£38,162,030	£38,162,030	
Option 5 - Rock revetment with rock groynes for enhanced amenity beach	£1,332,970	£38,162,030	£38,162,030	Sustained amenity beach

The benefit cost ratios of each of the options are shown in Table 4.3 below. As all the options will be designed to provide the same SoP, the incremental cost benefit ratio has not been shown. The Do Minimum and Option 3 (offshore breakwater) options are not cost beneficial. The revetment with minimal recharge has a benefit cost ratio of 2 to 1 and Option 5, revetment with amenity beach, has a marginally positive benefit cost ratio.

The option with the highest benefit cost ratio is Option 4 – Revetment with minimal recharge.

Table 4-3: Benefit:cost assessment

Option	PV costs	PV benefits	Average benefit:cost ratio (BCR)
2 - Do-minimum	£4,640,448	£7,834,401	1.7
3 - Offshore Breakwater	£39,606,395	£38,162,030	0.96
4 - Revetment minimal recharge	£18,992,051	£38,162,030	2.0
5 - Revetment with groynes	£31,318,640	£38,162,030	1.2

4.6 Costs sensitivity

The effect of placing differently sized material will be to modify the required recharge rates, with coarser material typically requiring slightly less recharge (sediment with almost 50% larger mean diameter reduces the ongoing recharge rate by approximately 15%), but finer material may require a far higher rate of recharge (sediment with 40% smaller mean diameter increases the ongoing recharge rate by approximately 30%).

The current recharge costs are based on a source that broadly reflects the existing material. There is confidence that this source will be available (see section 4.3.2) for beach recharge. However, if another recharge source is used that has a finer profile, then recharge costs could increase by up to 30%.

In addition, the recharge volumes and frequency are based on modelling estimates. In theory, none of the options require recharge, but in reality, it is sensible to make an allowance. This was developed by looking at the difference between net and gross sediment transport (i.e. what could fall 'out' from the shelter of the groynes or breakwater).

The options have costed a reccommended allowance for ongoing recharge but there is an upper limit. The difference between the allowance and the upper limit estimate is developed through the uncertainty associated with having material that is not in ‘equilibrium’ with the existing conditions. This rate can be 2-3 times faster than modelled, and even more so when unconstrained.

All of the options would be impacted by an increase in the recharge volumes and frequency so costing the upper end against each option will not alter the BCR. This PAR addendum has kept a high optimism bias of 60% event though more is known of the scheme and early ECI has already taken place with BB.

Any variation to the reccommended recharge allowances used and the planned supply source are accounted for within the £7million optimism bias.

4.7 Costs for the preferred option

The breakdown of costs for the preferred economic option are shown in Table 4.4 below. This is the option with the highest benefit cost ratio and not the final preferred option. Table 4.4 includes the costs used in the economic appraisal of the options, the whole life cash costs and the capital grant approval costs.

Table 4-4: Project costs for Option 4

Costs	Cost for economic appraisal (PV)	Whole-life cash cost	Capital grant approval project cost
Costs up to PAR: (not including costs of approved study)			
Existing staff costs	Sunk costs	£0	£0
Further staff costs	Sunk costs	£0	£0
Site investigation and survey	Sunk costs	£0	£0
Consultants' fees	Sunk costs	£50,000	£50,000
Contractors' fees (detention basin and refurb for existing seawall)	Sunk costs	£600,000	£600,000
Cost consultants' fees	Sunk costs	£0	£0
Subtotal	does not apply, sunk costs	£650,000	£650,000
PAR to construction:			
DCC staff costs	£36,000	£36,000	£36,000
BB staff costs	£387,689	£387,689	£387,689
Site investigation and survey	£195,531	£195,531	£195,531
JBA design fees	£665,264	£665,264	£665,264
Physical basin testing	£128,704	£128,704	£128,704
Subtotal	£1,413,188	£1,413,188	£1,413,188
Construction:			
Construction costs	£7,575,184	£7,575,184	£7,575,184
Inflation allowance for ** months	does not apply	does not apply	£788,530
Environmental enhancement and mitigation	£90,000	£90,000	£90,000
BB/contractor staff and site supervison costs	£2,435,070	£2,435,070	£2,435,070
DCC staff costs	£20,000	£20,000	£20,000
Cost consultant fees	£20,000	£20,000	£20,000
JBA and DCC Site supervision	£302,813	£302,813	£302,813
Subtotal (total PV capital)	£10,443,068	£10,443,068	£10,443,068
Future costs:			
Maintenance and future wall	£13,776	£13,776	does not apply*
Future beach recharge	£0	£0	does not apply*
Risk contingency:			
Optimism bias 60%	£7,122,019	£7,122,019	£7,503,753.63
Contributions	does not apply	does not apply	
Total costs from summary	**£18,992,051**	**£19,642,051**	**£20,010,010**

4.8 Summary

The offshore breakwater will cost significantly more than the two revetment options due to the high capital costs. A sustained amenity beach at east Rhyl will cost an additional ~£13m over the 100 year design life compared to the revetment option with a status quo beach. The amenity beach will not provide any additional flood risk benefits.

The option with the best benefit cost ratio is Option 4 – Revetment with minimal recharge.

5 Environment

5.1 Environmental constraints

A desk-based study was undertaken to identify environmental constraints within the proximity of sites for each option. A search area of 2km around the sites was used. However, environmental constraints outside of 2km were recorded where a potential impact pathway is feasible. Online resources such as the Multi Agency Geographic Information for the Countryside (MAGIC) Map application, Historic Wales, Archwilio, and downloaded datasets from Natural Resources Wales (NRW) have been consulted. Furthermore, a Preliminary Ecological Appraisal (PEA) has identified several ecological receptors that are afforded legal protection which will require further consideration throughout the planning process, with the level of mitigation dependent on the final preferred option. An environmental constraints plan has been produced, and is presented in appendix A.5. The main environmental constraints are listed below in table 5.1. Distances are quoted to 0.1km from the nearest option location, to reflect the level uncertainty at this stage regarding precise option locations and the extent of the works area.

5.2 Baseline Surveys

The environmental desk study has been supplemented by a Heritage Desk Based Assessment (DBA) (provided in Appendix A.6), which has been prepared following the Chartered Institute for Archaeologists (CIfA) Standard and Guidance for Historic Environment Desk-based Assessment (2017). The DBA identified that the foreshore at Rhyl has high archaeological potential, including evidence for coastal change and prehistoric activity.

A paleoenvironmental peat bed deposit, which in places is associated with the remains of a submerged forest, is known to exist immediately to the west of Splash Point and further to the east. The deposit is likely therefore to extend into the areas of the proposed works. A significant number of prehistoric artefacts have also been recovered from the foreshore and further finds might be expected to be encountered in the likely works areas of all the options. The DBA recommended that the proposed geotechnical investigations would provide further information on the peat deposits, which could be used to inform further assessment work and an appropriate mitigation strategy. Further consideration would need to be given to the potential impact of coastal processes on sensitive archaeological deposits outside of the immediate works area. This would need to be assessed on the basis of any predicted changes to coastal processes, where this could result in exposure or burial of archaeological remains.

A Preliminary Ecological Appraisal (PEA) was undertaken as part of the original PAR, which has since been updated with a Biotope Survey (provided in Appendix A.7) undertaken in accordance with the JNCC Marine Monitoring Handbook (2001). Historical data also suggest a small common mussel *Mytilus edulis* bed on mixed substrata immediately adjacent to Option 4. However, at the time of survey, this was not evident and may have been buried by mobile sands. Furthermore, honeycomb worm *Sabellaria sp*. was not recorded on the timber groynes on site, and reefs are unlikely to form despite some potential for settlement. Intertidal sand and mudflat comprises much if the site, and will be lost from either option of the scheme. Biodiversity enhancements opportunities are in the form of specially designed rock types to encourage a net gain in biodiversity and provide a good study example for the utilisation of biological enhancements in breakwater structures. Access to the beach will be via existing routes and therefore impacts to ecology are unlikely to occur. Once the location of the compound is known a study of the ecological impacts at that site is recommended.

The PEA recommended over-wintering bird surveys. This was undertaken from September 2016 to April 2017 following the British Trust for Ornithology (BTO) methodology (Bibby et al., 2000), and is provided in Appendix A.8. This identified a total of 36 species of wading, wildfowl and gull species, with a number of these forming part of the qualifying assemblage for the Liverpool Bay SPA designation. Only low numbers of Common Scoter and Red-throated Diver, qualifying features of the Liverpool Bay SPA, were recorded close to the proposed sites. As both of these species forage in open water, it is unlikely they will be disturbed by the proposed works. The survey also found wading and gull species on the foreshore at Rhyl. A peak count of 500 oystercatcher, 20 sanderling, 70 dunlin, 5 curlew, 120 redshank and 10 turnstone were recorded over the foreshore area, on a falling tide when best foraging opportunities were presented. However, numbers were generally low and were concentrated at the eastern extent of the foreshore, approximately 1km from the proposed options. Furthermore, frequent disturbance from dogwalkers that was observed during the survey, suggesting birds are habituated to disturbance. Therefore, it is considered unlikely that disturbance from the scheme will cause a significant impact on wintering birds that form part of the qualifying assemblage of the Liverpool Bay SPA, particularly given the availability of alternative habitat at low tide. Nevertheless, potential significant effects associated with sediment recharge activities, impacting on up to 25 ha of existing sand flat habitat adjacent to the Liverpool Bay SPA cannot be ruled out (see Appendix A.8, p2 - Sand Recharge Zone), and would therefore require Habitats Regulation Assessment Screening and possible subsequent examination of mitigation requirements.

