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Project title	Barmouth North Promenade	Job number
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Subject	Existing Coastal Defence Structures Review	

1 Introduction

Ove Arup and Partners (Arup) have been appointed in September 2018 by YGC, part of Cyngor Gwynedd Council (CGC) to deliver an Outline Business Case (OBC) for coastal risk management for the Barmouth North Promenade frontage.

1.1 Purpose & Information

The purpose of this technical note is to review the existing coastal defence structures based on the relevant information available from historical structural condition visual surveys, as-built drawings, ground investigation reports and a visual site walkover in September 2018. No structural or stability calculations have been undertaken for this assessment. This note complements a Barmouth North Promenade Coastal Process Study by ABPmer (2018).

This note will inform the following:

- What would reasonably be expected to occur to the structure in the absence of investment (i.e. baseline walkaway scenario)
- What actions would help maintain the current defences over 100 years (i.e. business as usual maintenance requirements and risks).
- Recommendations for further investigation.
- Risks/considerations needed to inform do-something options

The information used to establish the condition of these structures is:

- Martin Wright Associates, Barmouth North Promenade Final Project Appraisal Report (PAR), 2014 and updated in 2017, by Civil Engineering Solutions (CES)
- Mott MacDonald, Barmouth North Promenade PAR Review, 2018
- YGC, Asset inspections from 2010 to 2016

File Note

264326

26 October 2018

- YGC Ground and Site Investigation (2014)
- Typical cross section from historic drawings provided by YGC (Sept 2018)
- Arup, Site Visit Visual Walkover, 2018

The subsequent assessment of the condition of the existing structures (as outlined in Section 3) will refer to the following Environment Agency guidance, which uses condition grade deterioration curves offering a standardised approach to assess and quantify the deterioration of flood defence assets. Condition grades are based on the Condition Assessment Manual, CAM, (Environment Agency 2006) definitions of condition grades per asset type as shown below.

Condition Grade	Description of condition	Extent of defects
1	Very good	Cosmetic defects that will have no effect on performance.
2	Good	Minor defects that will not reduce overall performance of asset.
3	Fair	Defects that could reduce performance of asset.
4	Poor	Defects that would significantly reduce performance of asset.
5	Very poor	Severe defects resulting in complete performance failure.

Figure 1: Extract from the Environment Agency Guidance (2006) to qualitatively describe the condition of existing structures

1.2 Site Location and Structural Form

Barmouth is located in Gwynedd on the west coast of Wales, north of the Afon Mawddach estuary. The North Promenade is the northmost section of the Barmouth developed frontage, extending from residential housing estate at Heol y Llan to the northern extent of the promenade wall.

The frontage comprises a mixture of hard defences, including a vertical sheet piled sea wall, a concrete platform, stone blockwork revetment and precast concrete wave recurve wall units, with secondary and tertiary setback walls. The northern end of the promenade is fronted by a shingle berm with timber groynes, whilst to the southern end is fronted by a vegetated stabilised sand-dune. Defences deteriorate in condition towards the northern extent of the study area with beach lowering leading to undermining of the sea wall and access steps.

Coastal flooding is experienced during storm events with barriers deployed to prevent overland pathways through access points in secondary and tertiary setback walls.

The existing sea wall within the study area is approximately 1.3km in length stretching from the residential housing estate at Hoel y Llan to the furthestmost northern extent of the existing promenade. The study area does not include the southern extents of the frontage which extend beyond Barmouth Harbour towards the estuary of the Afon Mawddach, however, brief consideration towards this section has been included.

File Note

264326

26 October 2018

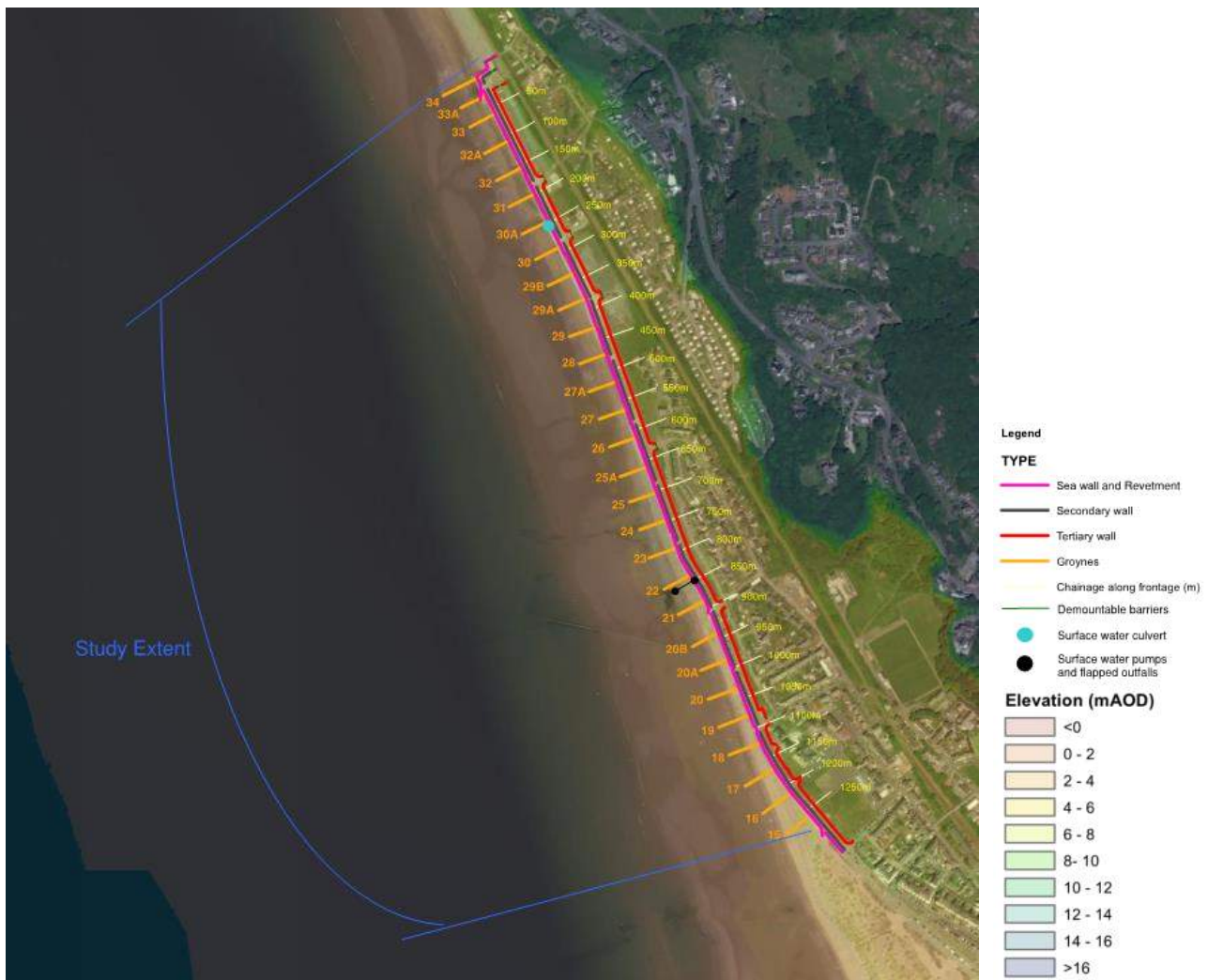


Figure 2: Plan of Barmouth coast showing extent of the existing coastal defence structures for study.

