Note / Memo

HaskoningDHV UK Ltd.
Water

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From: Pablo Laboreo, Greg Guthrie (Royal HaskoningDHV)
Date: 04 November 2016
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Subject: **Development of Coastal Engineering Options**

1. Purpose of this note

During the initial stages of consultation on the Newgale Adaptation Strategy, undertaken by Pembrokeshire Council, members of the community had asked that particular attention be given to examining the feasibility of maintaining the road along its existing alignment. This was recognised to be an important option providing a baseline case for management of the area. A range of possible options have been developed, assessed and cost estimated to ensure that this question could be answered sensibly, allowing the community to consider the impact of this option alongside other alternative routes.

The purpose of this note is to present the outcomes of such assessment of options that seek to maintain the integrity and functionality of the A487.

2. Context and assumptions taken into account

Previous studies

This note builds on previous works carried out by Royal HaskoningDHV, in particular the following reports:

- Newgale Shingle Bank Vulnerability Assessment, November 2014: this report confirmed the trend for movement back of the shingle ridge over the whole frontage and provided expected average retreat rates per section.
- Newgale – Wave Transformation Modelling, May 2016: this note presented the results of a detailed modelling analysis that provided joint probability of offshore wave and water conditions and performed wave transformation modelling to derive accurate nearshore wave conditions.
- Summary of Damage Assessment to Date, June 2016: in this note the Do Nothing Scenario impacts were assessed, contributing to the definition of the existing problem in Newgale.

The findings and assumptions of these documents have been carried forward in this note.

Design Parameters

Four different joint probability scenarios were considered in the previous assessments, with Joint Probability 1 being driven by water levels and Joint Probability 4 being driven by offshore wave height; Joint Probability 2 and 3 are variations in between. Joint Probability 2 was identified as the least favourable across representative profiles 6 and 8, giving the most onerous overtopping conditions. As a result, Joint Probability 2 wave and water level conditions set out the range of design parameters for the development of options. **Table 1.1** below presents these values.

The limit for tolerable overtopping mean discharge for all options is 0.05 l/s/m, in accordance to the EurOtop Overtopping Manual guidance (Limits for overtopping for vehicles driving at moderate or high speed). This value relates to overtopping at the defence, but assumes the road to be immediately behind the defence.

The new road is expected to match its current width of 7.5m. This influences the required crest width of the embankment, assumed 9.5m.

Do Nothing scenario

The Do Nothing scenario sets the baseline retreat conditions against which Do Something options are assessed. For the purpose of this exercise, and consistently with the outcomes of the above mentioned reports, it has been anticipated that the shingle ridge would retreat:

- **7.5m** in 20 years;
- **12.5m** in 50 years; and
- between **25m** and 47m in 120 years.

This retreat is understood as where the shingle bank "wants" to be, i.e. where it would naturally be in absence of human intervention. Along the northern part of the frontage in front of the road, with a retreat of 7.5m (20 years time) the crest of the ridge would be along the western edge of the road; a retreat of 25m (120 years time) would place the shingle bank beyond the line of some of the currently existing properties. **Figure 1** below illustrates the anticipated evolution of the shingle bank at profile 6. The crest of the shingle ridge would move from chainage +10m to chainage +35m and would have an approximate ridge height of 8.0m. The first line of properties would be at risk of overtopping long before that and would need to be relocated, presumably in 40-50 years. The road would be lost in 20 years.

Figure 1: Do Nothing. Profile in year 120 approximated to lower range retreat value (25m)

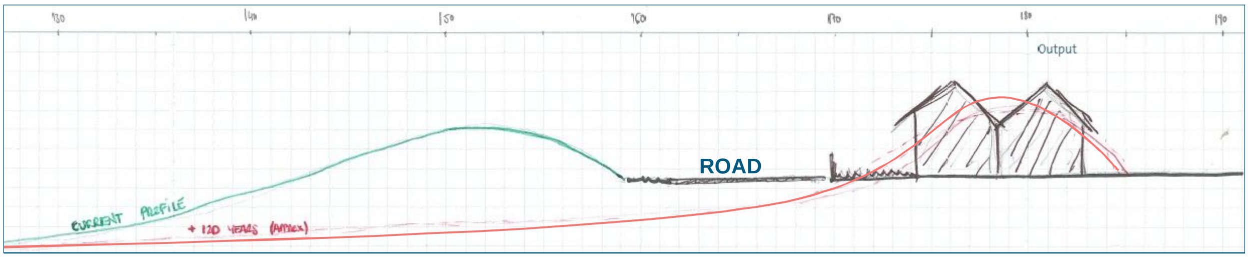


Table 1: Design parameters

Assessment of sea level rise on return period water levels only (all levels in m OD)					Design Parameters based on joint probability – scenario JP2 (**WL** – water level (m OD), **Wht** – wave height (m), **BC** – beach change[1] (m))										
Return period	Present day (2016)	Year 20 (2036)	Year 50 (2066)	Year 120 (2136)	Present day		Year 20			Year 50			Year 120		
					WL	Wht	WL	Wht	BC	WL	Wht	BC	WL	Wht	BC
MHWS					-	-	-	-	-	-	-	-	-	-	-
1:10	3.82	3.95	4.18	4.97	3.58	2.25	3.71	2.25	6.5	3.94	2.4	17.3	4.73	2.75	25 / 47.3
1:50	3.98	4.11	4.34	5.13	3.75	2.35	3.88	2.35	6.5	4.11	2.51	17.3	4.90	2.86	25 / 47.3
1:100	4.05	4.18	4.41	5.20	3.75	2.41	3.88	2.41	6.5	4.11	2.58	17.3	4.90	2.95	25/ 47.3

Note: 1. Beach change, taken as the unconstrained retreat at the 5m contour, is based on the geomorphological assessment of present beach erosion rates.