Table 5-1 Environmental constraints identified around East Rhyl

Topic	Environmental constraints	Description	Proximity to option sites
Biodiversity and nature conservation	Special Protection Area (SPA)	Liverpool Bay SPA – designated for red-throated diver (*Gavia stellata*) and common scoter (*Melanitta nigra*) as well as other overwintering bird species (due to be extended following consultation to include other species)	200m north
		Liverpool Bay pSPA – the Liverpool Bay SPA Proposed Extension could come into operation before the East Rhyl coastal defence proposals receive planning consent. The pSPA extension further inshore would provide protection to foraging common tern (*Sterna hirundo*) and little tern (*Sterna albifrons*)	3.2km east
		Dee Estuary SPA - supports internationally important populations of regularly occurring Annex I species including sandwich tern (*Sterna sandicensis*), little tern (*Sterna albifrons*), common tern (*Sterna hirundo*), and bar-tailed godwit (*Limosa lapponica*). It also supports an internationally important assemblage of waterbirds, providing feeding and roosting sites for ducks and waders in winter.	4.7km east
	Special Area of Conservation (SAC)	Dee Estuary SAC - designated for estuaries, mudflats and sandflat, Salicornia and other annuals colonising mud and sand, Atlantic Salt Meadows, and annual vegetation of drift lines. Also designated for river lamprey (*Lampetra fluviatilis*) and sea lamprey (Petromyzon marinus). Other habitats include fixed dunes with herbaceous vegetation ('grey dunes'); shifting dunes along the shoreline with *Ammophila arenaria* ('white dunes'), embryonic shifting dunes, humid dune slacks, vegetated sea cliffs of the Atlantic and Baltic coasts.	4.7km east
	Ramsar site	Dee Estuary Ramsar site - regularly supports 20, 000 or more waterbirds and 1% or more of the individuals in a population of one species or sub-species of waterbirds including redshank (*Tringa tetanus),* shelduck (*Tadorna* tadorna), teal *(Anas crecca*), Pintail (*Anas acuta*), oystercatcher (*Haematopus ostralegus),* grey plover (*Pluvialis squatarola).*	4.7km east
	Site of Special Scientific Interest (SSSI)	Gronant Dunes and Talacre Warren SSSI located between Prestatyn and Talacre on the North Wales coast, and is of special interest for botanical, entomological and ornithological reasons. These dunes, in combination with other associated coastal habitats, represent the only significant remnant of what was once an extensive dune system along the north coast of Wales.	4.7km east
		Dee Estuary SSSI - designated for special interest for its total populations of internationally important wintering waterfowl; its populations of individual waterfowl and tern species whose numbers reach national and in some cases, internationally important levels; its intertidal mud and sandflats, saltmarsh and transitional habitats; the hard rocky sandstone cliffs of Hilbre Island and Middle Eye with their cliff vegetation and maritime heathland and grassland; its assemblage of nationally scarce plants; and its populations of sandhill rustic moth (*Luperina nickerlii gueneei*), Red Data Book species.	5km east
	Local Nature Reserve (LNR)	Gronant Dunes LNR	4.7km east

	Wildlife Sites	Y Ffrith Wildlife Site (Denbighshire D011) - sand dune and herb-rich grassland	1.5km east
	Habitats	Range of sand dune habitats	1.2km east
		Intertidal rocky shore – rip-rap situated adjacent next to sea wall	Adjacent
		Intertidal sandflats - contains marine benthic invertebrates, such as mussels, which birds may feed on	Within
		Scrub and vegetation	Adjacent
	Species	Overwintering birds such as red-throated diver and common scoter likely to forage in the intertidal mud and sand flats adjacent to the site	Potentially adjacent
		Breeding birds, particularly in scrub vegetation adjacent to promenade	Potentially adjacent
		Ground nesting birds potentially in the adjacent golf course	Potentially adjacent
		Potential fish spawning and nursey grounds	Potentially adjacent
Cultural heritage	Conservation Area	Rhyl Central Conservation Area - 19th century town planning based on rectilinear grid	1.3km south west
	Listed building	Royal Alexandra Hospital – Grade II listed building	0.75km south west
		Multiple listed buildings within Rhyl Central Conservation Area and surroundings	1km south west
	Historic Environment Records (HER)	Rhyl foreshore submerged landscape - prehistoric submerged forest preserved in peat dating to 4000-3000 BC (late Mesolithic/early Neolithic) – 17103	Within
		Rhyl foreshore causeway (post-medieval trackway) - 106402	Adjacent
		Rhyl foreshore (Splash point) structures (post-medieval coastal defence/fish trap/prehistoric occupation site) – 123322	Adjacent
		Rhyl, Volunteers' rifle range - 37700	250m east
		Rhyl, Mantelet Targets - 128935	650m east
		St Olaf, Wreck Site - 271558	200m north east
	HER find spots	Rhyl foreshore (Splash Point) antler mattock (Mesolithic find) – 33099	Adjacent
		Rhyl foreshore Neolithic axes (Neolithic find) – 101936	Within
		Rhyl foreshore post medieval finds (bronze objects) – 58795	Within

		Rhyl foreshore macehead – 58796	Within
		Rhyl foreshore bronze chisel (Bronze Age find) - 101937	Within
Landscape and visual	Area of Outstanding Natural Beauty (AONB)	Clwydian Range and Dee Valley AONB	4km southeast
	Marine Character Area (MCA)	Colwyn Bay & Rhyl Flats MCA	Within
Water environment	Water Framework Directive (WFD) water body	North Wales coastal water body GB641011650000 (heavily modified water body) - moderate status (moderate ecological potential, fail chemical status)	Within
	WFD higher sensitivity habitat	Mussels beds (Mytilus edulis) – note that the ecological surveys have been unable to locate this feature on the foreshore	Adjacent
	WFD lower sensitivity habitat	Intertidal and soft sediments (sand, mud and mixed)	Within
		Rocky shore (intertidal rock)	Adjacent
Population and socio-economics	Local residents	Nearby residential properties along Eaton Avenue, Carlisle Avenue, Garford Road and Hilton Drive	Adjacent
	Local businesses	Rhyl Golf Club	Adjacent
	Traffic	Residential roads	Adjacent
	Recreation and amenity	Wales Coast Path	Within/adjacent
		North Wales Coastal Route 5 (traffic free cycle route)	Within/adjacent
		Public Rights of Way (PRoW) - local cycle routes and footpaths	Adjacent
		Ffrith Beach – recreational and water sports use	Within

5.3 Potential environmental impacts

Potential environmental impacts associated with each option have been identified and are summarised in Table 5.2. Impacts with the potential to result in likely significant effects, if left unmitigated, are highlighted in bold.

Table 5-2 Potential environmental impacts for each option with those with the potential for likely significant effects highlighted in bold.

	Potential environmental impacts identified (unmitigated)
Option 3 offshore breakwater	Change in longshore sediment transport affecting dune habitats to the east which support European protected species including a breeding population of little tern (Dee Estuary SPA designation, and Liverpool Bay SPA proposed extension)*
	Disturbance to birds during construction, specifically red-throated diver and common scoter and other overwintering bird species (adjacent Liverpool Bay SPA designation)*
	Disruption or modification of up to 25ha of intertidal sand/mud flat habitat during construction and operation, together with any inhabiting benthic invertebrates. Although outside of the Liverpool Bay SPA designation, this areas is utilised as overwintering bird foraging habitat.*
	Potential impact on amenity access to beach; impact on tourism and local businesses reliant on tourism during construction.
	Disturbance to fish species and marine mammals during construction
	Construction stage disturbance to known and unknown archaeology on the foreshore (particularly submerged forest and peat deposits)
	Impacts on landscape/seascape; potential impact on visual amenity
	Increased noise and disruption to local residents and visitors during construction
	Greenhouse gas emissions from bulky materials transport during construction
Option 4 new rock revetment with minimal recharge for 'status quo' beach	Some potential change in longshore sediment transport affecting dune habitats to the east which support European protected species including a breeding population of little tern (Dee Estuary SPA designation, and Liverpool Bay SPA proposed extension)*
	Disturbance to birds during construction, specifically Red-throated Diver, common scoter and other overwintering bird species (adjacent Liverpool Bay SPA designation) *
	Disruption or modification of intertidal sand flat habitat during construction and operation, together with any inhabiting marine benthic invertebrates. Although outside of the Liverpool Bay SPA designation, this areas is utilised as bird foraging habitat, specifically by red-throated diver, and common scoter and other overwintering bird species.*
	Disturbance to intertidal rocky shore habitat species during construction
	Vegetation removal with disturbance of nesting birds and reptiles
	Construction and operational phase disturbance to known and unknown archaeology on the foreshore (particularly submerged forest and peat deposits)
	Increased obstruction to views of the sea and landscape; impacts on visual amenity
	Increased noise and disruption to adjacent local residents and visitors

	during construction
	Potential impact on amenity access to beach; impact on tourism and local businesses reliant on tourism during both construction and operation.
	Disruption to users of the promenade and Wales Coast Path during construction
	Greenhouse gas emissions from embodied energy in materials, materials transport and construction
Option 5 new rock revetment with rock groynes for enhanced amenity beach	Change in longshore sediment transport affecting dune habitats to the east which support European protected species including a breeding population of little tern (Dee Estuary SPA designation, and Liverpool Bay SPA proposed extension)*
	Disturbance to birds during construction, specifically Red-throated Diver, common scoter and other overwintering bird species (adjacent Liverpool Bay SPA designation)*
	Disruption or modification of up to 25ha of intertidal sand flat habitat during construction and operation, together with any inhabiting marine benthic invertebrates. Although outside of the Liverpool Bay SPA designation, this areas is utilised as bird foraging habitat, specifically by red-throated diver, and common scoter and other overwintering bird species.*
	Disturbance to intertidal rocky shore habitat species during construction
	Vegetation removal with disturbance of nesting birds and reptiles
	Construction and operational phase disturbance to known and unknown archaeology on the foreshore (particularly submerged forest and peat deposits)
	Increased obstruction to views of the sea and landscape; impacts on visual amenity
	Increased noise and disruption to adjacent local residents and visitors during construction
	Potential impact on amenity access to beach, but which would be offset by improved beach amenity. Potential for an overall positive impact on tourism and local businesses reliant on tourism
	Disruption to users of the promenade and Wales Coast Path during construction
	Greenhouse gas emissions from embodied energy in materials, materials transport and construction

* Issue would require Appropriate Assessment Screening under the Conservation of Habitats and Species Regulations 2010 (as amended).