The existing coastal defences run parallel with the promenade adjacent to the Marine Parade highway. The defences vary along the frontage, but generally consist of a vertical sheet piled sea wall with a concrete platform, stone blockwork revetment and pre-cast concrete wave recurve wall units. Timber groynes are situated in front of the northern promenade from 0000 to 1250m at roughly 45m intervals.

1.3 Summary of structure history

Barmouth's sea defences originally reportedly date from the 1920s. A further contract was commissioned in 1930s, which included the construction of timber groynes and a concrete revetment, with a sheet pile toe added in 1956 (along with a new length of wall (up to 576m in length)) to protect from significant scouring and lowering of beach levels experienced along this section. The concrete wave recurve wall was constructed between 1972 and 1974, together with refurbishment of the timber groynes and importation of shingle beach nourishment. Since this date, on-going remedial works have been undertaken along the frontage supported by regular inspection regimes.

File Note

264326

26 October 2018



Figure 3: Historic photography showing the “promenade” from the beach circa 1880 (Martin Wright Associates, 2014)

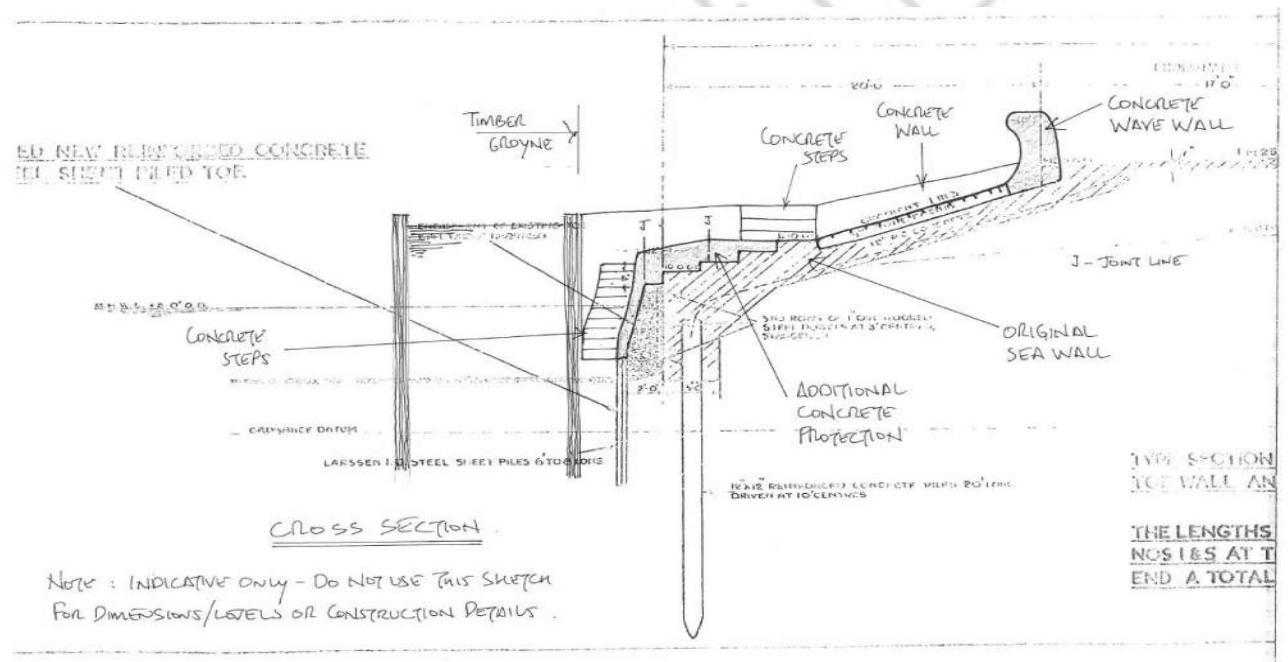


Figure 4: Typical cross section from historic drawings (YGC, 2018)

File Note

264326

26 October 2018



Figure 5: The concrete wave recurve wall (Arup, 2018)

Further structures include a second and third wall, situated either side of the highway (Marine Parade), as shown in Figure 6, which help to protect against coastal flooding caused by wave overtopping. Low-lying land immediately to the north of the Heol y Llan housing estate affords protection to the associated properties through attenuation, supported by a demountable flood defence wall, as indicated in Figure 7, at the junction between Marine Parade and Heol-Y-Llan.



Figure 6: Primary, secondary and tertiary flood defences (Arup, 2018)



Figure 7: Demountable stop logs were seen to be deployed (2018 MML report)

File Note

264326

26 October 2018

A shingle berm exists to the north of the promenade which provides protection to a section of the Cambrian railway line. A small sand-shingle beach fronts the northern end of the promenade.



Figure 8: Shingle berm providing protection to the railway line at the north of the promenade (Arup, 2018)

However, beyond the study extents, towards the southern end of the promenade, it is notable that the width of the beach increases considerably and a vegetated stabilised sand-dune system has formed along the frontage, providing a natural defence from the waves.



Figure 9: Sand dune system protecting the southern end of the promenade from wave action (Arup, 2018)

1.4 Background and Overall Project Scope

The West of Wales Shoreline Management Plan 2 (SMP2) (2011) sets out the policy for coastal risk management across the region. Barmouth North Promenade is located within the SMP2 Management area 24 (MA24) and Policy Unit 15 (Barmouth North) of SMP Sub Cell 9 and Policy Development Zone (PDZ) 11.

The current policy (epoch 1) for the urban frontage of Barmouth North Promenade is to continue to 'hold the line'. The SMP2 identifies significant pressures on the shoreline defences to the north of Barmouth. With the additional implications of climate change and sea-level rise, it suggests the present alignment is likely to become increasingly difficult to sustain. As such, for the medium and long term (epochs 2 and 3 respectively) the SMP2 recommends a change in approach to 'managed

File Note

264326

26 October 2018

realignment'¹. To the south the SMP2 policy for the area of southern Barmouth, Barmouth harbour and the access road to Barmouth is to 'Hold the Line' across the defined epochs.

Barmouth, and in particular, its north promenade are identified as at risk of coastal flooding and erosion. It is commonplace to see overtopping at the northernmost end of the promenade in what could be described as relatively "normal" conditions i.e. median level tides, without surge, swell, low pressure or high winds.

Between September 2018 and March 2019, the study will assess the flood and erosion risk in the area, appraise options and produce an outline business case recommending a preferred option. Options will be appraised to test if they are technically feasible, economically viable and environmentally acceptable. If the study identifies a feasible solution, then applications for funding will be made. If these are successful, further assessment, design and consultation will be undertaken, over several years.

