Retaining Wall Issue South of Trafalgar Bridge SA1.

Client – Welsh Government (WG)

Undertaken by – Shoreline Management Wales (SMW) – CEDM Ltd.

July 2024

CONTENTS

APPENDICES

1 - The Brief:

To undertake an inspection and assessment of the rock retaining wall and the supporting rock embankment on the east side of the Tawe between Trafalgar Bridge and a masonry promontory in SA1 (Swansea). To consider and draw up solution options for a period of 10 – 15 years with annual maintenance taking into account topographic information and a qualitative assessment of the local coastal process environment.

2 - Introduction and Background.

Shoreline Management Wales T/as CEDM Ltd (SMW) was asked by Welsh Government (WG) to carry out an assessment of a retaining wall south of Trafalgar Bridge in SA1 (Swansea). An order was issued 20th May 2024 following submission of a proposal for a purchase order in early March 2024. It is understood that other parties have been assisting WG for a period although SMW has not had sight of any formal advice or reports that may have been produced for WG by third parties prior to this commission.

The retaining wall first started showing signs of distress in December 2021. SMW was engaged by WG at the time to investigate a project concerning the Prince of Wales Dock. SMW also has a broader professional interest in coastal engineering in Wales and a personal maritime interest in Swansea and the Tawe, as a consequence of having vessels based in Swansea Marina. Issues concerning the retaining wall were first observed and reported by SMW on 14th December 2021 and photographs were taken of scouring along some sections of the toe of the rock retaining wall. After the issue was initially identified, SMW observed and photographed the wall from time to time and a dated photographic record is presented in this report in Appendix I, Photographic Record Sheet 1 – Historic. Further historic information was prepared and presented as part of this commission in the form of additional historic photographic record sheets located in Appendix I.

The formal site inspection for this report was carried out at the beginning of May 24. This section, Section 3 along with the inspection sheets in Appendix II commences with a general description of the structure and the surrounding area which includes a qualitative assessment of Coastal Processes. This observational assessment of processes is not detailed or extensive and is not intended as a substitute for quality time series data or possibly a detailed modelling assessment that would ideally be available. Time and budgetary restrictions did not allow for extensive data acquisition and monitoring although it would be useful to discover and acquire any and all available data that may have been collected by third parties recently and historically.

The site survey was undertaken on 18th May 2024 using a drone, following the establishment of GPS ground control and regulating data points. The additional ground information that was gathered using a GPS survey system was used to regulate the aerial data. The site based work was completed on 18th May 2024 and desk work continued through the remainder of May and early June 2024. The desk-based work examined the engineering options and concluded with a preferred outline design for works. The provisional works are presented on a plan with typical cross sections.

The final report with appendices is in electronic PDF form and comprises separate files for ease of reading and with reference to the appendices. The original data comprises large files which are too large for email transfer although some of the key files have been provide via WE transfer (drone video).

3 – Inspection and General Assessment.

3.1 - The General Disposition of the Site Over Time, the Surrounding Area and Processes.

The rock retaining wall is a structural element that supports the adjacent promenade and is founded on an existing rock embankment. The rock retaining wall comprises two layers of substantial edge armour with a bedstone berm or shoulder of varying width bridging the crest of the wall and the edge beam defining the promenade.

The area was historically an embankment with the adjacent land set at a lower crest than is currently the case compared with the elevated promenade. Google Earth records are presented for reference in Photographic Record Sheet 2 – Historic and Sheet 3 in Appendix I. The sheets include Google Earth imagery extending from 1999 to 2024 and sheet 3 also has some ground-based shots. It is essential to examine the general disposition of the surrounding area in terms of the current and historical environment. Changes made in the Tawe area over time will potentially have knock on effects and these require some examination and record. This is particularly important with regard to coastal processes which, for the purposes of this review, can be assumed to refer to tide and the actions of waves propagating up the Tawe towards the Barrage. The following tables provide a description/ date and narrative/ observations and reference should made to the Photographic record sheet in Appendix I.

Photographic Record Sheet 1 – Historic.

