Appendix F

Cost Estimates

F1 Contractor estimates for harbour entrance structures

The potential works to the South Pier at Southwold Harbour would need to be undertaken by a specialist marine contractor. To obtain appropriate cost estimates for the various options, a quote was requested from the marine contractor Mackley Ltd (part of the Van Oord group), who are experienced in undertaking similar works on the east coast of the UK.

Briefing information was provided, which introduced the project, conditions at the site, the existing South Pier form of construction and condition, and the options for which cost estimates were required.

Cost estimates were provided by Van Oord for the following options and are included in the tables below. The cost estimates are inclusive of mobilisation / demobilisation costs, preliminary items, risk allowance, contractor's fee and 60% Optimism Bias.

- **Table F1.1:** Repairs to existing structure
- **Table F1.2:** Like-for-like replacement (concrete frame structure)
- **Table F1.3:** Sheet-piled pier with rock armour on southern face
- **Table F1.4:** Rock armour breakwater
- **Table F1.5:** Concrete unit breakwater

Using the cost estimates prepared for the South Pier, estimates were also prepared for potential future works to the North Pier and the Knuckle. It was assumed that these structures would be replaced with a revetment comprised of either concrete units (similar to existing) or rock armour. These cost estimates are included in **Table F1.6** and **Table F1.7**.

The cost estimates for the replacement of the North and South Piers depend on the foundation depth required, which relates to the future rate of erosion of the channel. The original cost estimates provided by Van Oord assumed that the present rate of erosion of the channel would continue but would not increase. If the rate of erosion of the channel was to accelerate in the future, due to an increase in the tidal prism of the estuary and associated tidal flow rates, then the foundation depth of the harbour entrance structures may need to be increased to account for this.

For the rock and concrete unit breakwater options, these would be designed with the piles from the existing structure providing support the toe. The breakwater would be designed to be structurally stable without these toe piles in place, enabling adaptation to channel erosion. Eventually, with continuing channel erosion, additional toe piling might be required.

The proposed design of the rock breakwater would use the piles from the existing structure to support the toe, although the breakwater would be designed to be structurally stable without the toe piles in place. At present, the existing piles have a minimum cover of 3m. The current rate of erosion of the channel bed is about 100mm/year so if this was to continue the existing piles could be undermined within 30 years.

However, the breakwater would reduce wave disturbance within the entrance channel and would be expected to reduce scour of the channel bed as wave energy will be dissipated by the structure. Any seabed sediment excavated during construction of the breakwater could be placed against the toe piles to provide additional cover. Therefore, for the outline design of these structures it is appropriate to assume that the rate of erosion will not increase and it will not be necessary to include new, deeper toe piling as part of the breakwater design. Taking a conservative approach, an allowance will be included in the Investment Plan for installing toe piling in Year 30. The actual timing and depth of this piling would be dependent on the future rate of erosion.

For the like-for-like replacement and sheet piled pier options, there is greater potential for the rate of erosion of the channel bed to increase in the future, so the piled foundations would need to be designed to account for this. Therefore the cost estimates provided by Van Oord for piling were increased by 20% to allow for a greater foundation depth.

For the 'repair' option, an increase in erosion rate would be expected to change the time of failure. Sensitivity to timing of works or failure of structures is considered in **Section 11.2** of this report.

Table F1.1 – Cost estimate for repairs to existing structure

Description	Qty	Unit	Rate		Amount
Materials					
AZ28 - 700 @ 11m long	152	Tonne	£ 770.00		£ 117,040.00
Concrete Pre-Cast Pile	22	nr	£ 800.00		£ 17,600.00
Pre-Cast Beam	7	m3	£ 800.00		£ 5,600.00
Insitu Concrete Capping	30	m	£ 700.00		£ 21,000.00
Pre-Cast Capping	7	m3	£ 800.00		£ 5,600.00
Insitu Concrete Connections Pile to Beams	22	nr	£ 700.00		£ 15,400.00
Concrete Repairs	80	m3	£ 1,000.00		£ 80,000.00
			Sub Total		**£ 262,240.00**
			Fee	15%	£ 39,336.00
			Total Materials		**£ 301,576.00**
Labour & Plant (Access Road)					
Install By Jack Up Barge (as Demolition rate)	3	wks	£ 66,000.00		£ 198,000.00
Install Concrete works	3	wks	£ 54,000.00		£ 162,000.00
Barge to Access Concrete Repairs	8	wks	£ 66,000.00		£ 528,000.00
Gang to Set Up Welfare	4	wks	£7,500.00		£ 30,000.00
			Sub Total		**£ 918,000.00**
			Fee	15%	£ 137,700.00
			Total Labour & Plant		**£ 1,055,700.00**
Mob / Demobilisation & Demolition					
Jack Up Barge, 90t Long Reach Excavator, Cutting jaws, Work boat, Safety boat, Flat top barge, 50t Excavator + Grab and Crew	1	Wks	£ 66,000.00		£ 66,000.00
Mob / Demobilisation	2	each way	£ 75,000.00		£ 150,000.00
Disposal	1	Sum	£ 5,000.00		£ 5,000.00
			Sub Total		**£ 221,000.00**
			Fee	15%	£ 33,150.00
			Total Mob/Demob & Demolition		**£ 254,150.00**
			Sub Total		**£ 1,611,426.00**
			Prelims	20%	£ 322,285.20
			Contractors Risk	5%	£ 96,685.56
			Total		**£ 2,030,396.76**
			Total +60% OB		**£ 3,248,634.82**