Draft

¹ SMP2 Definition of Managed Realignment (MR): by allowing the shoreline to move backwards or forwards, with management to control or limit movement (such as reducing erosion or building new defences on the landward side of the original defences). The intention of a policy of MR is to either create or allow the conditions for the coast to realign and/ or retreat. (West of Wales SMP2, 2012)

File Note

264326

26 October 2018

2 Existing Information Review

2.1 Barmouth North Promenade PAR (2014) & (2017)

A Project Appraisal Report (PAR) was developed in 2014/15 by Martin Wright Associates, with a further revision in 2017 by Civil Engineering Solutions. These studies include a Structural Assessment of the Existing Structure, a summary of which is provided below:

General observations (Steel Sheet Piling and Beach draw down)

Steel Sheet Piling (Scour Protection)

Existing steel sheet piles had been subject to corrosion but without showing signs of failure. Based piling properties data sheet, the PAR noted an anticipated design life for Larssen 1 U sheet piles in seawater environment as 60 years with predicted final thickness of approximately 4.8mm. Observed minimum section thickness was 4.8mm and so it could be concluded the sheet piling had exceeded its design life. An initial assessment of the required minimum thickness of sheet pile to meet the loading criteria was undertaken for guidance.

Beach draw down

The visible underlying strata of cobble beach, the significant exposed depth of steel sheet pile and the elevated position of the lower steps indicate significant beach draw down. The PAR estimated that the beach level at construction would have been in the region of between 1.5m to 2m higher than current levels.

Structural observations (Seawall and Adjacent Sea Defence Structures)

Seawall

The seawall frontage together with the revetment and crest wall appeared in 2014 to be in a stable condition with no obvious significant movement. However, cracks and open joints were noted to the northern end return wall and on the main frontage to the side walls and steps to the seaward side of the wave wall on the line of the timber groynes. Although these did not appear to be affecting structural performance, from a durability point of view it was recommended to be repaired with a non-shrink grout suitable for the environment.

In addition, the PAR highlighted several alterations since the 1954 record drawing of the sea wall and highway.

Sheet Piling (Toe)

The 2014 structural assessment highlighted the steel piles have appeared dilapidated in places and generally the surface appeared heavily weathered, however these were considered able to continue performing satisfactorily for up to 25 years. Shingle abrasion of northernmost existing piles resulted in due to loss of section. No immediate remedial works were considered required. Recommendations included; annual monitoring for movement, measurement of sheet piling thickness was recommended, and protective measures to increase design life.

File Note

264326

26 October 2018

Timber Groynes

Northernmost groynes had the majority of boards damaged or missing. Repair and replacement would not significantly reduce wave loading and overtopping.

Footway and Secondary/Tertiary Walls

Both the seaward and landward masonry walls to the highway had sections missing and there were damages and cracks in remaining sections of wall. The boundary walls had been ineffective in both resisting the wave loading and preventing overtopping. Consideration should be given to a new defence wall to contain sea inflows and resist wave loading.

The paved area between the sea wall and highway had numerous cracked concrete slab panels. The majority had a single full-length crack s positioned towards or at the centre of the panel. The majority of the cracking appears was attributed to thermal movement from insufficient movement joints. From record drawings, concrete slab panels are ground bearing, however where loss of fines has occurred to the underlying ground, the slab panels could be spanning over the voids created. The PAR recommended voids were filled and cracks sealed with suitable flexible material to suit the environment. Grouting of the cracks was not recommended given the lack of movement joints in the pavement.

Promenade

From concrete cores at various locations along the frontage, the majority of the promenade contained no sign of void creation. Adjacent to the main slipway voids from loss of fines were found. Further remedial works were recommended. [See Section 2.4]

2.2 Barmouth North Promenade PAR Review (2018)

The 2018 report by Mott MacDonald Limited (MML) was to review the previous PAR reports and associated documents to date, and identify where additional work is required.

MML provided observations on the existing coastal defence assets following a site walkover by the MML on 13/12/17. The following comments were recorded from visual inspections:

“The southern promenade defences are in good condition as they are well defended from wave action by the natural dunes and healthy beach levels”.

“The beach levels are lower and their seaward extent reduces as you move northward along the frontage.”

“The exposed footings were more pronounced with larger extents of concrete exposed.”

“Significant drops in beach levels were observed between some adjacent groyne bays. Other groyne bays demonstrate a more gradual lowering of beach levels.”

“Low beach levels and wave action is leading to the undermining of concrete access steps and the sea wall.”

“Sheet piles were exposed at the northern end of the promenade and corrosion of the sheet piling was clearly visible.”

File Note

264326

26 October 2018

“Besides the defence toe, the rest of the defences (blockwork revetment and wave recurve wall) are generally in good condition throughout the study area.”

“The setback walls are in good condition considering their age. As the setback walls are not impacted on a regular basis by wave action these components of the defence system should have a reasonable residual life assuming they are well maintained and failure from undermining of the sea wall does not occur.”

“At the far southern end the timber groynes were buried so rates of deterioration are expected to have been slower. Visible sections at the southern end were mostly in good condition. The condition of the timber groynes deteriorates substantially moving northwards. At the far northern end some groynes have been reduced to only a handful of remaining piles and planks.”

“The shingle berm in front of the railway line north of the promenade is in good condition. Given the good condition of this shingle embankment, there is the potential that this may be proactively managed.”

“A number of ‘demountable’ stop logs were seen to be deployed, with a number fixed in place.”

The report concluded defences deteriorate in condition towards the north of the study area with beach lowering leading to undermining of the sea wall and access steps. The upper section of the sea wall and setback defences were overall in a good condition throughout.

Timber groynes were also in a poor condition to the north of the study area with notable voiding caused by missing timber planks. There was minimal evidence of beach retention by the existing timber groynes, calling into question their effectiveness along this section of coastal frontage.

2.3 YGC Asset Inspections (2010 - 2016)

Records from visual inspections by YGC between 2010 and 2016 have been provided. Inspections were subdivided into the North Promenade and North End Slipway. Inspection photos are included in Appendix 2.

From 2010 to 2013 both sea wall and toe were assessed as in fair condition, with large cracks noted in 2016. Since 2014 a loss of sea wall joint sealant has been recorded. From 2015 extensive toe corrosion was recorded.

Since 2010, access steps have been recorded to be in poor condition, with cracking and spalling. The stairs to the beach were weathered, abraded and hanging above the beach (note these have now been closed off at the upper level).

In 2010 the concrete surface of the slipway was considered in a good condition. During the 2011 inspection, weathering of the surface at the lower end as well as severe weathering of joints in some places of the slab with sealant missing was recorded. Moreover, damage was noted on the edge of the slipway.

Despite 2012 repair works, further damage has been recorded with sealant missing and damage to the slipway wall. A collapse occurred in the 2016 winter storms as fines were washed out.

File Note

264326

26 October 2018

A summary of the YGC Asset Inspections and Grade Conditions from 2010 to 2016 for both the North Promenade and North End Slipway are outlined in the following tables:

Table 1. North Promenade Asset Inspection Condition Grades (YGC): 1 (Very Good) – 5 (Very Poor)

Inspection dates	08/10	12/10	07/11	03/12	10/12	07/13	06/14	06/15	09/16
Sea Wall	3	3	3	3	3	3	3	3	3
Toe	3	3	3	3	3	3	3	3	3
Revetment	2	2	2	2	2	2	2	2	2
Apron	2	2	2	2	2	2	2	2	2
Steps-Apron	4	4	4	4	4	4	4	4	4
Sea wall Recurve	2	2	2	2	2	2	2	2	2
Handrails	2	2	2	2	2	2	2	2	2
Steps-Access	2	2	2	2	2	2	2	2	2
Steps Sea Wall	4	4	4	4	4	4	4	4	4

Table 2. North End Slipway Asset Inspection Conditions Grades (YGC): 1 (Very Good) – 5 (Very Poor)

Inspection dates	07/10	12/10	07/11	12/11	03/12	10/12	07/13	06/14	06/15	09/16
Toe-Sheet Piles	-	-	-	-	-	3	3	3	3	3
Slipway	-	-	-	2	2	2	2	2	2	2
Slab (38.2 item)	-	-	-	4	4	4	4	4	4	4
Slab (38.1 item)	-	-	-	5	5	5	5	5	-	-

The tables indicate no significant deterioration in condition from 2010 to 2016, however identify aspects of the frontage in poor to very poor condition, including the frontage steps and apron, and the north end slipway slabs.