Plate Ref.	Description	Observation
1	14th Dec 2021	These are images of the first recorded erosion along the toe of the rock armour retaining wall. Some of the rip rap / bedstone material forming the original embankment has been eroded along the interface between the toe of the rock armour wall and the embankment has been dislodged creating localised undermining of the rock wall.
2	14th Dec 2021	
3	14th Dec 2021	
4	14th Dec 2021	
5	28th Dec 2021	Swell waves sweeping along the toe almost parallel to the line of the rock wall and embankment.
6	1st Jan 2022	Localised area of toe scour where the stone along the crest of the embankment has been dislodged by wave action resulting in a section of the wall being undermined.
7	1st Jan 2022	
8	5th Feb 2022	Wave action sweeping along the embankment and toe of the rock wall.
9	20th Jan 2023	1st collapse of a small section of rock wall as a result of the undermining along the toe, which appears to have started around December 2021.
10	20th March 2023	Embankment scour and undermining of the rock wall accelerates through the winter storm season and inevitably more extensive failures occurred. The rock wall has failed as a result of the erosion of the embankment below and on which the rock wall was constructed.
11	20th March 2023	
12	14th April 2024	Undermining continued and further localised collapses have occurred. The wall is currently suffering from extensive undermining and there is a high risk of a general or complete collapse which would affect the promenade.

Summary Assessment – Sheet 1

The rip rap/ stone embankment started to erode in the early winter of 2021 resulting in the undermining of a section of the rock wall. Erosion of the bedstone embankment with the resultant undermining of the rock wall continued from December 2021 to January 2022 when the first partial collapse of the rock wall occurred. The wall held up well through an extended period of significant storm activity despite being compromised by the loss of the embankment material along the toe. The range of possible reasons for the erosion of the embankment will be considered later although the immediate or local coastal process environment should be referenced. Notwithstanding the likelihood that the wave climate in the adjacent Tawe has been modified by external factors, the local interaction between the rock wall and the bedstone embankment is relevant. There will be an interaction between the vertical rock wall and the top of the adjacent embankment acting as an apron in front of the toe of the rock wall. Waves propagating up the Tawe will not hit the embankment and rock wall perpendicularly but will rather sweep across obliquely. This may limit but not eliminate reflected wave energy or the possibility of some interaction/ scouring effect resulting from the presence of the rock wall.

Photographic Record Sheet 2 – Historic.

Plate Ref.	Description	Observation
1	December 1999	This is a strategic view of the Tawe approaches to Swansea dock and the area between the locks for the commercial port and Tawe Barrage/ Tawe lock to Swansea Marina. The promontory in the centre of the upper reaches of the Tawe can be seen with the open area access to the former dry docks to the east. The open area and area along the east side of the Tawe appears to be heavily silted up.
2	December 2003	This is a view of the central promontory referred to above and the rip rap embankment between Trafaglar bridge and the rectangular structure at the seaward end and on the western side of the promontory. This is the embankment on which a number of developments would be constructed including the latest promenade with rock armour wall protection.
3	December 2005	Remedial works appear to be underway to prepare the site for development with site clearance.
4	December 2010	The open area to the east has been infilled and the land reclaimed. A connection has also been made to the rectangular structure referred to in 2 above with a footpath on the top of the rock embankment.
5	July 2013	A rock revetment has been constructed along the seaward flank of the infilled area and a new stepped structure has been built extending east from the rectangular structure referred to above.
6	June 2018	There appears to be a line of vegetation along the pathway that has been constructed on the top of the rip rap embankment. There also appears to be construction activity underway or a site compound on the area adjacent to the rock embankment/ former promontory.
7	June 2020	This view shows the latest development which includes the following; 1 - The removal of the stepped structure extended east from the rectangular structure; 2 – The raising of the threshold levels and an extension to the rock revetment across the front of the infilled area to the east; 3 A new promenade and the appearance of the rock retaining wall.
8	June 2020	These views show the general disposition of the promenade works, the rip rap embankment and SA1 development in relation to the Tawe approaches to the barrage. The navigation channel should be noted along with the presence of the crib wall structure forming the inner portion of the west breakwater. The crib wall is in poor condition and will eventually be replaced with a solid sheet pile wall. The wave climate in the upper reaches of the Tawe approach to the barrage would have been heavily influenced by local bathymetry and the containing structures. It is clear that the western boundary of the Tawe along the upper reaches comprised an energy absorbing cribwall.
9	June 2020 Oblique 1	
10	June 2020 Oblique 2	
11	June 2020 Oblique 3	
12	June 2020 Oblique 4	

Photographic Record Sheet 3 – Historic.