5.4 Discussion and recommendations

Given that all options would fall within the Schedule 2 Screening Criteria set out in the Town & Country Planning EIA Wales Regulations 2017, and have potential for likely significant effects on the environment under Regulation 6(4), each of the options would require EIA Screening. EIA Screening would also be required under the Marine Works EIA Regulations 2017. Given the options would have potential to impact on European designated sites and so would require Appropriate Assessment Screening under the Conservation of Habitats and Species Regulations 2010 (as amended). Under the 2017 EIA regulations coordination between EIA and HRA is required.

Initial coastal processes sediment modelling work has indicated that none of the options has potential for likely significant effects on habitats that support European protected species including a breeding population of little tern (Dee Estuary SPA designation, and Liverpool Bay SPA proposed extension).

The breakwater and revetment options could potentially give rise to a likely significant impact on views of the sea and landscape and could impact on visual amenity. This would be dependent on the scale and appearance of the revetment and any associated coastal defences such as a sea wall.

Should the revetment Option 4, which may not include measures to significantly retain or recharge beach material, largely retaining the existing sediment dynamics, then there could potentially, over time, be an increased risk of exposure of buried archaeology on the foreshore, which could give rise to potential likely significant but localised effects. Any further reduction in beach material could potentially affect recreational amenity, but this is unlikely to give rise to significant effects on tourism and local businesses reliant on tourism.

Conversely however Options 3 & 5, which include proposals to provide significant beach recharge, the potential disruption or modification of intertidal sand/mud flat habitat over an area of up to 25 ha, together with any inhabiting marine benthic invertebrates, has potential to have a likely greater environmental effect on overwintering bird species associated with the Liverpool Bay SPA designation. Where beach recharge is unavoidable, its use closest to the shoreline and comprising a sand grain size and degree of sorting that matches existing beach sand, would be the least disruptive to benthic ecosystems.

It is assumed the other potential impacts identified could be addressed with standard best practice construction practices would reduce the potential for adverse environmental impacts, and it is assumed these would be included in the preferred option. Such practices would include:

- Vegetation clearance works should avoid breeding bird season (March to September), or any clearance should be supervised by an ecologist.
- Limit extent of scrub clearance and habitat loss; compensatory planting should be undertaken to replace any vegetation that is removed.
- Best practice guidelines contained within Institute of Air Quality Management Guidelines on the Assessment of Dust from Demolition and Construction should be followed to control dust from works, implemented through a construction environmental management plan.
- Plant used should conform to the relevant national standards with regards to working noise and vibration (including BS 5228 and the Control of Pollution Act).
- Any discharge to surface water or to groundwater (including via infiltration during a flood event) may require an environmental permit for the discharge. Any proposals for temporary outfalls during construction (i.e. compound drainage) would also require a permit, which should be sought from the relevant drainage authority (prior to commencement of the works. A flood risk activities permit could similarly be required, and would be sought by the construction contractor if required.
- Any fill material borrowed has the potential to contain contaminants, including non-native invasive species. Waste material requiring disposal off site, should be tested according to Waste Acceptance Criteria (WAC) for contaminants and disposed of at the appropriately licensed waste management facility. The procedure for management of land contamination should be provided in a construction environmental management plan.

Detailed proposals should be discussed with the local authority Environmental Health Officer as the construction contractor may need to obtain Section 61 (Control of Pollution Act) consent in order to undertake the works.

Lines of communication with local residents and businesses during construction should be established to keep them informed about any disruption.

Detailed environmental surveys and assessment would be required to determine the likelihood of the potential impacts identified above to have a significant environmental effect. Liaison with relevant officers of Denbighshire Council and Natural Resources Wales would be required to confirm the scope of further environmental surveys on the basis of the selection of the preferred option. Further recommended surveys and assessment are likely to include:

- Further sediment modelling refinements could further enhance understanding of likely effects of the preferred option on coastal processes.

- Ecological Impact Assessment in accordance with guidelines provided by the Chartered Institute of Ecology and Environmental Management. This may need to be supplemented by additional benthic invertebrate sampling on intertidal sand flats to ascertain the presence and abundance of species, and therefore the importance of the affected areas intertidal sand flat for bird foraging habitat. It is also recommended that any potential compound locations are investigated by a suitably qualified ecologist.
- Habitats Regulations Assessment (HRA) Screening to determine if there is potential for adverse effects to European sites, primarily Liverpool Bay SPA, and Dee Estuary SPA, SAC, and Ramsar site, and the species it is designated for (e.g. red-throated diver and common scoter, little tern, common tern).
- Water Framework Directive screening assessment to determine if the preferred option has potential to impact on the North Wales coastal water body.
- Landscape & Visual Impact Assessment to determine visual impact on existing views (including from archaeological receptors), and impact on the character of the exiting landscape/seascape.
- Archaeological investigations informed by the results of the geotechnical investigations (i.e. sampling and analysis of peat deposits recovered during coring). Should the Ground Investigation involve trial trenching, then these would need to be supervised under an archaeological watching brief).
- Socioeconomic assessment to consider the impact of the preferred option on recreational amenity and tourism.
- Climate change and sustainability assessment to consider the impact of the preferred option on use and transport bulky materials and resilience/adaptability to climate change.
- Cumulative effects assessment to ascertain the collective impact of the preferred option together with other coastal defence works that have been undertaken or are committed to in the surrounding area.

There are a number of potential wider environment benefits, and enhancement measures that could be incorporated into the scheme to improve the local environment. These could include:

- Biodiversity enhancements to the rock structures in order to provide a net gain in biodiversity value at the site as well as provide a good study example for the utilisation of biological enhancements in reef structures (mainly applicable to option 3).
- Information from ground investigations would contribute to paleo-environmental research being undertaken by University of Wales, Trinity St David on the submerged forest at Rhyl.
- Beach replenishment may reinstate eroded beach amenity and protect heritage assets locally on the foreshore from further erosion.

Improvements to Wales Coast Path are possible, such as raising the footpath and enhancing the amenity and recreational use of the grassland behind the footpath (mainly applicable to options 4 and 5).

Improved resilience to the effects of climate change (increased coastal flooding) as a result of improved coastal defences.

5.5 Summary

All options considered in this review would fall within the Schedule 2 Screening Criteria set out in the Town & Country Planning EIA Wales Regulations 2017, and have potential for likely significant effects on the environment under Regulation 6(4), each of the options would require EIA Screening. EIA Screening would also be required under the Marine Works EIA Regulations 2017. Given the options would have potential to impact on European designated sites and so would require Appropriate Assessment Screening under the Conservation of Habitats and Species Regulations 2010 (as amended). Under the 2017 EIA regulations coordination between EIA and HRA is required.

Initial coastal processes sediment modelling work has indicated that none of the options has potential for likely significant effects on habitats that support European protected species including a breeding population of little tern (Dee Estuary SPA designation, and Liverpool Bay SPA proposed extension).

Revetment Option 4, which does not include measures to significantly retain or recharge beach material and which largely sustains existing processes, would potentially increase the risk of exposure of buried archaeology on the foreshore, along with associated heritage impacts. Any further reduction in beach material could potentially affect recreational amenity, but this is unlikely to give rise to significant effects on tourism and local businesses reliant on tourism.

Conversely however should the options include proposals to provide significant beach recharge, the potential disruption or modification of intertidal sand/mud flat habitat over an area of up to 25 ha, together with any inhabiting marine benthic invertebrates, has potential to have a likely significant environmental effect on overwintering bird species associated with the Liverpool Bay SPA designation.

Other potential impacts identified could be addressed through standard best practice for construction.

Wider potential environment benefits and enhancement measures that could be incorporated into the scheme to improve the local environment could include

- **Biodiversity enhancements to the rock structures in order to provide a net gain in biodiversity value at the site;**
- **Contribution to paleo-environmental research;**
- **Improvements to Wales Coast Path;**
- **Improved resilience to the effects of climate change.**

6 Conclusions recommendations

6.1 Conclusions

East Rhyl is at risk of coastal flooding and recent events have been severe. In 2013 deep flooding of 130 residential properties led to 400 people being evacuated from their homes and others had to be rescued by boat. Flood modelling has shown that this risk is set to increase with climate change and therefore the effectiveness of the existing defences will continue to reduce. Action is needed to protect East Rhyl now and in the future to sustain this community and encourage investment in Rhyl as a popular tourist destination.

The 2016 PAR showed that there was an economic case for a coastal scheme in east Rhyl and two options came forward from the appraisal with similar benefit cost ratios. However, the costing of these options required assumptions to be made on the location of the breakwater and the volume and regularity of beach recharge required.

The sediment transport modelling has enabled more understanding on the viability of these options and the associated costs. This has led to a variation of the original options to present three Do Something options that have different costs but deliver the same flood risk benefits. A summary of the options specific engineering, economic and environmental issues are shown in Table 6.1 below.