2.3.1 YGC Asset Inspection 2018

A further inspection was undertaken by YGC in October 2018. A summary of the key findings is outlined below. It is significant to note that the condition of the seaward toe and steel sheet piling and the exposed concrete face of the northern structure extents, have been downgraded from fair to poor since 2016 – indicating the continual damage and abrasion to the defences along the frontage.

“Shore, Sand and Gravel - Condition Grading of 4 (Poor): Beach levels along the structure fluctuate from South to North. The Southern end levels are high which encroach the structure whilst the northern end are extremely low, exposing the Sheet Piling.

File Note

264326

26 October 2018

Seaward Toe, Steel Sheet Piling – Condition Grading 4 (Poor): Majority of this element is completely covered by the beach, however what can be seen towards the northern end are sections of the sheet piling which has suffered major loss of thickness due to corrosion, which has led to holes/gaps being formed. There is evidence of some movement at the Northern end due to material loss from underneath the structure.

Exposed Face 1, Concrete – Condition Grading 4 (Poor): Unable to see some sections of the element but the sections that are visible is in fair condition, with localised spalling, lengthy cracking, loss of sealant material and some movement. The condition grading has been downgraded as evidence suggest a loss of backfill material. See recommendations.

Berm, concrete – Condition Grading 3 (Fair): Unable to see some sections of the element but the sections that are visible is in fair condition, with lengthy cracking, loss of sealant material and minor movement of wall.

Exposed Face 2, Masonry – Condition Grading (Good): On a whole the condition of the element is good with some mortar loss, joint cracking and minor missing wall and joint material being evident.

Exposed Face 3, Concrete – Condition Grading (Good): The condition of the element is good with some minor cracking and sealant loss.

Crest, Concrete – Condition Grading (Good): The condition of the element is good with some minor cracking and sealant loss.

Landward Face, Concrete – Condition Grading (Good): The condition of the element is good with some minor cracking and sealant loss.

Promenade, Concrete – Condition Grading (Fair): The element is showing signs of weakness due to the lengths of cracking evident throughout. The issue of cracking is more evident toward to northern end of the structure suggesting that the material loss experiencing is affecting the Promenade element. See recommendations.”

File Note

264326

26 October 2018

2.4 YGC Ground and Site Investigation (2014)

In April 2014 a dynamic cone penetrometer test report was undertaken on the concrete slabs of the promenade. Core holes were located as follows:

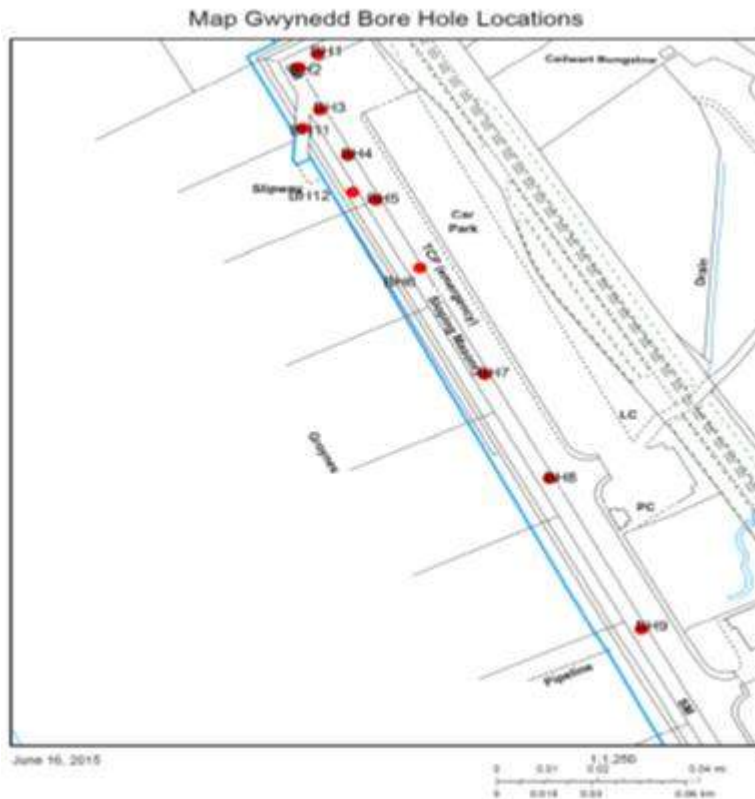


Figure 10: Map Gwynedd Bore Hole Locations



Figure 11 Bore Hole location 1

Concrete cores were taken at various locations of the concrete slab along the promenade. No void was recorded.

Trial holes at the toe of the defence were completed. The toe of the sheetpile was not assessed due to residual tide water in the excavations.

File Note

264326

26 October 2018



Figure 12: Sheet pile trial hole

2.5 Visual Site Walkover, 2018

A site walkover was carried out by Robin Campbell (Arup), Rosemary Jenkinson (Arup), Noelia Malvido (Arup) and Owain Griffith (YGC) on the 21st September of 2018.

Based on the observations made from the previous site walkovers and the additional available information sources reviewed as listed in Section 2, a qualitative assessment on the condition of the coastal defence structures has been carried out and is provided in **Appendix 1**.

General observations:

- At the northern end of the promenade notable deterioration in the characteristics and condition of the existing coastal defence assets was found. The beach levels have dropped since 2014. The corner mass concrete wall appeared to have some undermining. Cracking and significant fill material loss beneath the promenade slab was observed.
- Exposed sheet pile at the northernmost 200m, with signs of beach drawdown. Evidence of loss of sheet pile section and severe abrasion of concrete encasement was found at some locations (between chainage 0050-0100m approximately).
- Cracks and open joints, similar to those mentioned in previous assessments, are observed on the concrete slabs along the promenade (up to approximately chainage 1000m).
- Vertical cracks suggesting slight seaward movements at several locations along the frontage.
- Exposed groynes are found to be damaged. Many boards are missing and the damage is more evident towards the north. Limited deposits suggested a slight northwards sediment movement.
- The concrete wave wall on the southern of the promenade is in good condition due to the ample sediment supply that protects the promenade.

File Note

264326

26 October 2018

- Secondary masonry wall runs adjacent to the promenade, a number of repairs appear to have been undertaken (i.e. rebuilding the wall) where it has previously been subject to damages. The structure appears to be in a fair condition, however there is evidence of previous overtopping.
- Tertiary wall runs parallel to the secondary masonry wall on the opposite side of the Marine Parade highway, a number of stop logs (i.e. demountable flood defences) are present along the length of wall – both fixed in place and removed. The tertiary wall is constructed in similar materials to the secondary wall, and appears to be in a similar (i.e. fair) condition.