Plate Ref.	Description	Observation
1	September 2021	This is a view of the upper reaches of the Tawe approaching the barrage and Tawe Lock. The image shows the promenade and rock wall on the east side of the Tawe and also construction underway on the inside face of west breakwater to replace the crib wall with a solid sheet pile wall. The sheet pile wall was constructed in front of the existing and failing crib wall. It should be noted that the sanctuary pontoon servicing Swansea Marina is present at this time but was damaged and needed to be removed after completion of the sheet pile wall.
2	March 2024	This is a view of the middle/lower portion of the Tawe and sets out the general disposition of the structural elements. The former crib wall replaced with a solid sheet pile was present only in the upper reaches of the Tawe and starts from just opposite the old Cork ferry port.
3	March 2024	This is the latest view of the upper Tawe area and shows the collapsing rock wall.
4	August 2022	These are 2022 views of the Tawe area showing the navigation channel, new sheet pile wall on the west side and the promenade and rock retaining wall at SA1 on the east side. Particular reference should be made to Plate 7 and 8 which show the orientation of the rock wall and embankment on the east side relative to both the navigation channel and new sheet pile wall on the west side of the Tawe.
5	August 2022 Oblique 0	
6	August 2022 Oblique 1	
7	August 2022 Oblique 2	
8	August 2022 Oblique 3	
9	2018 Ground Shot 1	These are views of the crib wall located on the west side and upper reaches of the Tawe approaches to the Barrage and Tawe Lock. It is directly opposite the rip rap embankment and rock wall. The crib wall was in poor condition and partially collapsed in places. Waves propagate up the Tawe and the engineers of old clearly understood the need to control or mitigate the detrimental effects of wave energy in the restricted navigable region. The crib structure attenuates wave energy in the upper reaches of the Tawe and would have virtually eliminated any potentially damaging edge waves.
10	2018 Ground Shot 2	
11	2018 Ground Shot 3	
12	2018 Ground Shot 4	

Summary Assessment – Sheets 2 and 3

The SA1 area has undergone several stages of development in the last couple of decades. This started with the closing off and infilling of a dock area leading to the former dry dock on the east side of the Tawe. The central promontory became connected to the east breakwater of the commercial port and an energy dissipating rock revetment was installed along the seaward flank of the land reclamation area. A pathway was built on the rip rap/ rock embankment between Trafalgar Bridge and the rectangular structure on the seaward and western side of the promontory. It is likely that the rock embankment comprises old industrial material such as slag which is overlaid with a rock (limestone) rip rap revetment. The threshold levels have been raised on the promontory (area referred to above) and the latest promenade appears to have been established by 2020 along with a rock retaining wall which was built on the existing rock/ rip rap embankment. The embankment has clearly been in place well before the turn of the century although the geometry in the higher elevation has been modified in recent years. The effect of the introduction of new infrastructure at higher levels will need to be considered in relation to the tidal ladder. The topographic survey data indicates that the toe of the rock wall is at a level just above Mean High Water Spring tides and the crest of the wall is at a level of approximately 1m above Highest Astronomic Tide (HAT). The level of the promenade is 8m above ordnance datum which is around 2.5m above HAT. Thie would place the promenade well above the level of wave action with possible exception of the most severe and statistically rare storm events.

The upper reaches of the Tawe are narrow and confined and waves will propagate up the approaches to the barrage. This area is clearly not open coast and although the wave conditions are likely to be lower that the adjacent open coast, the confined nature of the upper Tawe will limit the attenuation of wave energy because of the presence of the reflective surfaces forming the boundaries. A key boundary structure influencing coastal processes will be the west breakwater and the presence, up until recently, of an energy dissipating crib wall arrangement in the narrow upper reaches of the Tawe. The navigation channel and bed levels are likely to also play a role and influence the wave climate in the upper reaches of the Tawe. The nearshore height of transitional waves will be governed by water depth and the resulting wave energy relationship to water depth is non-linear with wave energy increasing significantly for modest increases in water depth. Wave period is also relevant and longer swell waves will carry more energy up the Tawe during high tides. The presence of the former crib wall along the inside face of the west breakwater wall would have attenuated the wave energy in the upper reaches of the Tawe particularly on the west side. This would have been achieved by absorbing much of the edge wave which would otherwise impact, reflect and resonate from the hard surfaces in the confined area around the barrage. It is likely that the attenuation of the edge wave would have had a moderating effect on the adjacent wave crest of waves propagating up the Tawe channel.