3. Short-term options development

A number of short-term options have been considered to defend the road as part of this exercise:

I. Rebuilding the shingle bank in advance of a storm. It was reported that this work used to be carried out in the past.
II. Raising the crest of the shingle bank to prevent overtopping in the short term.
III. Reinforcing the core of the shingle bank to delay the need for more major works.

Rebuilding the shingle bank in advance of a storm

The viability of this option is reduced due to the increased vulnerability of the managed section of the bank (in front of the road) over the past decades. This section is now significantly different to the natural bank to the south and has become more difficult to manage. As such the bank in front of the road has lost volume and has become steeper. While efforts have increased to restore the profile of the bank after major storms, it has become increasingly vulnerable. Adding additional shingle will only have a minor effect and without the natural ability of the bank to retreat, placing shingle on the front face is more likely to be moved during a storm. Moving shingle from adjacent areas would reduce the ability for these areas to respond naturally to storm conditions, making these areas more vulnerable.

Raising the crest of the shingle bank to prevent overtopping

A second short-term solution would involve raising the crest of the bank by placing rock or gabion baskets. However, while this might improve the risk of overtopping at present, the analysis has shown that to deal with a major storm, the crest of the bank would need to be raised by 1m to 1.5m to have any meaningful benefit. More importantly, under storm conditions, the front face of the natural shingle bank would still be eroded and this would mean that significant works would have to be undertaken to protect the toe of the structure. Undertaking such works would potentially improve overtopping conditions at present but would not delay the need for much more major works over the next 10 to 15 years to deal with the long term problem. A crest wall by itself would be undermined during an event such as experienced in 2014 and would not provide increased protection against such an event.

Reinforcing the core of the shingle bank

Reinforcing the core of the bank, either on its own or as part of raising the crest, would suffer from similar problems to those stated above. If a substantial core were introduced within the shingle bank, together with raising the crest, then potentially this would reduce the risk of failure in the short term. However, it should be noted that there would still be the risk of flooding within the valley unless a complete barrier were created along the whole area. Even so there would still be the risk of flooding following heavy rainfall.

The main disadvantage of making the core of the shingle more resistant to erosion would be the fact that this would increase wave reflection when that core was exposed during a storm. This would tend to impact on the beach and lower part of the shingle bank such that increased erosion would occur. As such, while these major works could reduce the immediate risk of overtopping and overwash of shingle, by creating a harder structure it is very probable that the need for more major works would actually be hastened. Therefore this approach provides some temporary reduction in risk in the very short term but would not result in delay for the need to move towards one of the longer term options over the same period of time as anticipated now.

The analysis carried out in previous studies has indicated the severity of the underlying problem and suggests that these short-term solutions would provide limited benefit and actually might, as in the case of the third option listed above, hasten the need for more substantial works.

4. Long-term options development

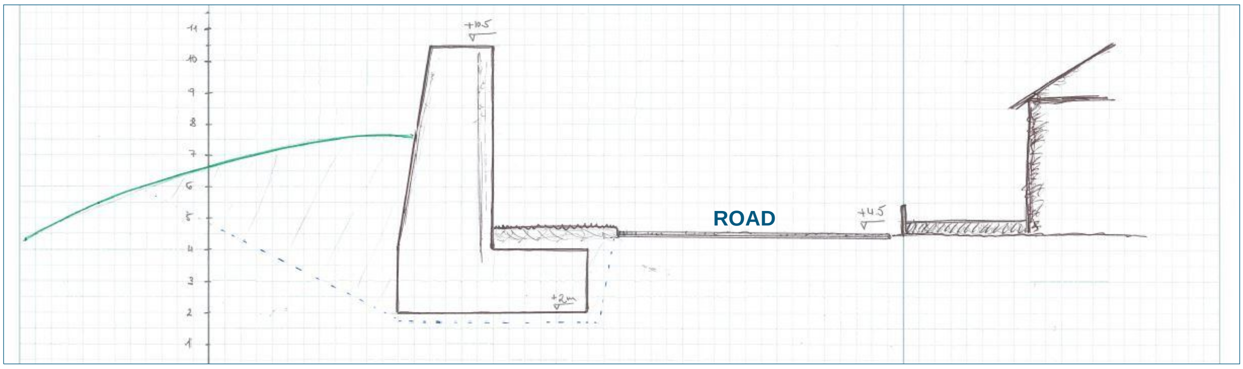
Three long-term options have been considered and assessed: a) a sea wall behind the shingle bank, b) an embankment with rock revetment and c) a composite solution - consisting of an embankment protected with gabions first and a rock revetment plus concrete wall after 20 years. All three solutions would extend along approximately 600m of frontage, where the road is located behind the shingle bank.

Option A: Sea wall

The first option considered consists of a vertical sea wall located behind the shingle bank. This solution aims to preserve the road at its current location and to prevent it being covered by over-washed shingle after significant events - as currently happens. No land would need to be taken although a high wall limits accessibility and visibility to and from the beach. The sea wall would be taken down below the existing level of the shingle to take account of erosion of the shingle bank and scour processes and would be designed for an expected lifespan of 50 years. After this period a similar optioneering exercise would need to take place considering alternative options, including the refurbishment of the sea wall. Typically within 50 years there would be the need to construct a rock revetment similar to that shown for option B or C.