Images associated with the comments above are located spatially and discussed further in **Appendix 1**.

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File Note

264326

26 October 2018

3 Discussion

A summary of the condition of the various structures is compiled in the table below following the various reviews that have been discussed in this report.

Table 3: Qualitative description of the condition of the existing structures

Element	Description of Condition	Discussion
Concrete retaining wall structure	Poor to very poor	(Chainage 000-020m): Comparison between 2014 and 2018 photos shows significant beach drawdown has occurred. Undermining presents risk of fill washout. Presence of vertical cracks suggests slight seaward movement and the potential of settlement. YGC to consider implementing a monitoring programme.
Sheet pile toe	Fair to poor	(Chainage 020 – 0200m): The 2014 assessment assumed piles are 2m long as this was unable to be proved by intrusive investigation. From preliminary corrosion and structural capacity checks, the PAR suggested a residual design life of <20 years. Subsequent beach drawdown and the visible abrasion of the exposed toe with almost complete section loss in places reduces this residual life. Voiding at the northernmost corner section was visible at low tide. There was no evidence of lateral movement or deformation of the wall.
Wave wall and revetment	Fair to poor	(Applicable to the full length of the site): The wave re-curve structure appears to be minimal, limiting its ability to reduce wave overtopping in both ‘normal’ and extreme conditions. In locations there are cracks and missing expansion-joint fillers. The cracks suggest potential of movement or settlement of the structure has occurred. There are discontinuities in the structure at ramps along the frontage – one situated at the northern most end of the frontage and a further ramp adjacent to Heol-Y-Plas highway. These locations will provide low-spot pathways for coastal flooding.
Concrete steps on beach	Very poor	Loss of foundation material (up to approximately chainage 1000m): Concrete stairs for access to the beach are weathered and cantilevered from the revetment due to the erosion of underlying material. They are closed due to safety concerns preventing beach access but also preventing safe egress at times of rising tide, exacerbated but the groynes.
Promenade slabs	Poor	Cracks on footway (applicable up to approximately chainage 1000m): Cracks on the concrete slabs are evident. The 2014 PAR attributed these to thermal expansion and contraction. They may be a worsening and due to settlement/movements and exacerbated by washout from open joints and cracks. The 2014 intrusive survey found the promenade concrete slabs rest directly on granular material and sand. Sand is easily washed out of the cracks and unsealed joints, due to overtopping. Although no voids were reported in 2014, during the 2018 walkover extensive voiding was visible (over 1m in depth) through exposed joint in the northernmost area of the promenade. YGC to consider measures to protect public from risk of promenade collapse where slabs span void.

File Note

264326

26 October 2018

Element	Description of Condition	Discussion
Groynes	Very poor	Damage to piles and loss of timber boards (applicable to the full length of the site): Most of the groynes have been subject to substantial segregation, with the loss of timber panels from the exposed sections, particularly towards the north. The structures have lost functionality and appear to have limited impact on the movement of sediment across the frontage.
Secondary wall	Fair	(Applicable to the full length of the site): Masonry wall is non-structural – with minimal resistance to impacts. Previous events (i.e. 2014/2015 storms) highlight the vulnerability of this structure to damages – i.e. sections of the wall had to be re-built, providing potential entry points for flood waters. The present condition is fair, with previous signs of overtopping.
Tertiary wall and stop logs	Fair Stop logs considered fair to poor	(Applicable to the full length of the site): As above, masonry wall is non-structural, with similar issues to the above. There are un-flapped drainage pathways, providing potential entry points for flood waters. The condition is fair. Stop logs (i.e. demountable flood defences) are present along the length of wall – both fixed in place and removed. The fixed defences appear to have been in places for an extended period, subject to weathering and in fair to poor condition.
SW pumps and flapped outfalls	Fair	(Chainage 850m): Minimal information is available on the historical condition or existing performance of these assets (at the time of writing). From the site walk-over, the structures appeared to be in working order, with the flap valve working as intended with considerable outflows present and as such, the condition is expected to be fair. The SW pumps are understood to serve a non-main river watercourse. The northern watercourse does not have an exposed flap valve. It is assumed that there is a non-return sluice structure, pending YGC drainage information.

3.1.1 Sheet pile potential failure mechanisms

Where the beach level drops below the top of sheet pile level, the sheet pile acts as an embedded retaining wall, retaining the fill and the structure which will exert earth pressures on the sheet piles. The ground in front of the sheet piles acts as a restoring force, ensuring the system remains in equilibrium. As the ground level in front of the retaining wall reduces, the restoring forces are reduced due to the shortened embedded length of the sheet pile. When the beach level reaches a certain level, a failure will occur as the system is no longer in equilibrium. The main potential failure mechanisms are considered to be the following:

- Structural failure – the sheet piles are required to carry shear forces and bending moments down the length of the sheet piles to transfer the earth pressures behind the wall to the resistance round in front. A structural failure will occur the forces in the sheet pile exceed the structural capacity of the sheet pile section. The capacity of the sheet pile to carry the forces is dependent on the strength of the steel, cross sectional profile and the cross-sectional area. The cross-sectional area is affected by the corrosion of the steel during the design life of the structure, and significant corrosion has been observed.

File Note

264326

26 October 2018

- Stability failure – A stability failure will occur when the earth pressures from the retained material exceed the restoring forces provided by the material in front of the sheet pile. This will typically result in a rotational failure of the sheet piles with the point of rotation occurring near the toe of the sheet pile.

Should a failure occur, this would result in the slumping of material immediately behind the wall. This also may cause the overlying structure to collapse into the void. In addition, the material underlying the structure would be exposed and susceptible to further washout and progress failures, particularly if the failure of the sheet piles occurs during a storm event.

The original design intent for the sheet piles walls is unknown, and therefore the allowance for reduction in beach level in front of the wall is unknown. However, there is the potential that only a small allowance was made for reduction in beach level as it may have been assumed that remedial action would be undertaken should the sheet piles be exposed.

In order to accurately assess the potential for stability failure, further investigation would be required, however, the below commentary is provided in order to better understand the risk of failure without undertaking any detailed assessments for the purposes of preparing the Outline Business Case to understand the likely nature of the issue.

The stability of the wall is affected by the following factors:

- The ground levels and slope of the ground in front and behind the wall
- The engineering properties of the ground in front and behind the wall
- The water levels in front and behind the wall
- The structural capacity of the sheet piles
- The restraint provided by the tangs and concrete at the top of the wall

In order to assess the stability of the wall and also the shear and bending moments in the sheet piles, detailed calculations are required. An initial assessment could be made based on the available information and using reasonable assumptions.

A commonly used rule of thumb for cantilevered embedded retaining walls is 2/3 embedded length to 1/3 retained length. This ratio also includes some factor of safety against failure. It is therefore considered that should more than approximately 1/3 of the height of the wall be exposed, there is a risk of failure occurring. Should the sheet piles be 2m in length, then approximately only 1/4 of the length of the wall was recorded as being exposed.