In 2021, a solid sheet pile wall was constructed in front of the old crib wall thereby removing the energy dissipating benefit provided by the crib wall structure. The new sheet pile wall will be considered further in Sheet 4. It is however worth refencing the aerial Google Earth images which illustrate the confined nature of the upper reaches of the Tawe and the position of the key elements such at the navigation channel, the new sheet pile wall in front of the old crib wall, the barrage/ Tawe Lock and the SA1 rock wall and embankment. It is particularly worth noting the cross section produced between the rectangular structure at the end of the SA1 rock retaining wall and the new sheet pile wall on the west side as this would determine the entry conditions for waves impinging on the confined area bounded by the Rock Wall/ embankment, barrage, Tawe Lock and the upstream section of the new sheet pile wall.

It is recommended that, if possible, the qualitative coastal process assessment contained in this report be complimented with a more comprehensive quantitative coastal process assessment. In light of the possible detrimental impacts arising from the installation of solid sheet pile in front of the old crib wall, it has been assumed that a comprehensive coastal process assessment was probably not carried out in advance of the installation of the new sheet pile wall. It may now be difficult to undertake a valid assessment post construction unless an accurate pre-construction survey / model of the precise disposition of the old crib wall and local bathymetry was available. It may however be appropriate to fall back on some basic coastal engineering and hydraulic principals to establish a reasonable narrative in relation to the cause and effect of significant hard reflective engineering intervention in this small and restrained area.

Photographic Record Sheet 4 – Historic Ground Based Images ***SHEET PILE WALL***

Plate Ref.	Description	Observation
1 & 2	Sheet pile wall under construction.	These are views of the sheet pile under construction and show the solid near vertical sheet pile being build in front of the old energy dissipating crib wall. The plates also show the Tawe navigation channel with the sanctuary pontoon in place. Unfortunately it is likely that the pontoon did not survive because of the modified wave climate arising from the installation of the sheet pile wall. The previous attenuation of the edge wave propagating up the channel as a result of the presence of the old crib wall appears to have been removed by the introduction of the sheet pile wall.
3, 4and 5	Navigation channel to Tawe lock	These views show the general disposition of the navigation channel with the distinct diagonal alignment of the channel from Tawe Lock to the brick building on the eastern wall adjacent to the former ferry terminal. Note the raised bank along the west breakwater in Plate 4.
6	Entry conditions to upper Tawe.	This is a view through the wire netting of Trafalgar Bridge. It shows the entry conditions to the upper Tawe bounded by the sheet pile wall on the west breakwater and the masonry promontory on the eastern SA1 side. The surfaces upstream of this entry point are mostly non-reflective since the installation of the sheet pile wall. This increases the presence of reflected wave energy and potential wave resonance in this basin like area.
7 & 8	Long period edge waves	These are views of long period edge waves driving into the Tawe lock area. The energy entering the enclosed upper Tawe area has increased since the installation of the sheet pile wall and may have exacerbated embankment erosion on the eastern side/ SA1 area.

Summary Assessment – Sheet 4

The comments made in the Summary Assessment applying to Sheets 2 & 3 above apply to this sheet also. It is worth noting that the substantial edge wave moving along the sheet pile wall is a long period swell wave typical of an Atlantic swell shoaling in the Bristol channel area. It does not appear to be a locally generated system that would perhaps discourage or prevent vessels from taking to the sea. These swell waves would however potentially pose a significant issue in Tawe Lock and over time could threaten the integrity of the floating pontoons in the lock. The increase in edge wave energy as result of the sheet pile works almost certainly resulted in the demise of the sanctuary pontoon outside Tawe Lock. The removal of the sanctuary pontoon has had a detrimental impact on the operation of the Swansea maritime sector.