6.2 Summary of options

Table 6-1 - Engineering, economic and environmental summary of the options

Options	Engineering	Economics	Environment
2 - Do-minimum	Regular beach recharge still required to protect the existing revetment toe. However, this will not be an amenity beach as levels will remain at existing with minimal recharge to maintain the status quo. The existing upstanding wall is expected to fail within 50 years, leaving east Rhyl at greater risk.	PV costs £4.6m BC 1.7 NPV £3.2m Cost beneficial but low SoP	Potential loss of intertidal mud/sand-flats and impact on marine benthic species and foraging habitat. Some positive impact on amenity and protection of heritage assets. Longer term loss of amenity from failure of wall.
3 - Offshore Breakwater	The breakwater will need to be in an intertidal area, reducing the working window and increasing technical risks. Recharge will be required to protect the existing wall toe. This means there will be an enhance sandy beach compared to the status quo. The upstanding wall will still be exposed to some wave action and not protected by a new revetment, so it will need to be replaced within the design life.	PV costs £40m BCR 0.96 NPV minus £1.4m Not cost beneficial	Potential changes in eastwards longshore sediment transport affecting designated foreshore, dune and shingle habitats. Potential loss of intertidal mud/sand-flats and impact on marine benthic species and foraging habitat. Impact on seascape and visual amenity. Disturbance and disruption during construction, including, species, archaeology and amenity Scope for intertidal

			habitat creation through engineered features.
4 - Revetment minimal recharge	The new revetment will be resistant to scour so beach recharge will not be required for protection. Beach levels will remain at existing levels with minimal recharge to maintain the status quo. The existing upstanding wall will need to be replaced at some stage in the 100 yr design life.	PV costs £19m BCR 2.0 NPV £19.3 Cost beneficial	Some potential changes in eastwards longshore sediment transport, relative to current trends, affecting designated foreshore, dune and shingle habitats. Limited potential loss of intertidal mud/sand-flats and impact on marine benthic species and foraging habitat. Limited impact on seascape and visual amenity. Some limited disturbance and disruption during construction, including, species, archaeology and amenity Scope for intertidal habitat creation through engineered features
5 - Revetment with groynes	Works will be required on the existing wall (rock revetment) and in an intertidal area for the rock groynes. Beach recharge will be for amenity purposes not toe protection. The existing upstanding wall will need to be replaced at some stage in the 100 year design life.	PV costs £31m BCR 1.2 NPV £6.9 Cost beneficial	Potential changes in eastwards longshore sediment transport, relative to current trends, affecting designated foreshore, dune and shingle habitats. Limited loss of foraging habitat and impacts on marine benthic species. Impact on seascape and visual amenity. Disturbance and disruption during construction, including, species, archaeology and amenity Scope for intertidal habitat creation through engineered features. Potential net improvement of beach amenity within the defined area

6.3 Overall recommended option

The sediment transport modelling and new engineering analysis has shown that Option 4 (revetment minimal recharge) provides the most cost beneficial option. This option provides a 1 in 200 year SoP up to the end of the design life, taking into account climate change.

Option 3, breakwater, is no longer cost beneficial based on the new beach recharge and the costs of placing the breakwater further off shore than originally estimated.

The only other option that has a positive cost benefit ratio is Option 5, revetment with groynes. This option provides an enhanced amenity beach through beach recharge and control structures. This beach is not needed for flood protection or to protect the toe of the new revetment from scour. Compared to Option 4, the amenity beach will cost ~£12.4m over the 100 year design life.

The potential range of environmental impacts of the options are broadly similar, with an anticipated lower likelihood of negative impacts from Option 4.

Option 4, revetment with minimal recharge, is the recommended option on technical, economic and environmental grounds, but a value for money judgement needs to be made on the amenity beach that is provided by Option 5.

Appendices

A Supporting documents (provided separately)

A.1 Full modelling report

A.2 Options drawings

A.3 Flood maps

A.4 Economic appraisal tables

A.5 Environmental Constraints Plans

A.6 Heritage Desk Based Assessment

A.7 Biotope Survey Plan

A.8 Overwintering Bird Survey Report

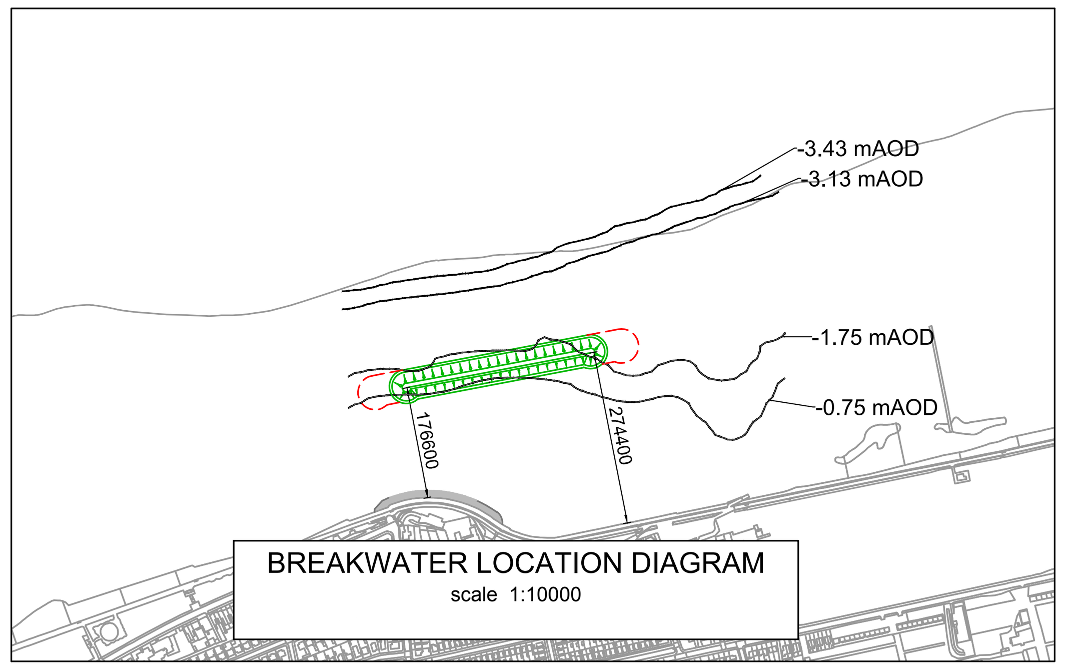
JBA consulting

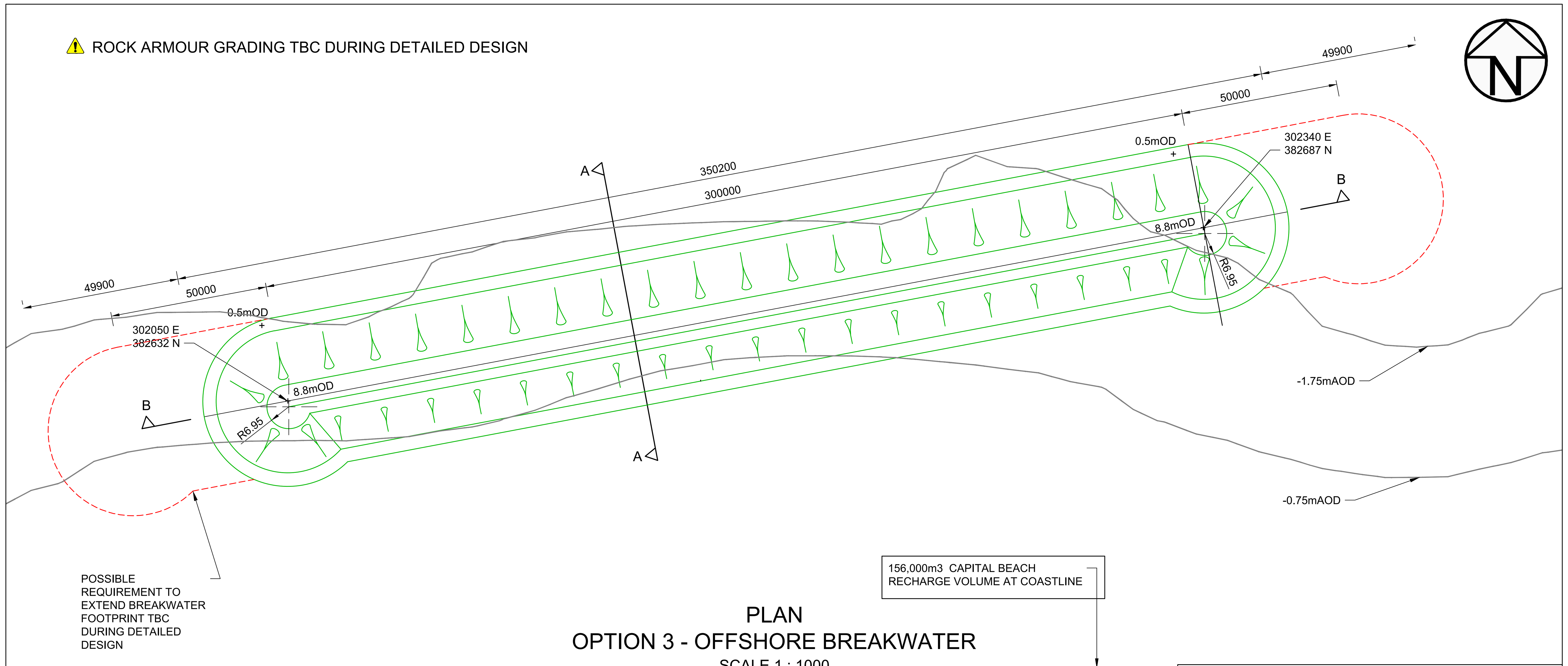
Offices at
Coleshill
Doncaster
Dublin
Edinburgh
Exeter
Glasgow
Haywards Heath
Isle of Man
Limerick
Newcastle upon Tyne
Newport
Peterborough
Saltaire
Skipton
Tadcaster
Thirsk
Wallingford
Warrington