Table F1.2 – Cost estimate for replacement with similar concrete frame structure

Description	Qty	Unit	Rate		Amount
Materials					
AZ28 - 700 @ 11m long	1,378	Tonne	£ 770.00		£ 1,061,060.00
Concrete Pre-Cast Pile	189	nr	£ 800.00		£ 151,200.00
Pre-Cast Beam	66	m3	£ 800.00		£ 52,800.00
Insitu Concrete Capping	270	m	£ 700.00		£ 189,000.00
Pre-Cast Capping	66	m3	£ 800.00		£ 52,800.00
Insitu Concrete Connections Pile to Beams	189	nr	£ 700.00		£ 132,300.00
			Sub Total		**£ 1,639,160.00**
			Fee	15%	£ 245,874.00
			Total Materials		**£ 1,885,034.00**
Labour & Plant (Access Road)					
Install By Jack Up Barge (as Demolition rate)	20	wks	£ 66,000.00		£ 1,320,000.00
Install Concrete works	27	wks	£ 54,000.00		£ 1,458,000.00
Gang to Set Up Welfare	4	wks	£ 7,500.00		£ 30,000.00
			Sub Total		**£ 2,808,000.00**
			Fee	15%	£ 421,200.00
			Total Labour & Plant		**£ 3,229,200.00**
Mob / Demobilisation & Demolition					
Jack Up Barge, 90t Long Reach Excavator, Cutting jaws, Work boat, Safety boat, Flat top barge, 50t Excavator + Grab and Crew	6	Wks	£ 66,000.00		£ 396,000.00
Mob / Demobilisation	2	each way	£ 75,000.00		£ 150,000.00
Disposal	1	Sum	£ 40,000.00		£ 40,000.00
			Sub Total		**£ 586,000.00**
			Fee	15%	£ 87,900.00
			Total Mob/Demob & Demolition		**£ 673,900.00**
			Sub Total		**£ 5,788,134.00**
			Prelims	20%	£ 1,157,626.80
			Contractors Risk	5%	£ 347,288.04
			Total		**£ 7,293,048.84**
			Total +60% OB		**£ 11,668,878.14**

Table F1.3 – Cost estimate for sheet piled walls plus rock armour to south face

Description	Qty	Unit	Rate			Amount	
Materials							
6t to 10t Rock Armour	13,650	Tonne	£	60.00		£	819,000.00
1t to 3t Rock Armour	3,600	Tonne	£	60.00		£	216,000.00
Quarry Run Material	5,000	Tonne	£	45.00		£	225,000.00
Aggregate Tax	22,250	tonne	£	2.00		£	44,500.00
HZ King Piles 1080 MB @ 20m long	900	Tonne	£	910.00		£	819,000.00
AZ42-700 Intermediate Piles @ 14m Long	578	Tonne	£	750.00		£	433,500.00
				Sub Total		**£**	**2,557,000.00**
				Fee	15%	£	383,550.00
				Total Materials		**£**	**2,940,550.00**
Labour & Plant (Access Road)							
Place Rock Armour	17,250	tonnes	£	25.00		£	431,250.00
Place Quarry Run Material	5,000	tonnes	£	20.00		£	100,000.00
Install Combi Piles	14	wks	£	54,000.00		£	756,000.00
Gang to Set Up Welfare	4	wks		£7,500.00		£	30,000.00
				Sub Total		**£**	**1,317,250.00**
				Fee	15%	£	197,587.50
				Total Labour & Plant		**£**	**1,514,837.50**
Mob / Demobilisation & Demolition							
Jack Up Barge, 90t Long Reach Excavator, Cutting jaws, Work boat, Safety boat, Flat top barge, 50t Excavator + Grab and Crew	6	Wks	£	66,000.00		£	396,000.00
Mob / Demobilisation	2	each way	£	75,000.00		£	150,000.00
Disposal	1	Sum	£	40,000.00		£	40,000.00
				Sub Total		**£**	**586,000.00**
				Fee	15%	£	87,900.00
				Total Mob/Demob & Demolition		**£**	**673,900.00**
				Sub Total		**£**	**5,129,287.50**
				Prelims	20%	£	1,025,857.50
				Contractors Risk	5%	£	307,757.25
				Total		**£**	**6,462,902.25**
				Total +60% OB		**£**	**10,340,643.60**