The amount of wave energy entering the upper Tawe basin would have increased as a result of the introduction of the sheet pile wall in front of the old crib wall. The upper Tawe area mainly comprises hard impermeable surfaces that will reflect wave energy around the effective enclosed basin potentially giving rise to wave resonance. This could have had an impact on the rip rap rock embankment in front of the SA1 rock wall. It is also possible that the rock wall itself could have contributed to a local increase in reflected wave energy that may have contributed to the undermining of the rock wall, although the reflecting face of the rock wall is very high up in the tidal ladder (above mean high water springs). A key point to consider is whether or not the sheet pile wall has resulted in a significant increase in wave energy entering the Tawe upper basin. This qualitative assessment is unable to confirm the extent of potential detrimental impact but it is the opinion of the author that the new wall has had a negative impact.

It is also worth noting that in extreme conditions where the tide is high and large waves are entering the Tawe, the presence of water above the Tawe barrage weir is likely to have a mitigating effect on the wave climate.

3.2 - Site Inspection and Assessment.

A site inspection was carried out in early May and a series of photographs were taken and mounted on the Photographic Record Sheet 5 and 6. The following tables provide a description and narrative/ observations and reference should made to the Photographic record sheets in Appendix II.

Photographic Record Sheet 5

Plate Ref.	Description	Observation
1	SA1 Embankment, Tawe Channel and Sheet Pile Wall.	This is a view of the broader upper Tawe area including the bottom of the SA1 embankment (with box culvert along toe) and the Tawe channel both to Tawe lock and over the barrage. The view shows the extent of the recently installed sheet pile wall.
2	The SA1 embankment and Tawe Channel.	This view specifically shows the shape of the lower portion of the embankment which ties into the masonry promontory forming the eastern hard point to the enclosed are of the upper Tawe area. The embankment is elevated towards the barrage to accommodate a culvert.
3	SA1 embankment and rock wall	This is a view to the embankment and collapsed section of rock wall. another section immediately seaward of the failed section is undermined, unsafe and could collapse at any moment. Two small headwall structures can be seen in the foreground.
4	Upstream section of rock wall	The upstream section of rock wall is in an area where the embankment is shallower. It is worth noting the section that has collapsed is in an area which would be at more risk from waves leaving the shadow of the masonry promontory.
5	Edge armour	The rock wall is formed with carefully selected edge armour with a mass of between approx. 2T and 4T. The selected rock is difficult to source and sort because of the particular rectangular geometry that makes it ideal for rock wall construction.
6	Rip rap embankment	The material making up the embankment varies in size but is generally a rip rap probably overlaying industrial waste such as slag. The material is clearly not of sufficient mean mass to cope with the storm events and possible change in conditions in recent years.
7	SA1 embankment upstream	This is a view of the shallow embankment and sheet pile wall leading toward Trafalgar Bridge. This area is less volatile notwithstanding the presence of a vertical sheet pile wall.
8	Upstream end of rock wall.	Rock wall tie into the sheet pile return to form reclaimed land at entry to Trafalgar Bridge. A short section of the three rock armour high wall.
9, 10 & 11	Culverts discharging high on SA1 Rip Rap embankment	Two culvert with solid flap valves that are almost closed as result of rip rap embankment material filling the area bounded by the wing walls and headwall. It is likely that water seeps out of the restricted end of each outfall although the larger outfall is more severely affected.
12	Collapsed section of rock wall	The section of rock wall that has collapsed has drawn down the bedstone material supporting the promenade and will need reinforcement to prevent damage to the promenade.

Photographic Record Sheet 6

Plate Ref.	Description	Observation
1 & 2	Steep Embankment adjacent to Promontory	These are views of the steep embankment immediately adjacent to the masonry promontory. This geometry is problematic and will need to be carefully considered in any engineering design solution options. The rock armour wall is perched on top of the steeply sloping embankment but is somewhat protected by the promontory.
3	Undetermined rock armour	This is view of a surveyor's staff pushed into a void under the rock armour wall. The void extends the full base width of the rock armour and is therefore not supported from the base and probably tentatively held in place by other means. There are other sections which appeared to be even more at risk of collapse and it was not possible to safely stand in front of these sections of wall.
4, 5 & 6	Collapsed and about to collapse rock wall	Plates 4 and 5 show section of failed wall with rock amour strewn across the upper portion of the embankment. Plate 6 is a view of a section of rock wall that is about to collapse and it was not possible to get any closer to the void under the rock for closer inspection.
7	Steep embankment from toe.	Seaweed over steep rock embankment leading up to rock wall.
8	Toe of embankment	The toe of the embankment has a small flat area which leads upstream into the large box culverts and elevated section of embankment.
9	Steep embankment (Plates 1 & 2) from toe	Steep geometry of rock slope at masonry promontory.
10 & 11	Top of rock wall & promenade	Narrow and steep shoulder linking the top of the rock wall to the promenade. This is a challenging geometry in the area where the embankment is steeply sloping at the seaward end/ half of the rock wall.
12	Embankment and Barrage.	View from the masonry promontory towards the barrage including the general disposition of the embankment.