It is anticipated that in 20 years the shingle bank would become a sloped face against the wall and in the longer term the shingle beach would be effectively lost. **Figure 2** below illustrates this option and the anticipated evolution of the shingle bank.

Figure 2: Option A: Sea wall. Sketch



Option B: Embankment with rock revetment

A second option is based on the idea of raising the road high enough to place it out of reach of the waves and it involves building an embankment and rock revetment. The road would be located on top of the embankment itself, i.e. road level would be that of the embankment.

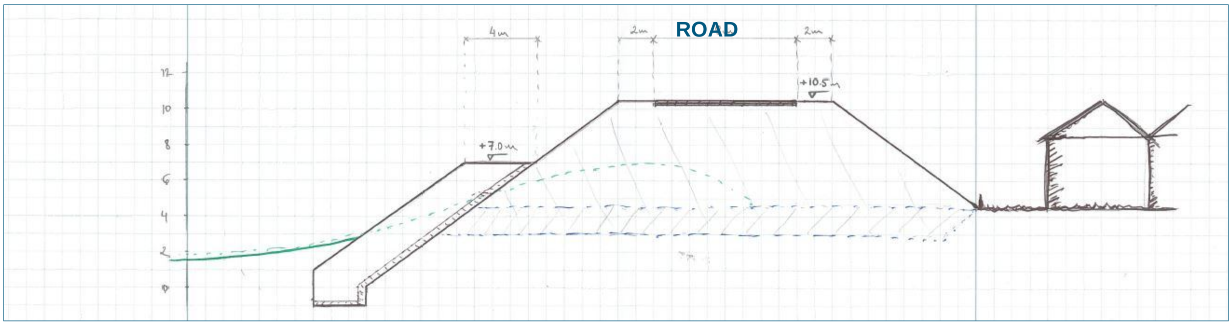
An overtopping assessment has been carried out to determine the required crest height of the embankment. Wave conditions related to a T100 storm event (1% annual exceedance probability) and under a 120 years climate change have been used for the calculations (Wht=2.95m, Tp=10.16s, WL=4.90m). The results show the required crest height to be +10.5m OD, which could be achieved with different cross sections – the modelled cross-sections include:

- an embankment +10.5m OD high;
- an embankment +10.0m OD high, with a low wall 0.5m high located 0.5m from the ridge of the embankment; and
- an embankment +9.5m OD high, with a low wall 1.0m high located 0.5m from the ridge of the embankment.

All three cross-sections include a rock revetment with a 4m wide berm and concrete or pitched rock protection at the toe, built to protect the embankment itself and help reduce the required crest height. Embankment slopes would be 1:1.5 at both sides due to the limited space; the slope for the embankment would be 1:1.5 as this has been shown to reduce overtopping discharges.

In order to maintain the existing properties to the east of the road, the embankment would be located seawards, effectively replacing the shingle bank. Excavated material would be moved but it is expected to be lost due to by wave action in short to medium to long term. **Figure 3** below illustrates this option.

Figure 3: Option B: Embankment with rock revetment. Sketch



Option C: Composite (short-term gabion solution replaced in the longer term by a rock revetment and concrete wall solution)

Option C seeks to provide a solution that reduces the required embankment height by placing a structure that protects the road from wave overtopping. Key aspects are that the cross-section adapts to existing wave conditions and therefore spreads the necessary investment over time. Figure 4 and Figure 5 below illustrate this option that would involve raising the road to +6.5m OD with an embankment. An embankment of such size would fit between the existing properties at current location without significantly impacting on the active front face of the shingle bank. However, as beach material is lost, the new defence would become exposed directly to wave action.

To protect the road against the waves in the short term, a +8.5m OD high gabion structure would be placed at the rear of the shingle bank. Over time, probably within the next 10 to 20 years, the beach is expected to drop in the front and, due to the natural retreat trend of the frontage, the embankment would eventually be exposed. In addition, gabions have a limited lifespan. It is therefore anticipated that in 20 years time a rock revetment will need to be placed to protect the embankment and the gabions will need to be replaced with a +10.5m OD high concrete wall to ensure overtopping mean discharges do not exceed maximum tolerable values over the life time. The rock revetment to be added would have the same characteristics that for Option B – a 4m wide berm at +7.0m OD and 1:1.5 slope.

In the long term the shingle bank would disappear completely and be replaced by the composite structure as the sea level rises and the frontage retreats.