Registered Office
South Barn
Broughton Hall
SKIPTON
North Yorkshire
BD23 3AE
United Kingdom

t:+44(0)1756 799919
e:info@jbaconsulting.com

Jeremy Benn Associates Ltd
Registered in England
3246693





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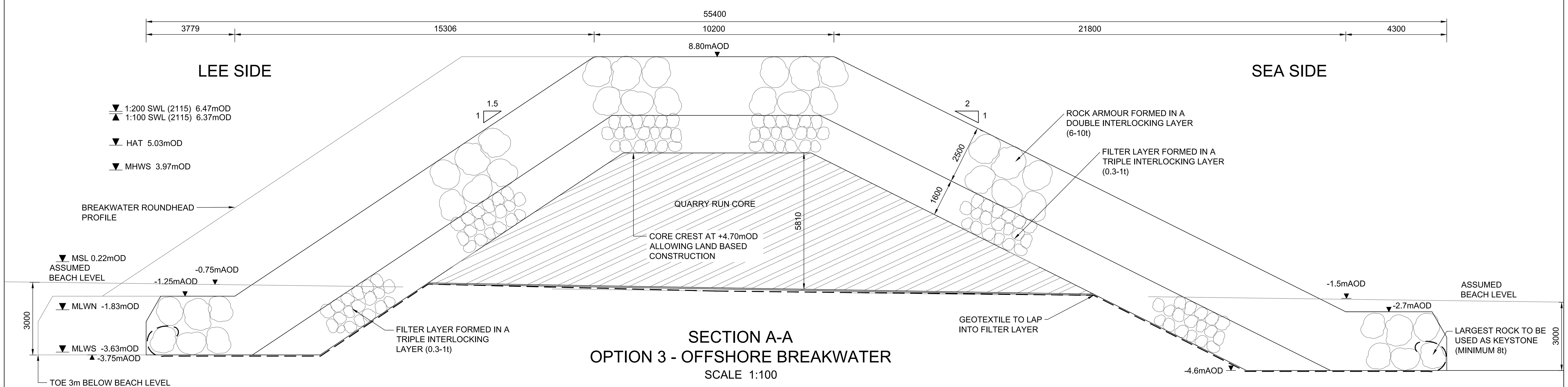

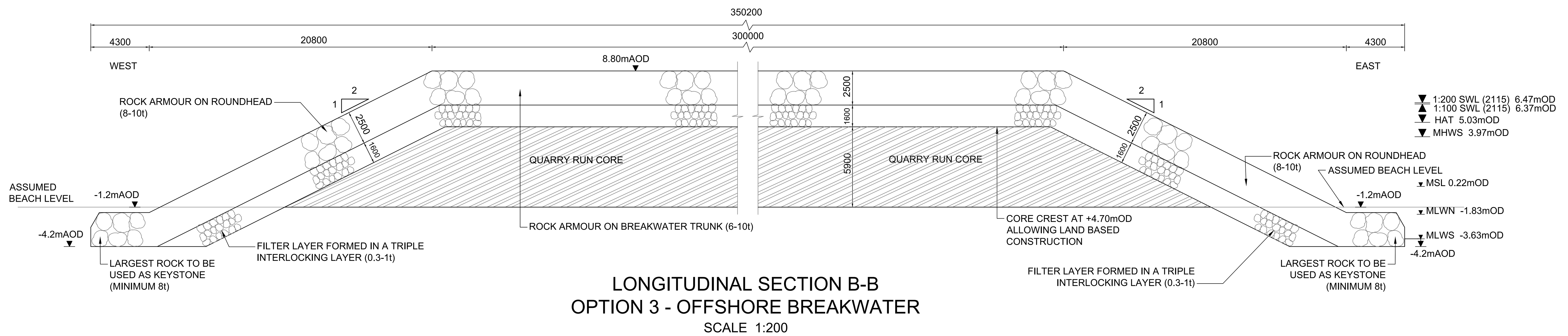

Construction Risks	Public Risks	Environmental Risks
• Collision with breakwater by vessel traffic delivering materials • Risk of damage to land-based construction plant in large storm events • Restricted access and egress through Rhyl • Working in an exposed coastal environment • Movement of plant in and around the sea • Unknown ground conditions • Services information currently unknown • Placement of rock armour	• Navigation markers to be installed on ends of breakwater roundheads • Working on public amenity beach and public open space • Public interaction with rock armour • Working adjacent to public right of way • Unauthorised site access	• Pollution hazards associated with working near the sea • Risk of damage to flora and fauna

In addition to the hazards/risks normally associated with the types of work detailed on this drawing take note of the above.
It is assumed that all works detailed on this drawing will be carried out by a competent contractor working, where appropriate, to an appropriate method statement.

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION BOX

General Notes

1. All dimensions shown are in millimetres unless otherwise stated and levels are in metres to Ordinance Datum.
2. Do not scale from this drawing. All dimensions must be checked/verified on site.
3. All levels quoted on drawings were derived from LiDAR.
4. All works on the coast will be carried out with care to minimise the risk of pollution adhering to Pollution Prevention Guidelines.
5. All works affecting flood defences, main watercourses and/or ordinary watercourses will be subject to Consent for Permanent and Temporary Works under the Land Drainage Act 1991.

Design Notes

1. Services information unknown. The Contractor will confirm the location of any services prior to the commencement of any works.
2. Ground conditions unknown.
3. Rock armour to be sourced in accordance with BS13383-1:2002.
4. Landscape enhancements to be developed during detailed design.

	Comments				
Rev.:	Date	Drawn	Designed	Checked	Approved
	Comments				
Rev.:	Date	Drawn	Designed	Checked	Approved
	Comments				
Rev.:	Date	Drawn	Designed	Checked	Approved
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	Comments				
Rev.:	Date	Drawn	Designed	Checked	Approved
	Comments				
Rev.:	Date	Drawn	Designed	Checked	Approved

Client Approval
A - Approved
B - Approved with Revisions
C - Do Not Use

Purpose of Issue	Status
For comment	Concept

JBA consulting
35 Perrymount Road
HAYWARDS HEATH
West Sussex
RH16 3BW
United Kingdom
www.jbaconsulting.com
t +44 (0)1444 473652
f +44 (0)845 8627772
e info@jbaconsulting.com
Offices at Coleshill, Doncaster, Dublin, Edinburgh, Exeter, Haywards Heath, Limerick, Newcastle upon Tyne, Newport, Saltaire, Skipton, Tadcaster, Thirsk, Wallingford and Warrington