3.1.2 Further considerations

Further considerations to the above should be noted:

- The existing and continuing structural defects impose significant hazards to the general public which may restrict the use of the structure in the future. **YGC to consider Public Safety Risk Assessment.**
- There was no available as-built information for the northern corner of the frontage. Information and sketches received from YGC on 2018 suggest that the structure is on RC concrete piles on concrete piles rather than a sheet pile toe as per the remaining end of the structure. This is an uncertainty within the review of the coastal defences. **YGC to provide information if available.**

File Note

264326

26 October 2018

- There is a risk of vehicle impact to both the sea-wave and the secondary and tertiary flood defence walls. The promenade is used by a land train and various service vehicles, as well as cyclists and pedestrians. The wave wall is directly accessed from the road at slipway locations with no barriers or bollards provided. The secondary and tertiary flood walls are non-structural masonry walls and there are several junctions, meaning vehicles could impact directly on the walls.

Further consideration of a design parameters and a risk assessment for vehicle containment of these structures is required prior to option long-listing and development. A design risk assessment is recommended to inform whether the outline design should allow for provision of a vehicle restraint system as part of the promenade parapet proposals. **YGC to consider and advise.**

3.2 Walkaway and Business As Usual

‘Walkaway’ and ‘Business As Usual’ cases have been considered (in line with the Welsh Government FCERM-BCG):

Walkaway

In the absence of maintenance, progressive structural failure of the sea-wall and revetment is reasonable to assume, with the northern most area at greatest risk. Washout of infill material from unsealed joints, cracks and openings through corroded piles would be the most likely cause. The exposure and corrosion of the sheet piles will become more pronounced with more wave attack and erosion of the beach expected at the toe. Over time the progressive failure of the sheet pile toe due to abrasion and corrosive section loss is likely. The 2014 PAR estimated a further 10 to 15 year residual life, it is reasonable to assume a residual life of less than 10 years.

Should beach drawdown continue (pending Coastal Process Study) then the global stability of the structure from sheet pile toe exposure increasingly becomes a concern, as outlined in Section 3.1.1.

The wave wall and promenade is expected to experience frequent overtopping (both white and green water overtopping). The increase in flows along the promenade slabs will further act to unseal and weaken joints, providing additional pathways for material washout beneath the promenade structure. Eventually the loss of granular material will reach the promenade, affecting the secondary wall and highway – impacting on vehicular access along the Marine Parade.

The on-going deterioration of the structure and sheet pile section loss, coupled with the wash-out of material is likely to lead to failure of the sea-wall and revetment structures. This will ultimately lead to a breach in the defences, with significant coastal flooding associated – this is largely expected to directly impact the land-uses behind the frontage, including the Heol-Y-Llan housing estate, with floodwaters extending north/south of the study area. The failure of the frontage will lead to limited access, particularly to the northern extents, of the promenade and the continued deterioration of the structures are likely to pose a safety hazard and eye-sore to the local area. The serviceability of the promenade will be compromised, impacting accessibility to the beach and general usage by the public.

This series of events will further exacerbate drainage issues along the promenade. The highway and promenade drains are likely to become blocked with sand and the surface water drainage flap valves and culverts ceasing to operate. The surface water pumps will not be operated. The resulting impact

File Note

264326

26 October 2018

will be increasing surface water flood risk along the promenade and potentially further upstream, as out-falling watercourses are unable to discharge appropriately.

The groynes will keep losing timber elements and eventually only some piles will remain. These elements have already lost their functionality; therefore, are unlikely to impact coastal risk (pending Coastal Process Study).

Business As Usual

Assuming the existing 'as and when' programme of inspection and maintenance is continued by YGC, continued works to the promenade and sea-wall and revetment will be required on an increasingly regular basis – including filling of voids, sealing of joints and mortar replacement of the revetment. Additional cracking or joint movement on the revetment or the promenade might cause further loss of granular material, therefore joints and cracks will need to be regularly maintained.

The secondary wall is expected to be subjected to continued overtopping and as a result, experience multiple failures. YGC will need to undertake multiple repairs to the masonry wall as has been undertaken previously.

Measures to protect or replace the sheet pile section and arrest the abrasion/corrosion are likely to be significant and not considered a do-minimum intervention. Therefore, continued loss of structural section is expected and the residual life of less than 20 years would not be considered unreasonable.

4 Conclusion

In the absence of investment, under a 'Do Nothing' scenario, it is expected that the current coastal defences would progressively fail (initially in certain locations), during significant storms event.

Whilst maintenance could address voiding, measures to protect or replace the corroding sheet piles will be more significant.

Detailed examination and intrusive testing is recommended to quantify the residual life of the structure. With the extensive voiding visible from the toe of the sheet piles and the promenade slab joint, the structure at the northernmost area appears at risk of progressive failure should a significant and prolonged storm period continue to cause washout of fill material.

File Note

264326

26 October 2018

5 References

Final Project Appraisal Report PAR (2014). Martin Wright Associates.

Appendix C- Ground Investigation Report. (April 2014). Sandberg Consulting Engineers.

Appendix D- Structural Assessment. (April 2014). Martin Wright Associates.

Barmouth North Promenade PAR Review (March 2017). Civil Engineering Solutions Ltd.

Barmouth North Promenade PAR Review (February 2018). Mott Macdonald House.

Asset Inspections 2010-2016. YGC (Ymgynghoriaeth Gwynedd Consultancy).

Ground and Site Investigation. YGC (Ymgynghoriaeth Gwynedd Consultancy).

Site Walkover 21th September 2018 (Arup)

Scanned historic cross-sectional drawings

DRAFT

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264326

26 October 2018

Appendix 1 – Structural Review

Barmouth North Promenade – Plan of visual surveys for PARs

Draft



Legend

TYPE

- Sea wall and Revetment
- Secondary wall
- Tertiary wall
- Groynes
- Chainage along frontage (m)
- Demountable barriers
- Surface water culvert
- Surface water pumps and flapped outfalls

Elevation (mAOD)

<0
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
>16

P0	2018-10-04	NM	RJ	RC
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Issue	Date	By	Chkd	Appd
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Metres

0 100 200 400

ARUP

4 Pierhead Street
Cardiff CF10 4QP
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www.arup.com

Client

YGC
(Ymgynghoriaeth Gwynedd Consultancy)

Job Title

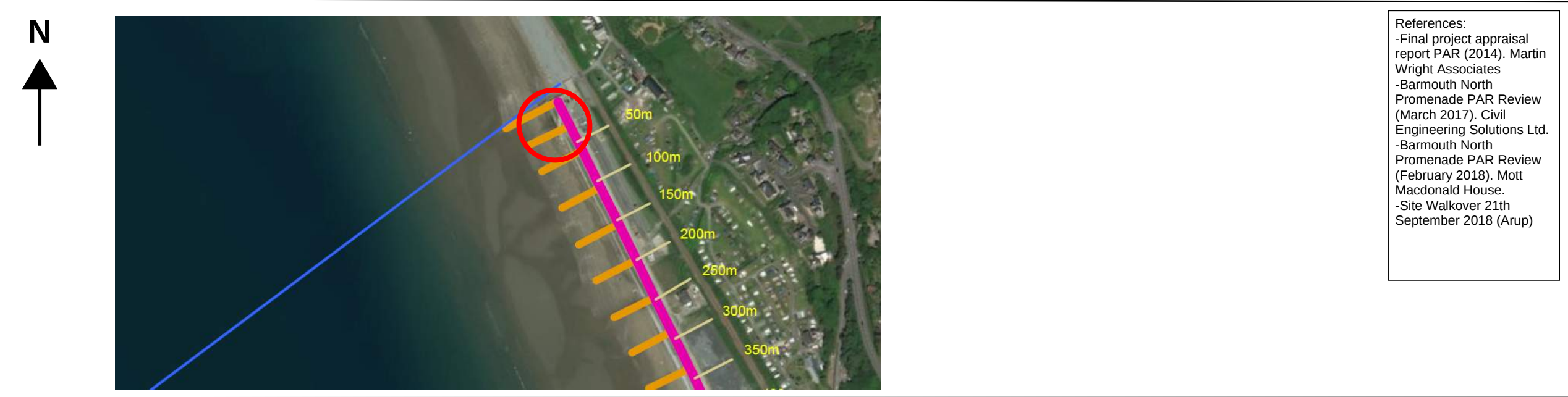
Barmouth North Promenade

Existing Structures Spatial Arrangement

Scale at A3

1:7,500

Job No	Drawing Status
264326-00	Preliminary
Drawing No	Issue
SKT-002	P0



Legend

TYPE

Sea wall, promenade and stone revetment

Groynes

Chainage along frontage (m)