Figure 4: Option C: Composite solution, year 0. Sketch

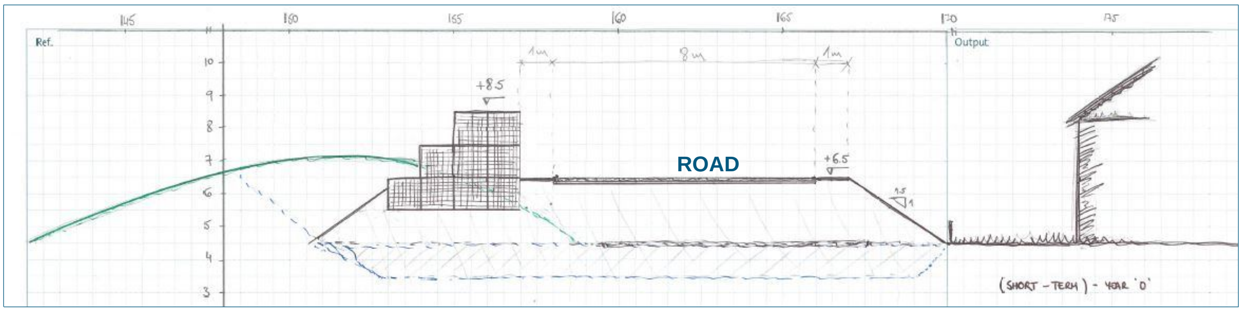
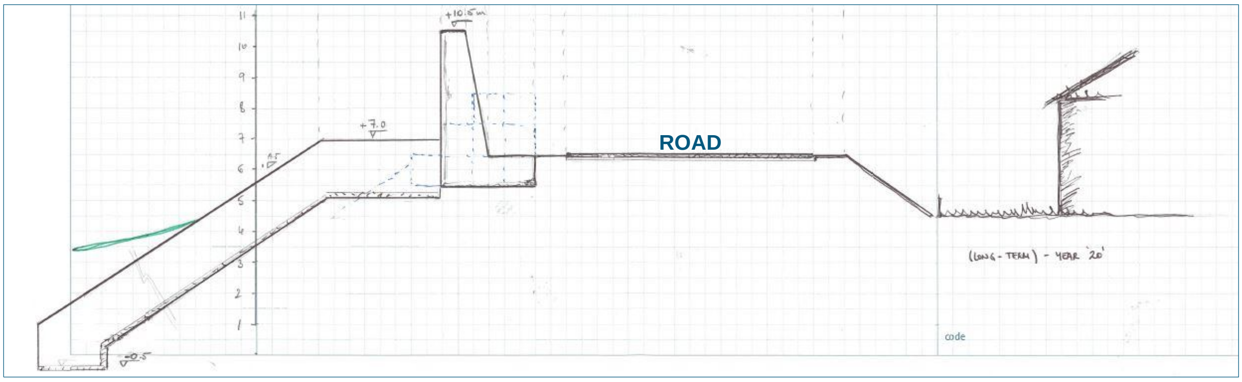


Figure 5: Option C: Composite solution, year 20. Sketch



In summary, designing protection to the existing road would require (for long-term protection) a crest height of around 10.5m OD. Depending on the different options this could be provided by raising the road embankment to this full height (Option B) or installing a forward defence at this height with a lower road embankment behind. All options would impact on the natural development of the shingle bank and would result in substantial erosion and loss of the upper beach over time.

5. Options assessment

Considering all the above, Option C would be ranked first based on present value costs, Option B second and Option A would be last. Do Nothing is not considered acceptable as it is incompatible with having the road at or nearly at its current location.

Option C comprises a much lower embankment (+6.5m OD) than Option B (+9.5m OD to +10.5m OD), reducing the space required. Both the existing properties and shingle bank would be maintained at their current locations. The case of the shingle bank is especially important, as removal and artificial relocation of the shingle bank would inevitably affect its natural integrity and stability and would leave it further exposed to the action of the waves. Option A would take less space, effectively fitting the defence structure between the bank ridge and the road.

The lower elevation of the embankment in Option C would provide higher safety for vehicles and would incur in lower construction initial costs than Option B. Option C is in fact based on an adaptive approach, adjusting the crest height of the wave protection over time and spreading the costs in two interventions instead of one major investment. The Present Value (PV) of the costs related to Option C is lower than the costs of Option B. However, this is based on further works required in year 20, resulting in higher overall real costs. Option A presents the highest initial capital costs overall and would require further significant investment within 50 years..

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Option A would also present high constraints in terms of accessibility to the beach along the frontage and a stronger visual impact than other options– the village would symbolically turn its back to the beach by building a 600m long high wall. Option C and certainly Option B would allow for accessibility alternatives, although still with major impact on beach use and landscape. None of the options would allow the view of the beach from the road.

All three options would provide protection for the road against overtopping. However, flooding of the area behind the defences would still occur due to storm surges and sea level rise, with water entering through the Brandy Brook outlet. In addition, holding the existing line would have a 'coastal squeezing' effect so the shingle beach would be washed away and eventually lost, incurring in significant impacts on landscape and the environment. As this process continues, there would also be loss of the lower beach, potentially exposing the underlying platform.

6. Cost estimation

A summary of the costs for all options as set above is included in **Table 2**. A more detailed breakdown of all the costings, as well as of all cross-section sketches are included as an Appendix to this note. *Note: the costs are limited to coastal defence, i.e. do not include the new road infrastructure required for Option B or Option C.*

Table 2: Summary of costs

Option Description	Cost (£)
Option A: Seawall and rock revetment	
Option A: Seawall - Year 0	13,400,000
Option A: Rock revetment - Year 50	6,110,000
Option A total cost	**19,510,000**
total PV cost (assuming 50 year delay for rock revetment)	*14,500,000*
Option B: Embankment	
Option B: total cost	**12,500,000**
Option C: Composite solution	
Option C: Composite solution – Year 0	4,500,000
Option C: Composite solution – Year 20	11,300,000
Option C total cost	**15,800,000**
total PV cost (assuming 20 year delay for rock revetment)	*10,200,000*

7. Conclusions

It is technically feasible to maintain the A487 in its current location and protect it against the action of the sea. Such approach, however, would have irreversible consequences regarding impacts on landscape and the environment. Holding the existing line would have a 'coastal squeezing' effect so the shingle beach would be washed away and eventually lost.