Summary Assessment – Sheets 4 and 5

The images and descriptive notes in the above tables are self explanatory and illustrate the current condition of the rock wall and surrounding area. A number of sections of the rock wall have been undermined and some parts have collapsed. Other sections could fail at any time and WG have recently committed to try to stabilise the most perilous sections (see 3.2 below) in order to preserve future engineering options to properly defend the promenade. It should be noted that no damage to date has befallen the actual promenade. However, the defences are disintegrating which will inevitably lead to the loss of part or a significant portion of the promenade.

3.3 – Emergency Works

Part of the rock wall has collapsed and other sections are undermined and are perilously close to collapse. At the time of writing this report, WG have commissioned emergency works in an attempt to prevent the undermined section from collapsing. Whilst this task is overdue, it is nonetheless worth trying to prevent further collapse in order to temporarily stabilise the situation. It has been made clear to WG that the rock wall could collapse at any time and the act of trying to shore up the wall by working in the area with the necessary machinery could precipitate a collapse. It has been made clear that should a section of the wall fail, then having the resources on site at the time will enable mitigation measures to be undertaken and reduce the risk of significant damage to the promenade. It is understood by all parties that doing nothing will guarantee further failures of the rock wall due to undermining which will lead to damage to the promenade.

4 – Topographic Survey

Preparations were made for the topographic survey through early May and the survey was carried out on the 18th May 2024. The main part of the survey was carried out with a drone using photogrammetry techniques and the drone also captured aerial video (see short film). Ground control and other general check points were surveyed using an RTK (Real Time Kinematic) GPS survey system operated by the survey team of four plus the author in attendance. The survey represents an important part of the study and provides the ground layout on which the engineering options can be considered.

A contour plan and cross sections were produced and reference should be made to Appendix III which contains the survey plan. A video and photo mosaic are also available on the USB stick version of the report. This is because the files are too large to transmit electronically.

Whilst the contour plan generated from the drone survey, GPS control and desk analysis is adequate for the purposes of outline design, further detail or infill survey data will be required in the detailed design phase.

5 – Engineering Options.

5.1 Strategic Overview – Engineering Options

Potential engineering solutions need to be considered in an initial overview of engineering options. The potential management options include the following:

1 – Set Back or Managed Realignment - This option would not seek to protect the existing promenade in favour of setting back the asset further into the hinterland to render protection unnecessary. This is unlikely to be acceptable as the hinterland is valuable development land and the cost of retreat would not be trivial. If the promenade was to be set further to landward, it would not only use development but would be in a less desirable position for public use.

2 – A deep sheet pile wall along the line of the rock armour wall – This option would be expensive and disruptive. It would also be challenging as it would be difficult to avoid significant disruption to the existing promenade. The embankment into which piles would need to be driven is also likely to heavily contaminated with artificially hard material that would obstruct the piling operation. It would also not deal with the structurally inadequate and vulnerable embankment in the Tawe which gave rise to the current issues. Although this option would be costly and potentially challenging, it would be possible but probably not economically viable.

3 – Reinforcing the existing Embankment from the bottom up – this option comprises the introduction of a robust energy dissipating rock revetment that would secure the existing embankment and promenade. Whilst this option has both positive and negative aspects, the advantages far out way the disadvantages. A rock revetment can be designed in such a way to be flexible in terms of cost and design life. Some advantages being the energy absorbing properties, the natural material, cost and the ability to enhance the effectiveness of the armour to extend the design life at some point in the future to suit the economic environment. One of disadvantages may be the approval and consent process as the works would be below mean high water spring tides (MHWST). It is possible that the bureaucratic hurdles in pursuing the most efficient hydraulic solution could have influenced the original decision to install the rock wall above MHWST.