DENBIGHSHIRE COUNCIL - CONCEPT SEA DEFENCE OPTIONS

EAST RHYL
OPTION 3 - OFFSHORE BREAKWATER
PLAN AND SECTION

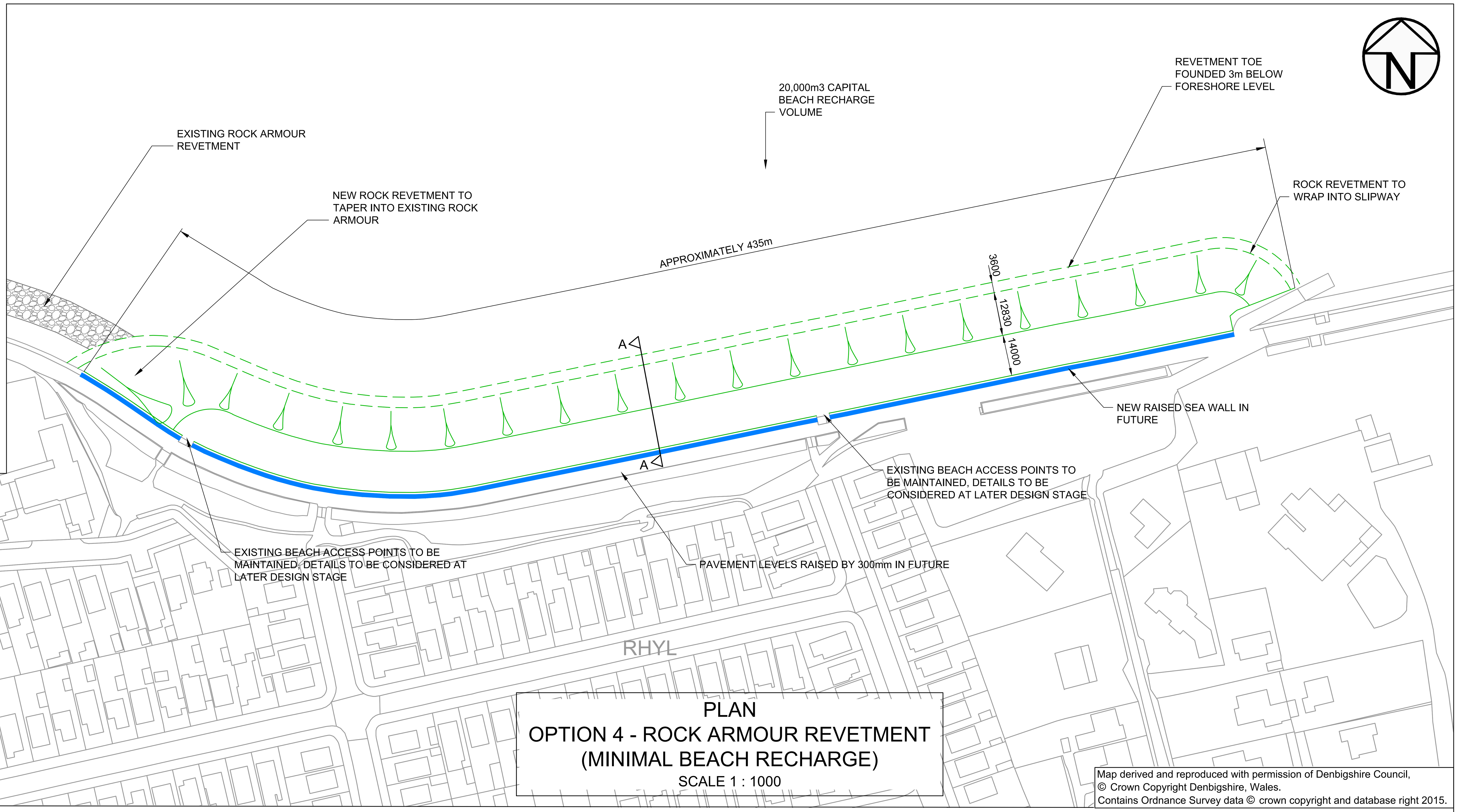
for

Cyngor sir ddinbych denbighshire County Council

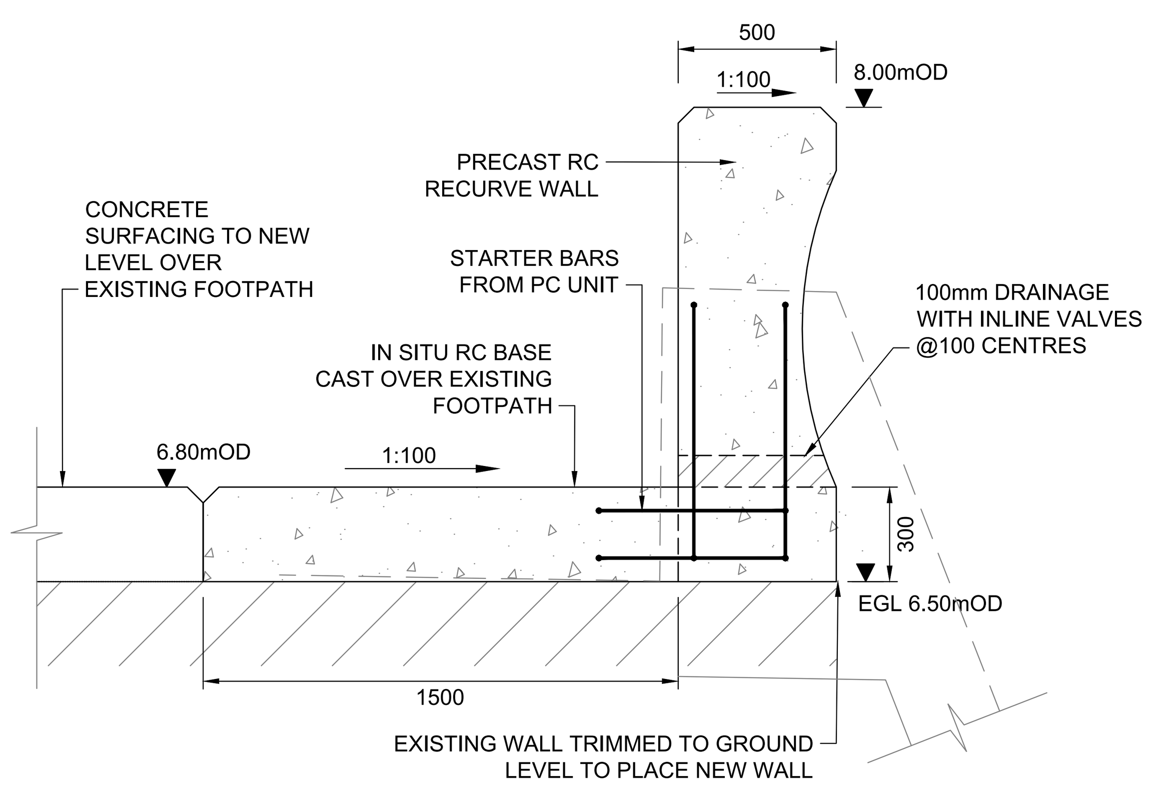
Scale:			
As shown @ A1	Drawn:	R.Groves	12/07/17
	Designed:	A. Dane	12/07/17
	Checked:	G. Kenn	12/07/17
	Approved:	G. Kenn	12/07/17

Digital File Name: 2016s5126/.../ ER-JBA-00-00-DR-C-0001-Option 3.dwg

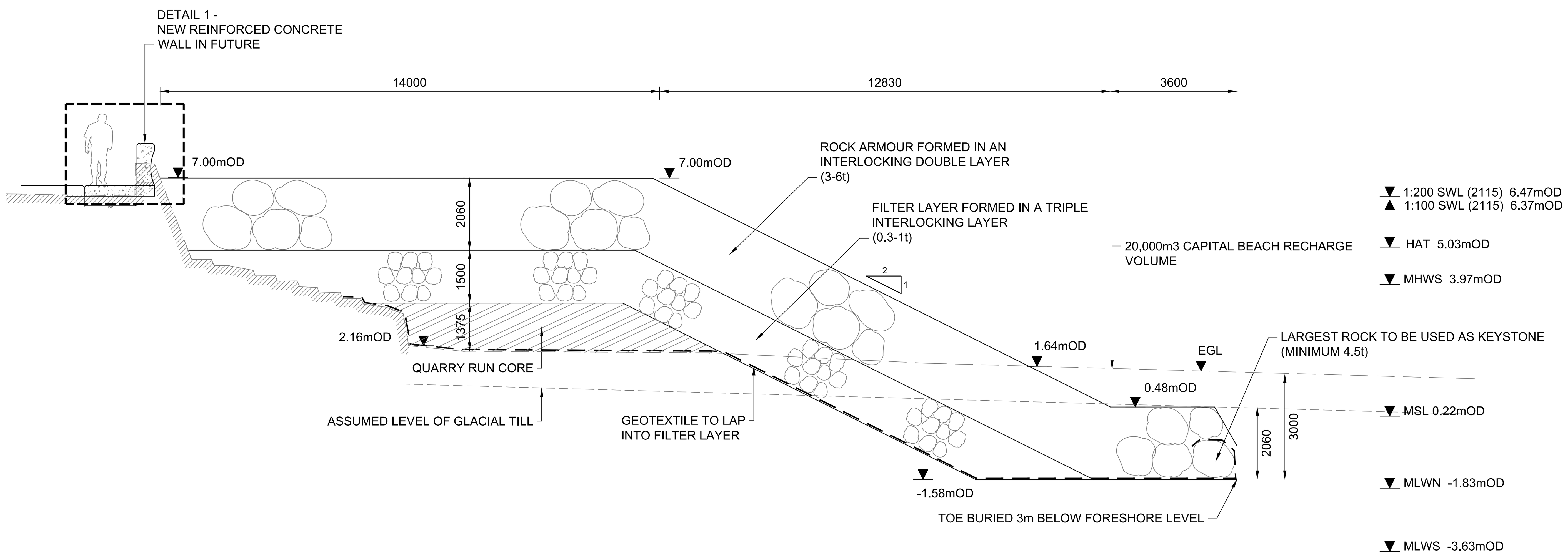
Drawing Number:	Revision
ER-JBA-00-00-DR-C-0001	S8-PO1



PLAN
OPTION 4 - ROCK ARMOUR REVETMENT
(MINIMAL BEACH RECHARGE)
SCALE 1 : 1000



DETAIL 1
scale 1:20



TYPICAL SECTION A - A
OPTION 4 - ROCK ARMOUR REVETMENT
SCALE 1:100

Construction Risks	Public Risks	Environmental Risks
• Restricted access and egress through Rhyl • Working in an exposed coastal environment • Movement of plant in and around the sea • Unknown ground conditions • Unknown condition and structural capacity of existing revetment and access points • Services information currently unknown	• Working on public amenity beach and public open space • Public interaction with rock armour • Working adjacent to public right of way • Unauthorised site access	• Pollution hazards associated with working near the sea • Risk of damage to flora and fauna

In addition to the hazards/risks normally associated with the types of work detailed on this drawing take note of the above.
It is assumed that all works detailed on this drawing will be carried out by a competent contractor working, where appropriate, to an appropriate method statement.

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION BOX

General Notes

1. All dimensions shown are in millimetres unless otherwise stated and levels are in metres to Ordinance Datum.
2. Do not scale from this drawing. All dimensions must be checked/verified on site.
3. All levels quoted on drawings were derived from LiDAR.
4. All works will be carried out with care to minimise the risk of pollution adhering to Pollution Prevention Guidelines.
5. All works affecting flood defences, main watercourses and/or ordinary watercourses will be subject to Consent for Permanent and Temporary Works under the Land Drainage Act 1991.