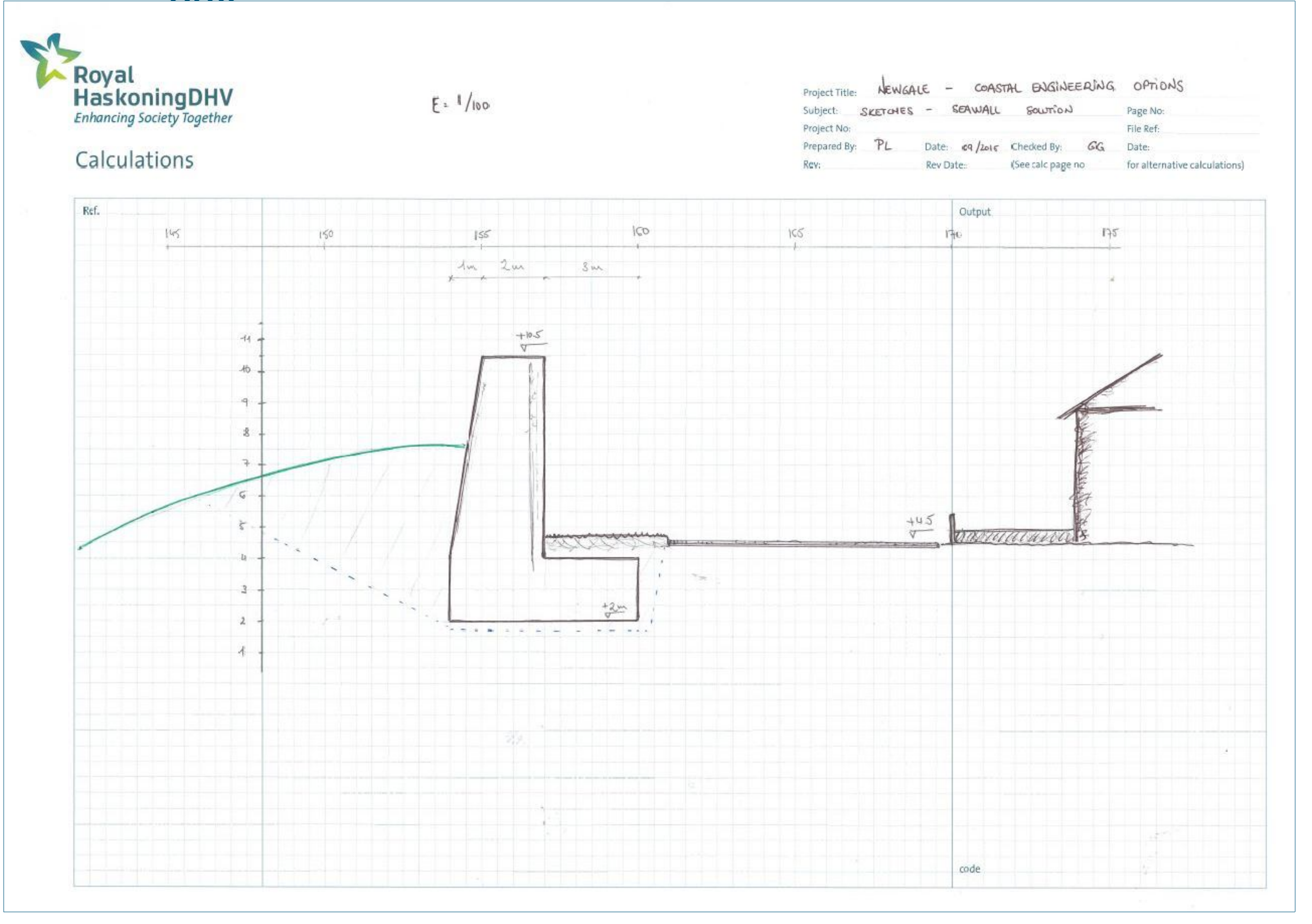
Short-term solutions such as raising the crest or reinforcing the core of the shingle bank would provide limited benefit and might hasten the need for more substantial works in the medium term.

Long-term solutions would consist in placing a hard structure along the frontage – three solutions consisting of a sea wall (Option A), a large embankment (Option B) and a composite solution (Option C) have been assessed. From the assessment, Option C would be ranked first, Option B second and Option A would be last. Option C would not constrain accessibility to the beach as much as Option A, and would require less space and incur in a lower visual impact and risk for vehicles than Option B. Option C would also allow for adjusting the crest height of the wave protection over time and spreading the costs in two interventions instead of one major investment, for an overall present value costs lower than both Option A and Option B.