4 – Stepped Concrete Revetment – A stepped concrete revetment build on top of the existing rip rap embankment would be very costly and hydraulically detrimental to the upper Tawe area. The hard surfaces of the concrete structure would reflect wave energy in an area that is already volatile in term of coastal processes. This option would potentially be the most costly option and although a hybrid scenario could be considered with a rock toe and upper concrete revetment, the cost would probably remain prohibitive.

Strategic engineering option 3 is recommended as the preferred approach and will be considered further below.

5.2 – Economically Viable - Preferred Option.

The term economically viable should not be taken to mean less effective or a compromise as the maintenance of engineering integrity is a fundamental requirement applicable to all options. The parameters or criteria are however set by the available budget and a target design life. It is for this reason that the preferred option provides scope for a lower initial capital investment with scope for future enhancement if necessary. One could for example consider an initial design life in terms of a few decades rather than perhaps 100 years. The statistical approach to rock revetment design refers to the likelihood of storm events and crucially includes a parameter related to the level of acceptable storm damage. Rock revetments tend not to catastrophically fail but rather have areas of displaced armourstone that can often be relatively straight forward to repair. The preferred option is Option 3 and is a robust rock revetment.

There are two approaches that may be considered as potential engineering solutions for the short and medium term. These may be described as 1) Works at the top with a new high level toe and 2) Start at the bottom and work up to secure the whole embankment. It is worth noting that the failure of the rock armour wall is primarily due to the erosion of the rip rap embankment and not because of an issue with the rock wall itself. It is however acknowledged that it is possible that the rock wall could have slightly modified the wave climate in front of the rock wall during certain conditions and contributed to some local scour. It is most important to address erosion issues on the embankment either in its entirety or in that area which could affect the rock wall. It is also possible that the works solution could vary along the length of the frontage to take into account the geometry of the existing embankment, the shoulder between the rock wall and the promenade and potentially variable wave exposure. An examination of the topographic survey indicates that confining works towards to the top of the existing embankment becomes unworkable in the seaward half of the frontage because the existing embankment is too steep to accommodate new works.

Coastal engineering is principally an exercise in energy management with the prime contributor or forcing parameter being wave energy. There appears to often be a tendency to simply erect monumental barriers to robustly defend coastal assets from the destructive forces of wave action. This approach can typically result in the installation of hard reflective structures that do not dissipate or effectively manage wave energy. It is incumbent on coastal engineers to be ever mindful of the need, wherever possible, to dissipate wave energy and where this is not possible, to appreciate and mitigate the effects of substantial reflected wave energy. This is particularly relevant in confined areas such as the upper Tawe basin area where there are currently many hard reflective surfaces with more being added recently. The embankment along the study frontage is the only sloping surface comprising a rock rip-rap material in the area and it is essential that the energy absorbing properties are not diminished and preferably enhanced. Continuing the principle of energy dissipation, this can be achieved by using a rock armour revetment where the main body of the works or rock envelope contains at least 30% voids yielding a maximum packing factor of around 1.8T/m3.

As indicated above, the embankment is much steeper towards the seaward end of the frontage where the shoulder between the top of the rock wall and promenade is also very narrow. In this area there is little room towards the top of the embankment to establish new works in front of the rock wall with an adequate toe. Works in this area will need to start at the bottom of the embankment and extend beyond the existing toe and around part of the rectangular promontory. It should be noted that the form of the engineering works will comprise quarried rock as all other materials have been ruled out on economic and hydraulic grounds as explained above. The area has too many hard surfaces already and an energy dissipating rock solution is the only realistic option for a durable embankment that will not increase the amount of reflected wave energy in the vicinity.

Particular consideration is required at the seaward end of the proposed new rock revetment and there is a hydraulic imperative to manage wave energy around the large rectangular promontory. This will be achieved by wrapping a rock armour slope around part of the vertical side of the promontory to form a new toe from which the new revetment can be formed.

5.3 - Engineering Elements – Outline Design

Reference should be made to the engineering drawing comprising a plan and typical cross sections.