Area in consideration

0000-0030m						
	0000-0010m	0000-0010m	0000-0010m	0010-0020m	0010-0020m	0020-0030m
PAR 2014						
PAR Review 2018						
Site Walkover September 2018						
Notes	2014: General photo of the north facing extent of the promenade. 2018: A shingle embankment provides flood and erosion protection to the railway line. 2018 (Arup): Loss of beach material has reached the base of the structure. Risk of undermining.	2014: Abraded cold joint at the northern extent of the promenade. 2018 (Arup): This seems to be in similar condition in 2018.	2014: Vertical joint suggesting slight seaward movement at the northern side of the promenade. 2018 (Arup): The joint aperture does not show additional movement.	2018 (Arup): Open joints suggest displacements, maybe due to settlement.	2018 (Arup): Fill material loss through one of the promenade slab joints.	2014, 2018 review and 2018 (Arup): Some groynes at the northern end of the beach are in extremely poor condition, in some cases the majority of boards are missing and the existing piles are rendered useless due to loss of section through the effect of shingle abrasion.

P01	2018-10-12	NM	PA	
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Issue	Date	By	Chkd	Appd

ARUP

Client

YGC
(Ymgynghoriaeth Gwynedd Consultancy)

Job Title

Barmouth North Promenade

Visual representation of defects on the vertical concrete retaining wall and stone revetment. Sheet 1 of 6

Scale at A3

Job No	Drawing Status
264326-00	Preliminary
Drawing No	Issue
SKT-003	P01



Legend

TYPE

Sea wall, promenade and stone revetment

Groynes

Chainage along frontage (m)

Area in consideration

P01

2018-10-12

NM

PA

Issue

Date

By

Chkd

Appd

ARUP

Client

YGC

(Ymgynghoriaeth Gwynedd Consultancy)

Job Title

Barmouth North Promenade

Visual representation of defects on the vertical concrete retaining wall and stone revetment. Sheet 2 of 6

Scale at A3

Job No

264326-00

Drawing Status

Preliminary

Drawing No

SKT-004

Issue

P01

0030-0100m					
	0030-0050m	0050-0060m	0050-0060m	0060-0070m	0070-0100m
PAR 2014					
PAR Review 2018					
Site Walkover September 2018					
Notes	2014: A significant proportion of the steel sheet pile is exposed at the northern side of the promenade, through years of beach draw down. 2018 (Arup): Further draw down of beach material has occurred since 2014, further exposing the sheet piles. Voids are present behind the sheet piles.	2014 & 2018: Existing sheet piles have been subject to corrosion from exposure. 2018 (Arup): Further material draw down has occurred affording less protection to the sheet piles.	2018 & 2018 (Arup): The majority of the groynes (even those in better condition) at the northern end are having no effect as the beach level is below the level of the bottom plank	2014 & 2018: Evidence of partial loss of the steel sheet pile section and severe abrasion of the concrete encasement. 2018 (Arup): Continued corrosion of materials has occurred.	2014: Damage to the masonry walls andjacen to the turning head at the northern extent of the promenade. 2018 (Arup):Those previous damages to the mansory wall have been repaired



Legend

TYPE

Sea wall, promenade and stone revetment

Groynes

Chainage along frontage (m)

Area in consideration

P01	2018-10-12	NM	PA	
Issue	Date	By	Chkd	Appd

ARUP

Client

YGC
(Ymgynghoriaeth Gwynedd Consultancy)

Job Title
Barmouth North Promenade

Visual representation of defects on the vertical concrete retaining wall and stone revetment. Sheet 3 of 6

Scale at A3

Job No	Drawing Status
264326-00	Preliminary
Drawing No	Issue
SKT-005	P01

0100-0220m					
0100-0120m	0150-0170m	0190-0210m	0190-0210m	0210-0220m	0210-0220m
PAR 2014 					
PAR Review 2018					
Site Walkover September 2018 					
Notes 2018 (Arup): Notable beach draw down exposing the underside of existing steps (note that the steps have been closed off at the upper level).	2018 (Arup): Cracking observed on the first wall of the promenade and throughout the defences. Probably due to settlement of the structure.	2018 (Arup): Cracks and displacement of joints are present in several places along the promenade. This can result in a loss of granular material from underneath the slabs if the voids are not filled. Cracks found parallel to the promenade alignment may be due to settlement of the defence sea-wards.		2018 (Arup): The promenade exhibits a large number of structural discontinuities.	2018 (Arup): Stop logs at northern extents of the promenade.



Legend

TYPE

Sea wall, promenade and stone revetment

Groynes

Chainage along frontage (m)

Area in consideration

0230-0360						
	0230-0240m	0250-0260m	0280-0300m	0300-0320m	0320-0340m	0340-0360m
PAR 2014						
PAR Review 2018						
Site Walkover September 2018						
Notes	2018 (Arup): Dilapidated groynes serving no purpose.	2018 (Arup): Presence of a surface water culvert out-falling along the beach, with no sluice or flap-valve present.	2014: Damage to masonry walls adjacent to the Promenade Café. 2018 (Arup): Damages have been repaired but there is evidence of previous wave overtopping	2014: Damage to existing concrete steps (note cold joint abrasion is present) 2018 (Arup): The concrete steps have been repaired	2018 (Arup): Current defences are a vertical sheet piled sea wall, concrete platform, blockwork revetment, concrete wave recurve wall. Clear designs of disrepair in the steps and the defence structure can be seen	2018 (Arup): Vertical joint suggesting slight seaward movement.

P01	2018-10-12	NM	PA	
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Issue	Date	By	Chkd	Appd

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Client

YGC
(Ymgynghoriaeth Gwynedd Consultancy)

Job Title

Barmouth North Promenade

Visual representation of defects on the vertical concrete retaining wall and stone revetment. Sheet 4 of 6

Scale at A3

Job No	Drawing Status
264326-00	Preliminary
Drawing No	Issue
SKT-006	P01



Legend

TYPE

Sea wall, promenade and stone revetment

Groynes

Chainage along frontage (m)

Area in consideration

0360-0650					
	0360-0380	0390-0400	0490-520	0620-0640	0640-0650
PAR 2014					
PAR Review 2018					
Site Walkover September 2018					
Notes	2018 (Arup): Presence of joints along the revetment which require additional repointing.	2018 (Arup): In some specific points the groynes are completely damaged. The groyne here appears to have been refurbished historically with a different type of wood which has not weathered as well.	2018 (Arup): Some metal joints in groynes exhibit oxidation and corrosion.	2014: Damage to the masonry walls adjacent to Tai'r Heli 2018 (Arup): The walls have been reconstructed	2018: A number of "demountable" stop logs were seen to be deployed. (In the photo appeared to be fixed in place.) 2018 (Arup): Same location without the stop logs.