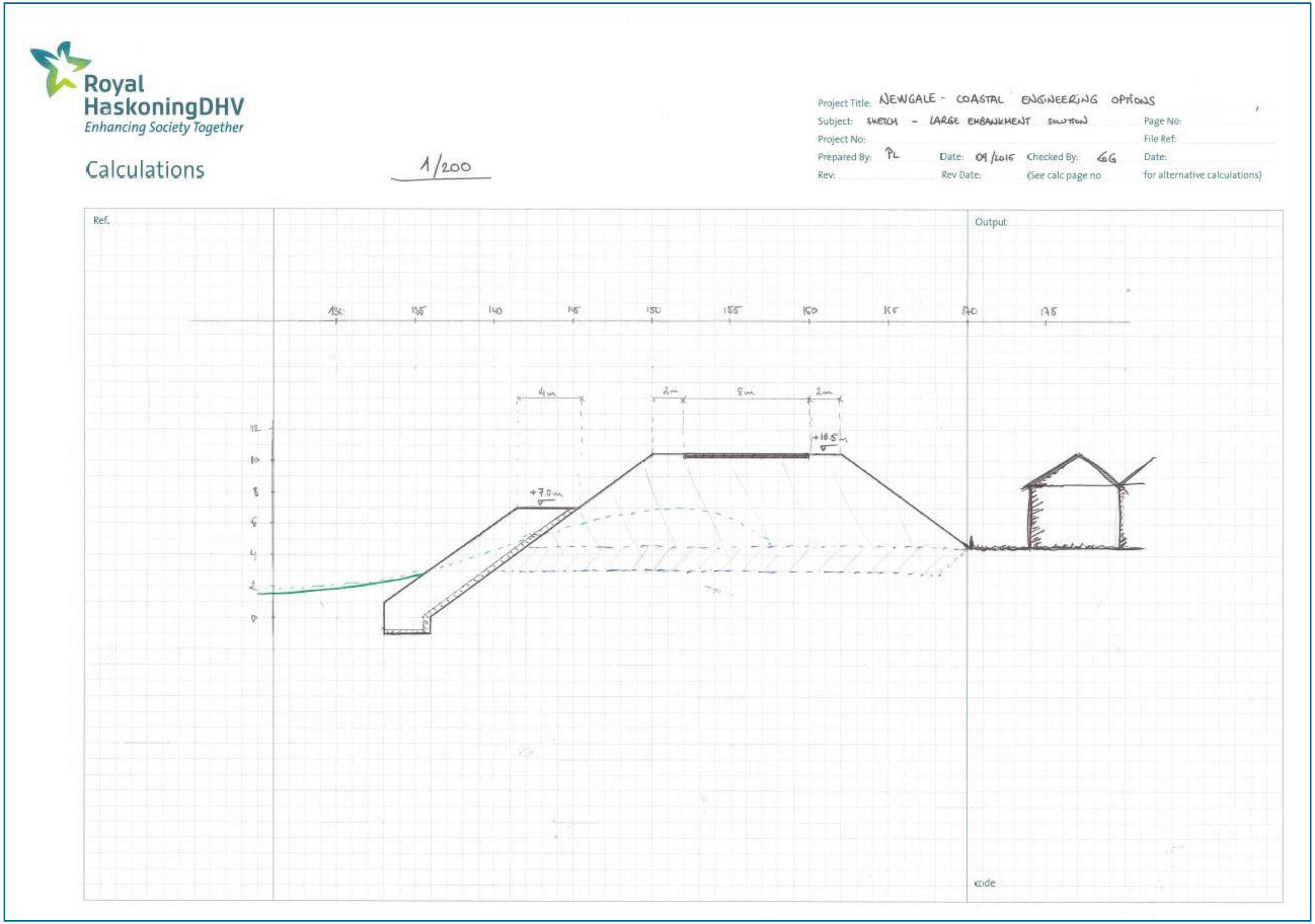
All three options would provide protection for the road against overtopping but not against flooding of the area behind the defences, as sea level rise and storm surges would still cause water flowing into the valley through the Brandy Brook outlet.