Design Notes

1. Services information unknown. The Contractor will confirm the location of any services prior to the commencement of any works.
2. Ground conditions unknown.
3. Care to be taken when excavating adjacent to existing sea wall.
4. Rock armour to be sourced in accordance with BS13383-1:2002.
5. Landscape enhancements to be developed during detailed design.
6. EGL = Existing ground level

Rev.:	Date	Drawn	Designed	Checked	Approved
Comments					
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Rev.:	Date	Drawn	Designed	Checked	Approved
Comments					
Rev.:	Date	Drawn	Designed	Checked	Approved
Comments					
Rev.:	Date	Drawn	Designed	Checked	Approved

Client Approval
A - Approved
B - Approved with Revisions
C - Do Not Use

Purpose of Issue	Status
For comment	Concept

JBA consulting

35 Perrymount Road
HAYWARDS HEATH
West Sussex
RH16 3BW
United Kingdom
www.jbaconsulting.com
t +44 (0)1444 473652
f +44 (0)845 8627772
e info@jbaconsulting.com

Offices at Coleshill, Doncaster, Dublin, Edinburgh, Exeter, Haywards Heath, Limerick, Newcastle upon Tyne, Newport, Saltaire, Skipton, Tadcaster, Thirsk, Wallingford and Warrington

DENBIGHSHIRE COUNCIL - CONCEPT SEA DEFENCE OPTIONS

EAST RHYL
OPTION 4 - ROCK ARMOUR REVETMENT
(MINIMAL BEACH RECHARGE)
PLAN AND SECTION

for

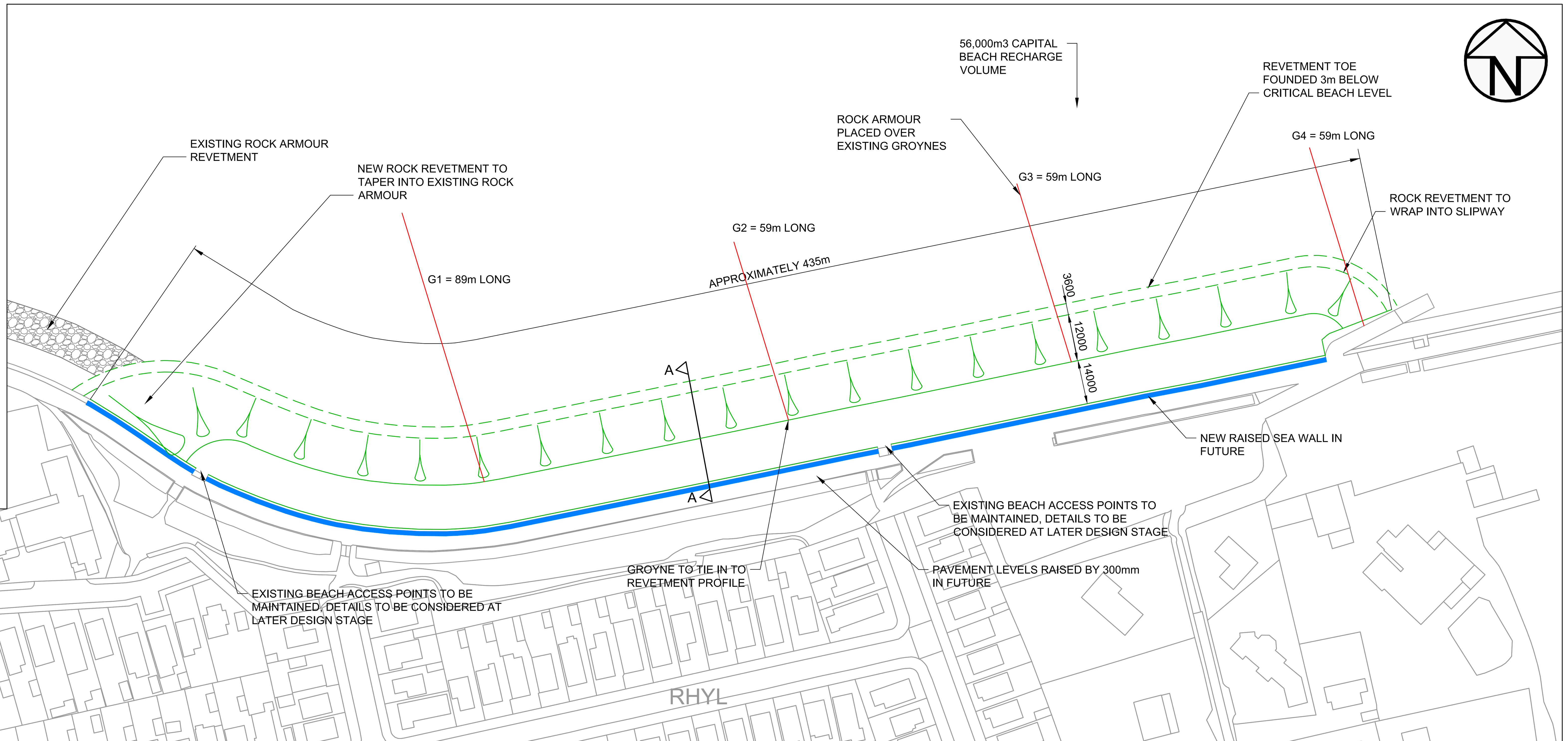
Cyngor sir ddinbych denbighshire County Council

Scale:			
As shown @ A1	Drawn:	R.Groves	04/07/17
	Designed:	A. Dane	04/07/17
	Checked:	G. Kenn	12/07/17
	Approved:	G. Kenn	12/07/17

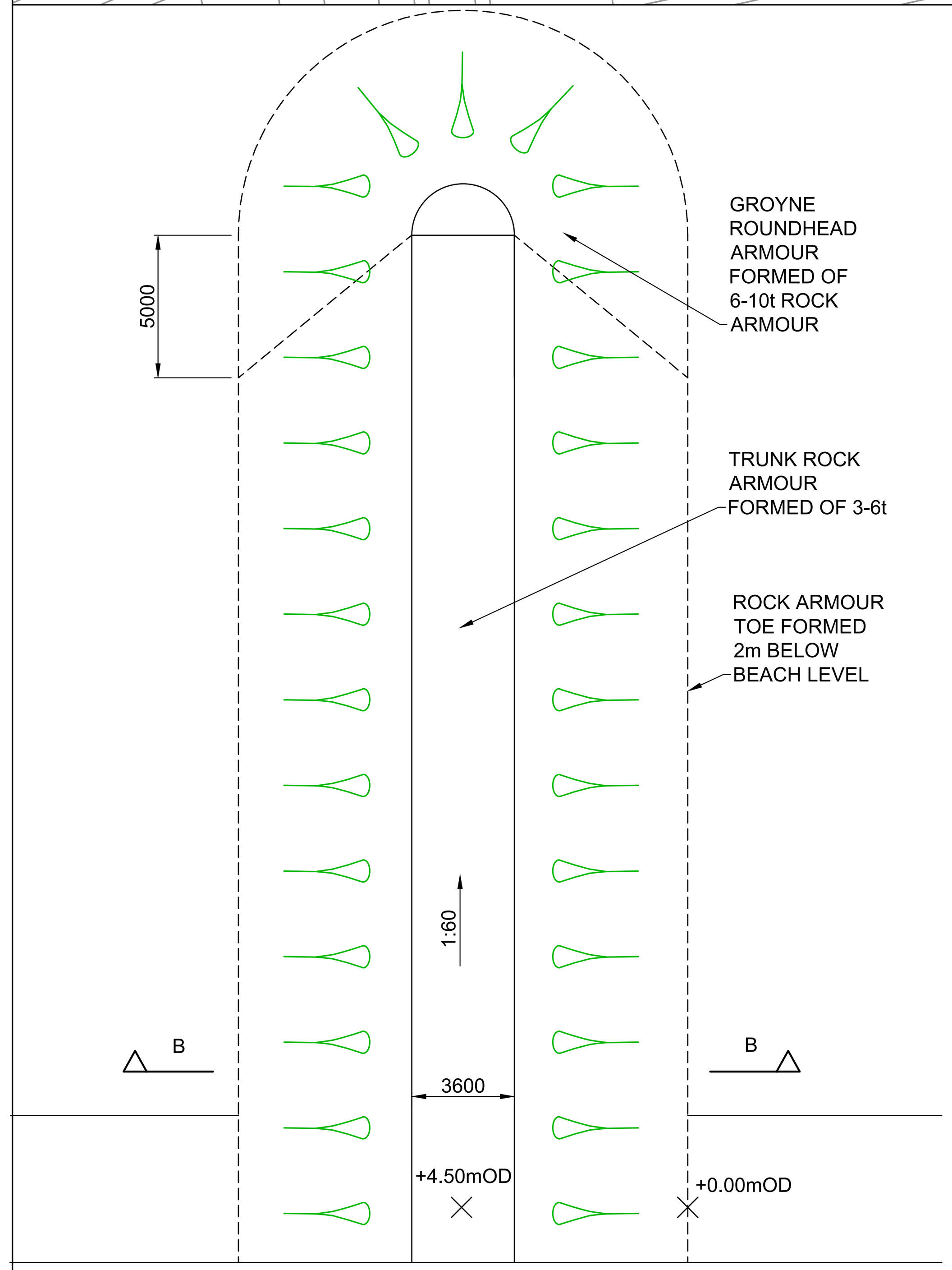
Digital File Name: 2016s-5126/.../ ER-JBA-00-00-DR-C-0002 OPTION 4.dwg