P01	2018-10-12	NM	PA	
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Issue	Date	By	Chkd	Appd
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ARUP

Client

YGC
(Ymgynghoriaeth Gwynedd Consultancy)

Job Title

Barmouth North Promenade

Visual representation of defects on the vertical concrete retaining wall and stone revetment. Sheet 5 of 6

Scale at A3

Job No	Drawing Status
264326-00	Preliminary
Drawing No	Issue
SKT-007	P01



Legend

TYPE

- Sea wall, promenade and stone revetment
- Groynes
- Chainage along frontage (m)
- Area in consideration

		0840-1900m			Beyond extents of study	
		0840-0860m	1040-1060m	1240-1250m	1490-1500m	1850-1900m
PAR 2014						
PAR 2018						
Site Walkover September 2018						
Notes	2014: During storm events flood waters were actively pumped from the road's drainage system over the sea defences 2018 (Arup): The system is considered to be in good condition structurally, except oxidation damage on the seaward face	2018 (Arup): Outfall point of surface waters. Flap valve considered to be in fair condition and working as expected.	2018 & 2018 (Arup) : Secondary wall has been retrofitted with benches	2018 & 2018 (Arup): A significant dune system has formed to the southern extents of the frontage, protecting the southern end of the promenade from wave action.	2018 & 2018 (Arup): Concrete wave wall on the southern of the promenade is in good condition	

P01	2018-10-12	NM	PA	
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Issue	Date	By	Chkd	Appd
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Client

YGC
(Ymgynghoriaeth Gwynedd Consultancy)

Job Title

Barmouth North Promenade

Visual representation of defects on the vertical concrete retaining wall and stone revetment. Sheet 6 of 6

Scale at A3

Job No	264326-00	Drawing Status	Preliminary
Drawing No	SKT-008	Issue	P01

File Note

264326

26 October 2018

Appendix 2 – YGC annual asset inspection images

North Promenade General Observations:

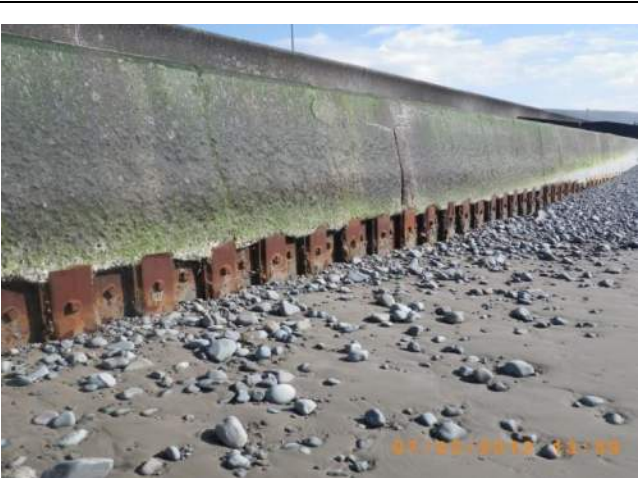
In the following tables presented below are shown the main issues localised (illustrated with pictures) on different elements per years.

Year	Structural Elements – Sea wall / toe	
2010		
2011		

File Note

264326

26 October 2018

2012		
2013		
2014		

File Note

264326

26 October 2018

2015		
2016		

File Note

264326

26 October 2018

Year	Safety elements – Steps, Apron (Groyne 16)
2010	A photograph showing a concrete structure with three steps leading up to a flat apron. A blue bucket is placed on the apron. In the background, a beach and the sea are visible. A photograph showing the same concrete structure from a different angle, highlighting the steps and the apron. A blue bucket is also visible.
2011	A photograph showing the concrete structure with steps and apron. A date stamp in the bottom right corner reads "20/07/2011 14:08".
2013	A photograph showing the concrete structure with steps and apron. There is a pile of gravel or stones at the base of the steps.

File Note

264326

26 October 2018

2014	
2015	

File Note

264326

26 October 2018

2016	
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File Note

264326

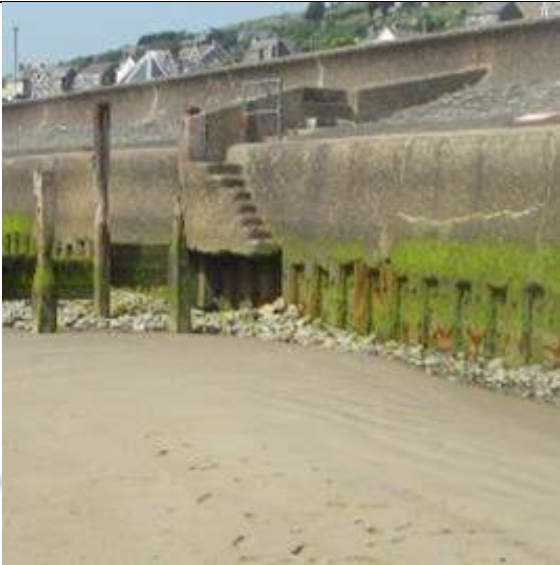
26 October 2018

Year	Other elements - Steps to the beach from the sea wall	
2010	 A photograph showing a concrete structure with several steps leading down to a sandy beach. A blue rectangular marker is placed on one of the steps. The concrete is weathered and has some green algae or moss growing on it.	
2011	 A photograph showing a concrete structure with a wooden post leaning against it. The concrete is weathered and has some green algae or moss growing on it. The ground in front is covered with small stones and pebbles. A date stamp '04/03/2011 14:15' is visible in the bottom right corner.	
2012	 A photograph showing a concrete structure with several wooden posts in front of it. The concrete is weathered and has some green algae or moss growing on it. The ground in front is covered with small stones and pebbles. A date stamp '07/03/2012 13:39' is visible in the bottom right corner.	

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264326

26 October 2018

2013	 Groyne 25	 Groyne 27
2014		
2015		

File Note

264326

26 October 2018

2016	
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North End Slipway General Observations:

Year	Slipway (<i>Structural element</i>) and Slab (<i>Safety element</i>)	
2010		

File Note

264326

26 October 2018

2011	
2012 March	
2012 October	

File Note

264326

26 October 2018

2013	
2014	
2015	

File Note

264326

26 October 2018

2016	
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Further Comments and Examples from site inspections:



*Back of parapet, 5th groyne from north,
weathering of joint edge*



Example of vertical crack in parapet

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264326

26 October 2018



Parapet joint sealant missing - near north slipway



*Crack in back of parapet opposite
end of Tai'r Heli*



Base of concrete haunch exposed



Flap valves missing

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264326

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Pipe removed between groynes 23&24



Safety railings at Groyne 26 need removing

DOCUMENT CHECKING (not mandatory for File Note)

	Prepared by	Checked by	Approved by
Name	Rosemary Jenkinson	Paz Arteijo	Robin Campbell
Signature			