Appendix A: Cross-section sketches of long-term options

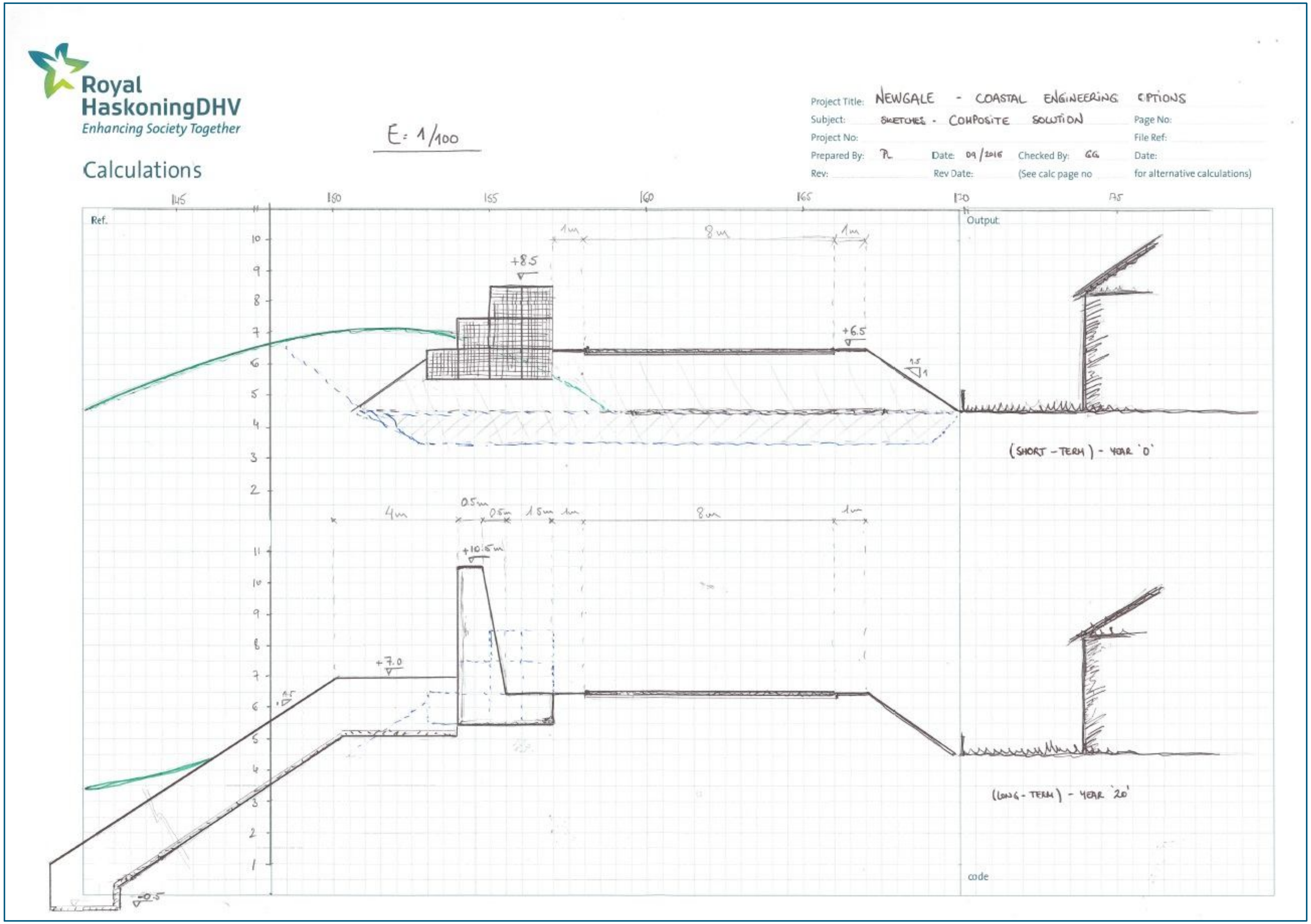
Option A: Sea wall



Option B: Embankment with rock revetment



Option C: Composite solution



Appendix B: Detailed cost estimations

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<u>Note:</u> all unit rates are based on the SPON's Civil Engineering and Highway Works Price Book 2015 and/or in unit rates from similar projects.

Option A Element	Quantity	Unit	Rate	Rate unit	Cost	Rounded cost
Concrete wall						
In situ concrete. Provision and placing of concrete; reinforced, thickness exceeding 500 mm	28.75	m3	136.06	£/m3	3,911.73	
Formwork; fair finish	16.1	m2	64.22	£/m2	1,033.90	
Supply and placing of steel reinforcement; approx. 0.15t/m3	4.30	t	1246.95	£/t	5,361.89	
Finishing of formed surfaces; rubbing down concrete surfaces	19.1	m2	2.48	£/m2	47.37	
Subtotal cost per metre of wall					10,354,92	10,400.00
Excavation						
Excavate material other than topsoil, rock or artificial hard material 1.0 -2.0 m maximum depth (shingle)	21.0	m3	5.65	£/m3	118.65	
Selected excavated material other than topsoil or rock. Filling general (shingle)	21.0	m3	1.69	£/m3	35.49	
Subtotal cost per metre of excavation					154.14	160.00
Estimated cost per meter Option A						10,560.00
Prelims	10%				1,056.00	
Construction contingency	20%				2,323.20	
Cost per metre Option A					13,939.20	13,950.00
Cost Option A	**600**	**m**				**8,370,000.00**
Optimism bias	60%				5,022,000.00	5,030,000.00
Initial (year 0) cost Option A						**13,400,000.00**
Rock revetment (year 50)						
3-6t rock armour	32	m3	125	£/m3	4000	
60-300Kg rock in fill	7.75	m3	90	£/m3	697.5	
Geotextile	20	m2	4.55	£/m2	91	

Subtotal rock revetment						4,788.50	4,800.00
Estimated cost per meter Option A (year 50)[1]							4,800.00
Prelims	10%					480.00	
Construction contingency	20%					1,056.00	
Cost per meter Option A (year 50)						6,336.00	6,350.00
Cost Option A (year 50)	**600**	**m**					**3,810,000.00**
Optimism bias	60%					2,286,000.00	2,300,00.00
Final cost Option A (year 50)							**6,110,000.00**

Total Cost Option A		**19,510,000.00**
Present Value Overall Cost Option A: [Cost Option A (year 0) + PV(Cost Option A (year 20))]	14,494,016.12	**14,500,000.00**

[1] EA guidance includes cost examples and average costs for rock revetment of £1,564 to £4,649 per meter.

Option B Element	Quantity	Unit	Rate	Rate unit	Cost	Rounded cost
Embankment						
Breaking up of redundant flexible pavement. Using scraper and ripper bulldozer; 100 to 200mm deep	9.0	m2	9.68	£/m2	87.12	
Excavate material other than topsoil, rock or artificial hard material 1.0 -2.0 m maximum depth	74.0	m3	5.65	£/m3	418.10	
Excavate material other than topsoil, rock or artificial hard material 1.0 -2.0 m maximum depth (shingle)	33.0	m3	5.65	£/m3	186.45	
Selected excavated material other than topsoil or rock. Filling embankments (30% from excavation)	22.2	m3	1.97	£/m3	43.73	
Imported natural material other than topsoil and rock; granular selected material. Filling embankments	131.8	m3	37.81	£/m3	4,983.36	
Compaction of granular fill material in embankments and other areas of fill	154.0	m3	0.79	£/m3	121.66	
Trimming of filled surface, material other than topsoil rock or artificial hard material; inclined at an angle 10-45 degrees to the horizontal	26.0	m2	1.9	£/m2	49.40	
Preparation of filled surface, material other than topsoil rock or artificial hard material; inclined at an angle 10-45 degrees to the horizontal	26.0	m2	2.72	£/m2	70.72	
Geotextile: slope reinforcement and embankment support; inclined at an angle 10-45 degrees to the horizontal	35.0	m2	4.55	£/m2	159.25	
Subtotal embankment[2]					6,119.79	6,200.00
Rock revetment						
3-6t rock armour	23.5	m3	125	£/m3	2,937.50	
60-300Kg rock in fill	6.75	m3	90	£/m3	607.5	
Geotextile	16	m2	4.55	£/m2	72.80	
Subtotal rock revetment [3]					3,617.80	3,650.00

[2] EA guidance includes cost examples and average costs for embankments of £33 to £50 per meter cube.
[3] EA guidance includes cost examples and average costs for rock revetment of £1,564 to £4,649 per meter.