Drawing Number:	Revision
ER-JBA-00-00-DR-C-0002	S8-P01

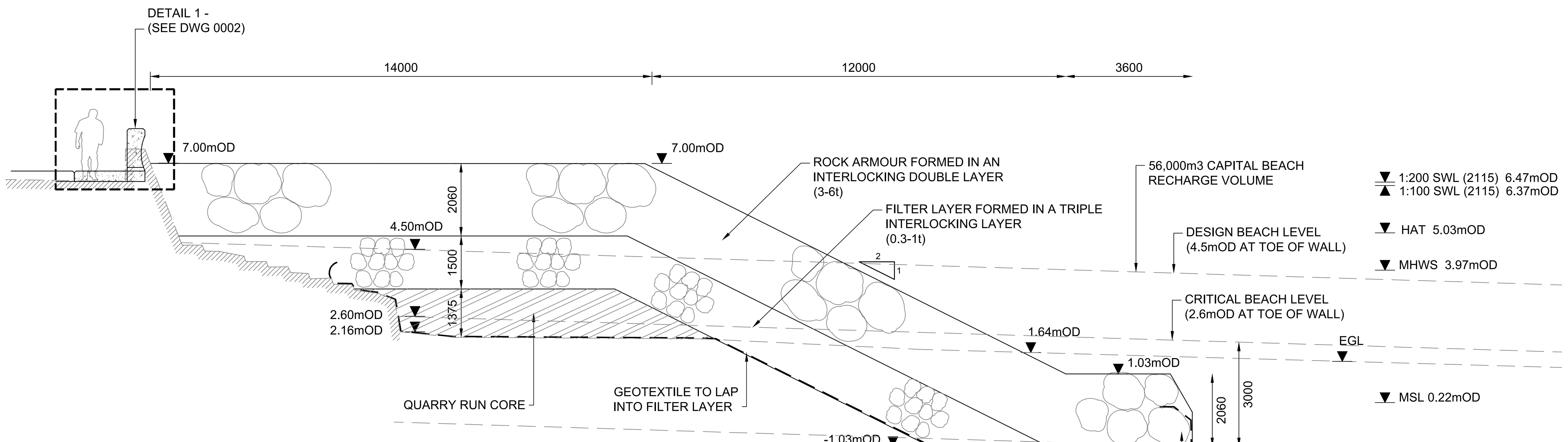
LOCATION PLAN
scale 1:300000



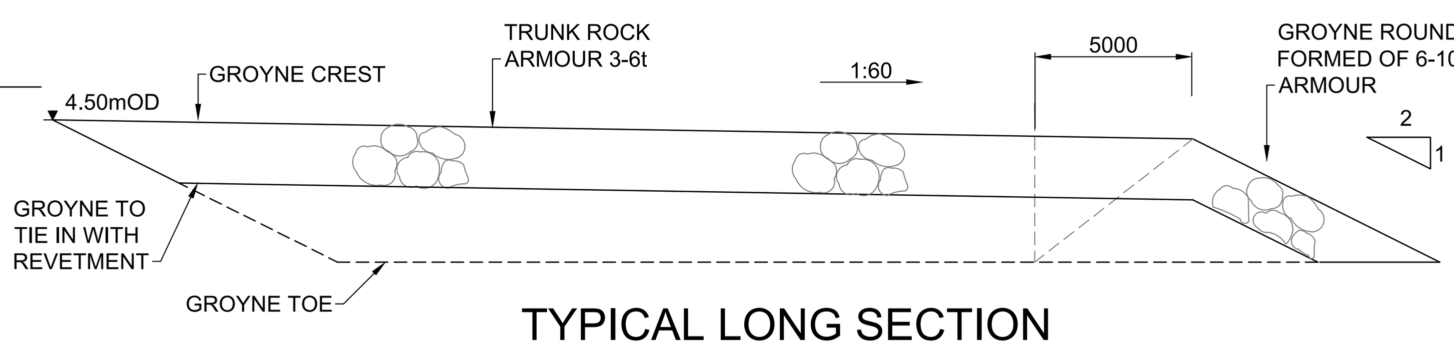
PLAN
OPTION 5 - ROCK ARMOUR REVETMENT
(WITH AMENITY BEACH RECHARGE)
SCALE 1 : 1000



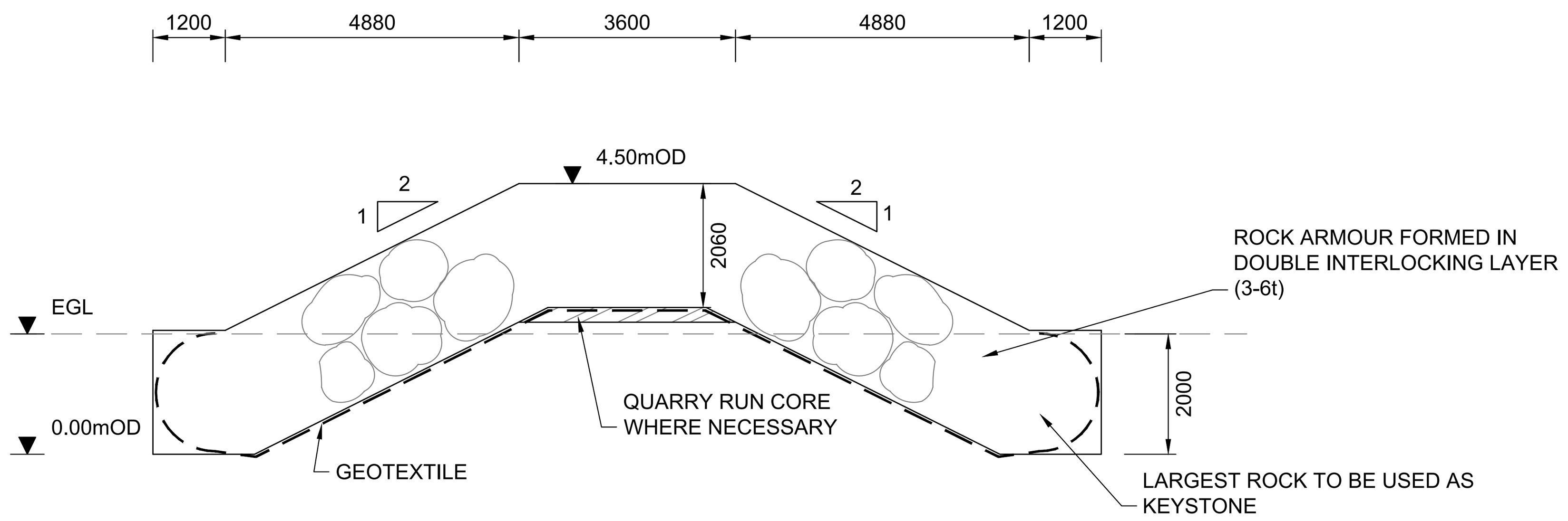
PLAN ON TYPICAL GROYNE
SCALE 1:200



TYPICAL SECTION A - A
OPTION 5 - ROCK ARMOUR REVETMENT
SCALE 1:100



TYPICAL LONG SECTION
THROUGH GROYNES
SCALE 1:200



TYPICAL SECTION B-B
SCALE 1:100

Construction Risks	Public Risks	Environmental Risks
• Hand-arm vibration from scabbling • Restricted access and egress through Rhyl • Working in an exposed coastal environment • Movement of plant in and around the sea • Unknown ground conditions • Unknown condition and structural capacity of existing revetment and access points • Services information currently unknown	• Working on public amenity beach and public open space • Public interaction with rock armour • Working adjacent to public right of way • Unauthorised site access	• Pollution hazards associated with working near the sea • Risk of damage to flora and fauna

In addition to the hazards/risks normally associated with the types of work detailed on this drawing take note of the above.
It is assumed that all works detailed on this drawing will be carried out by a competent contractor working, where appropriate, to an appropriate method statement.

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION BOX

General Notes

1. All dimensions shown are in millimetres unless otherwise stated and levels are in metres to Ordinance Datum.
2. Do not scale from this drawing. All dimensions must be checked/verified on site.
3. All levels quoted on drawings were derived from LiDAR.
4. All works on the coast will be carried out with care to minimise the risk of pollution adhering to Pollution Prevention Guidelines.
5. All works affecting flood defences, main watercourses and/or ordinary watercourses will be subject to Consent for Permanent and Temporary Works under the Land Drainage Act 1991.

Design Notes

1. Services information unknown. The Contractor will confirm the location of any services prior to the commencement of any works.
2. Ground conditions unknown.
3. Care to be taken when excavating adjacent to existing sea wall.
4. Rock armour to be sourced in accordance with BS13383-1:2002.
5. Landscape enhancements to be developed during detailed design.
6. EGL = Existing ground level
7. Navigation markers to be installed at Groyne roundhead

	Comments				
Rev.:	Date	Drawn	Designed	Checked	Approved
	Comments				
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Rev.:	Date	Drawn	Designed	Checked	Approved
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Rev.:	Date	Drawn	Designed	Checked	Approved
	Comments				
Rev.:	Date	Drawn	Designed	Checked	Approved
	Comments				
Rev.:	Date	Drawn	Designed	Checked	Approved

Client Approval
A - Approved
B - Approved with Revisions
C - Do Not Use

Purpose of Issue	Status
For comment	Concept

JBA consulting
35 Perrymount Road
HAYWARDS HEATH
West Sussex
RH16 3BW
United Kingdom
www.jbaconsulting.com
t +44 (0)1444 473652
f +44 (0)845 8627772
e info@jbaconsulting.com
Offices at Coleshill, Doncaster, Dublin, Edinburgh, Exeter, Haywards Heath, Limerick, Newcastle upon Tyne, Newport, Saltaire, Skipton, Tadcaster, Thirsk, Wallingford and Warrington

DENBIGHSHIRE COUNCIL - CONCEPT SEA DEFENCE OPTIONS

EAST RHYL
OPTION 5 - ROCK ARMOUR REVETMENT
PLAN AND SECTION
(WITH AMENITY BEACH RECHARGE)
for
Cyngor sir ddinbych
denbighshire County Council

Scale:			
As shown @ A1	Drawn:	R.B.Groves	12/07/17
	Designed:	A. Dane	12/07/17
	Checked:	G. Kenn	12/07/17
	Approved:	G. Kenn	12/07/17

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Drawing Number:	Revision
ER-JBA-00-00-DR-C-0003	S8-P01