The proposed works comprise a sloping rock armour revetment with a robust toe formed with selected edge armour founded on a new bedstone apron. The works are intended to cover a 10 to 15 year period with annual maintenance as required. The bedstone apron will extend beyond the edge amour to provide local scour protection. The apron will need to be slightly wider along the seaward transition to the vertical wall which forms part of the rectangular promontory. The apron may also be used as a regulating layer and may therefore vary in thickness, although it will need to be a minimum of 500mm thick. Geofabrirc may be required in certain areas and this should be included as a provisional contract item as it will probably not be possible to confirm the full extent pre works commencement.

The new rock revetment will need to be substantial in the seaward half of the scheme, extend to the low water level and tie into the rectangular promontory. In this area, which is approximately 50m long, the existing bank is very steep and the new revetment will need to be robust and use rock armour with a substantial mean mass. Whilst the rock design will be carried out in the detailed design phase, a provisional rock armour mean mass has been estimated at 2T. The existing embankment changes shape at around 55m from the seaward start point where it rises to form a much shallow embankment and tie in with the top of the box culverts in the Tawe. A transition will be designed to bring the position of the new toe closer to the promenade thereby reducing the slope length of the new revetment in the northern half of the scheme. Some local bedstone reinforcement will be required on the seaward side of the new toe in this area. The edge armour in the northern half of the scheme will need to be excavated into the existing embankment with suitable scour protection on the seaward side as referred to above.

The works will involve excavation and filling in order to reprofile the existing embankment and specifically along the toe area where the bedstone apron and edge amour will need to be set into the existing ground. The reprofiling of the existing embankment will be required to produce the formation for the rock armour and the surface will need to conform to specific requirements. These requirements may be satisfied by the recovery and reuse of the rip rap stone on the existing embankment under the footprint of the new revetment. It is likely that there will be a surplus of excavated material and it is hoped that this material will be accommodated on site. The extent of the excavation and filling will be confirmed in the detailed design and some additional targeted site surveying will be required to produce the required resolution for data to complete this task.

From the work carried out to date it has been possible to provisionally estimate quantities of key constituents for a proposed scheme. The total quantity of rock required has been estimated at around 8,000T and it is emphasised that this figure should be treated as approximate only. Rough approximations for the cost of earthworks, access and geofabric with an allowance for prelims etc. have been estimated. The construction only costs of the works outlined has been estimated at around £1.1m. Obviously, the works will be issued for competitive tender to a cohort of contractors. Other costs will include detailed design fees, the cost of obtaining the necessary consents, contract preparation and contract management/ administration.

The actions to provide the information required to progress into the detailed design phase and consents/ approvals are listed below:

1. Assess the thickness of the existing rip rap surface in the present embankment to confirm that sufficient material is available to form the foundation layer for the new revetment. This may be referred to as a modest ground investigation.

2. Supplemental topographic survey data in targeted areas.

3. The works will require a marine licence which will probably involve the production of a specialist environment assessment. The licensing process could take 4 to 6 months to complete, provided the required environmental assessment are not significant.

4. The works will require a planning application and other consents such as a marine licence will need to be obtained (WFD etc).

5. It is possible that the administrative process and procurement could be completed over the winter of 24/25 with a potential start date for construction in the spring/ summer of 25. Should this not be achieved then it will be necessary to confirm whether or not there are any environmental restrictions on winter construction as the works are close to the Tawe river. A provisional list of tasks and timescales are presented below:

- Appointment – 2 months.
- Planning Permission – 4 – 6 months.
- Marine licence incl. any environmental assessments – 4 – 6 months.
- Design – 3 Months.
- Contractor Procurement – 3 – 4 months.

Some tasks will run concurrently and the estimated total period is 12 months.

6 – Summary and Recommendations.

The report provides an assessment of the situation along with strategic design options and a preferred option with an outline design and budget estimate. The work includes an historic review of activity and influences including a qualitative coastal process assessment. An inspection and assessment of the site was undertaken and a topographic survey was also carried out. An outline design has been produced and developed to a level of detail to enable a budget estimate to be presented for an approximate cost of direct contract works.

The outline design can now be development further to produce a detailed design for contract. It is recommended that the detailed design work is commissioned and SMW can provide a proposal with a budget to progress the outline design to a level of detail for construction. This would include drawings and specification clauses for inclusion in the construction contract.

APPENDICES

Appendix I – Photographic Record Sheets – Historic.

Appendix II - Photographic Inspection Sheets - Current

Appendix III - Topographic Survey and Cross Sections

Appendix IV - Engineering Option & Drawings