Option B Element	Quantity	Unit	Rate	Rate unit	Cost	Rounded cost
Estimated cost per meter Option B						9,850.00
Prelims	10%				985.00	
Construction contingency	20%				2,167.00	
Cost per metre Option B					13,002.00	13,000.00
Cost Option B	**600**	**m**				**7,800,000.00**
Optimism bias	60%				4,680,000.00	4,700,000.00
Final cost Option B						**12,500,000.00**

Element	Quantity	Unit	Rate	Rate unit	Cost	Rounded cost
Embankment						
Breaking up of redundant flexible pavement. Using scraper and ripper bulldozer; 100 to 200mm deep	9.0	m2	9.68	£/m2	87.12	
Excavate material other than topsoil, rock or artificial hard material 1.0 -2.0 m maximum depth	52.5	m3	5.65	£/m3	296.63	
Selected excavated material other than topsoil or rock. Filling embankments (30% from excavation)	15.75	m3	1.97	£/m3	31.03	
Imported natural material other than topsoil and rock; granular selected material. Filling embankments	32.0	m3	37.81	£/m3	1,209.92	
Compaction of granular fill material in embankments and other areas of fill	47.75	m3	0.79	£/m3	37.72	
Trimming of filled surface, material other than topsoil rock or artificial hard material; inclined at an angle 10-45 degrees to the horizontal	18.0	m3	1.9	£/m3	34.20	
Preparation of filled surface, material other than topsoil rock or artificial hard material; inclined at an angle 10-45 degrees to the horizontal	18.0	m3	2.72	£/m3	48.96	
Geotextile: slope reinforcement and embankment support; inclined at an angle 10-45 degrees to the horizontal	20.0	m2	4.55	£/m2	91.00	
Selected excavated material other than topsoil or rock. Filling general (shingle)	25.0	m3	1.69	£/m3	42.25	
Subtotal embankment					1878.825	1,900.00
Gabion structure						
Gabion structure; includes geotextile, 9 x gabion welded mesh cages (2m x 1m x 1m), flint rejects approx. 75mm to 150mm and all necessary operations and complements	9.0	m3	175.5	£/m3	1579.5	1600.00
Subtotal gabion structure						1,600.00
Estimated cost per meter Option C (year 0)						3,500.00
Prelims	10%				350.00	
Construction contingency	20%				770.00	
Cost per metre Option C (year 0)					4,620.00	4,620.00

Element	Quantity	Unit	Rate	Rate unit	Cost	Rounded cost
Cost Option C (year 0)	**600**	**m**				**2,772,000.00**
Optimism bias	60%				1,663,200.00	1.728,000.00
Final cost Option C (year 0)						**4,500,000.00**

Element	Quantity	Unit	Rate	Rate unit	Cost	Rounded cost
Earthworks						
Demolition/clearance of gabion structure	9.0	m3	75	£/m3	675.00	
Excavate material other than topsoil, rock or artificial hard material 1.0 -2.0 m maximum depth	48.0	m3	5.65	£/m3	271.20	
Compaction of granular fill material in embankments and other areas of fill	6.3	m3	0.79	£/m3	4.98	
Trimming of filled surface, material other than topsoil rock or artificial hard material; inclined at an angle 10-45 degrees to the horizontal	18.0	m3	1.9	£/m3	34.20	
Preparation of filled surface, material other than topsoil rock or artificial hard material; inclined at an angle 10-45 degrees to the horizontal	12.0	m3	2.72	£/m3	32.64	
Geotextile: slope reinforcement and embankment support; inclined at an angle 10-45 degrees to the horizontal	15.0	m2	4.55	£/m2	68.25	
Selected excavated material other than topsoil or rock. Filling general (shingle)	25.0	m3	1.69	£/m3	42.25	
Subtotal earthworks					1086.27	1,100.00
Concrete wall						
In situ concrete. Provision and placing of concrete; reinforced, thickness exceeding 500 mm	7.0	m3	136.06	£/m3	952.42	
Formwork; fair finish	10.2	m2	64.22	£/m2	655.044	
Supply and placing of steel reinforcement; approx. 0.15t/m3	1.05	t	1246.95	£/t	1309.2975	
Finishing of formed surfaces; rubbing down concrete surfaces	12.2	m2	2.48	£/m2	30.256	
Subtotal concrete wall					2,947.02	3,000.00
Rock revetment						
3-6t rock armour	32	m3	125	£/m3	4000	

Element	Quantity	Unit	Rate	Rate unit	Cost	Rounded cost
60-300Kg rock in fill	7.75	m3	90	£/m3	697.5	
Geotextile	20	m2	4.55	£/m2	91	
Subtotal rock revetment [4]					4,788.50	4,800.00
Estimated cost per meter Option C (year 20)						8,900.00
Prelims	10%				890.00	
Construction contingency	20%				1,958.00	
Cost per meter Option C (year 0)					11,748.00	11,750.00
Cost Option C (year 20)	**600**	**m**				**7,050,000.00**
Optimism bias	60%				4,230,000.00	4,250,000.00
Final cost Option C (year 20)						**11,300,000.00**

Total Cost Option C		15,800,000.00
Present Value Overall Cost Option C: [Cost Option C (year 0) + PV(Cost Option C (year 20))]	10,178,994,49	**10,200,000.00**

[4] EA guidance includes cost examples and average costs for rock revetment of £1,564 to £4,649 per meter.

Royal HaskoningDHV
Enhancing Society Together