Table F1.4 – Cost estimate for rock armour breakwater

Description	Qty	Unit	Rate			Amount	
Materials							
6t to 10t Rock Armour	27,380	Tonne	£	60.00		£	1,642,800.00
1t to 3t Rock Armour	7,250	Tonne	£	60.00		£	435,000.00
Quarry Run Material	10,090	Tonne	£	45.00		£	454,050.00
Box culverts	30	Units	£	3,000.00		£	90,000.00
Aggregate Tax	44,750	tonne	£	2.00		£	89,500.00
				Sub Total		**£**	**2,711,350.00**
				Fee	15%	£	406,702.50
				Total Materials		**£**	**3,118,052.50**
Labour & Plant (Access Road)							
Place Rock Armour	34,630	tonnes	£	25.00		£	865,750.00
Place Quarry Run Material	10,090	tonnes	£	20.00		£	201,800.00
Place box culverts	30	units	£	500.00		£	15,000.00
Gang to Set Up Welfare	4	wks		£7,500.00		£	30,000.00
				Sub Total		**£**	**1,112,550.00**
				Fee	15%	£	166,882.50
				Total Labour & Plant		**£**	**1,279,432.50**
Mob / Demobilisation & Demolition							
Jack Up Barge, 90t Long Reach Excavator, Cutting jaws, Work boat, Safety boat, Flat top barge, 50t Excavator + Grab and Crew	6	Wks	£	66,000.00		£	396,000.00
Mob / Demobilisation	2	each way	£	75,000.00		£	150,000.00
Disposal	1	Sum	£	40,000.00		£	40,000.00
				Sub Total		**£**	**586,000.00**
				Fee	15%	£	87,900.00
				Total Mob/Demob & Demolition		**£**	**673,900.00**
				Sub Total		**£**	**5,071,385.00**
				Prelims	20%	£	1,014,277.00
				Contractors Risk	5%	£	304,283.10
				Total		**£**	**6,389,945.10**
				Total +60% OB		**£**	**10,223,912.16**

Table F1.5 – Cost estimate for concrete armour unit breakwater

Description	Qty	Unit	Rate			Amount	
Materials							
Box culverts	30	Units	£	3,000.00		£	90,000.00
Core-Loc Concrete Units	4,929	nr	£	1,000.00		£	4,929,000.00
3t to 6t Rock Armour	5,400	Tonne	£	60.00		£	324,000.00
0.3t to 1t Rock Armour	5,010	Tonne	£	60.00		£	300,600.00
Quarry Run Material	10,670	nr	£	45.00		£	480,150.00
Aggregate Tax	21,080	tonne	£	2.00		£	42,160.00
				Sub Total		**£**	**6,165,910.00**
Fee				Fee	15%	£	924,886.50
				Total Materials		**£**	**7,090,796.50**
Labour & Plant (Access Road)							
Place box culverts	30	units	£	500.00		£	15,000.00
Place Rock Armour	10,410	tonnes	£	25.00		£	260,250.00
Place Quarry Run Material	10,670	Days	£	20.00		£	213,400.00
Place Core-Loc Concrete Units	4,929	nr		£120.00		£	591,480.00
Gang to Set Up Welfare	4	wks		£7,500.00		£	30,000.00
				Sub Total		**£**	**1,110,130.00**
				Fee	15%	£	166,519.50
				Total Labour & Plant		**£**	**1,276,649.50**
Mob / Demobilisation & Demolition							
Jack Up Barge, 90t Long Reach Excavator, Cutting jaws, Work boat, Safety boat, Flat top barge, 50t Excavator + Grab and Crew	6	Wks	£	66,000.00		£	396,000.00
Mob / Demobilisation	2	each way	£	75,000.00		£	150,000.00
Disposal	1	Sum	£	40,000.00		£	40,000.00
				Sub Total		**£**	**586,000.00**
				Fee	15%	£	87,900.00
				Total Mob/Demob & Demolition		**£**	**673,900.00**
				Sub Total		**£**	**9,041,346.00**
				Prelims	20%	£	1,808,269.20
				Contractors Risk	5%	£	542,480.76
				Total		**£**	**11,392,095.96**
				Total +60% OB		**£**	**18,227,353.54**

Table F1.6 – Cost estimate for replacement of North Pier with concrete armour units

Description	Qty	Unit	Rate			Amount	
Materials							
Core-Loc Concrete Units	2,460	nr	£	1,000.00		£	2,460,000.00
3t to 6t Rock Armour	2,700	Tonne	£	60.00		£	162,000.00
0.3t to 1t Rock Armour	2,505	Tonne	£	60.00		£	150,300.00
Quarry Run Material	5,335	nr	£	45.00		£	240,075.00
Aggregate Tax	5,270	tonne	£	2.00		£	10,540.00
				Sub Total		**£**	**3,022,915.00**
				Fee	15%	£	453,437.25
				Total Materials		**£**	**3,476,352.25**
Labour & Plant (Access Road)							
Place Rock Armour	5,205	tonnes	£	25.00		£	130,125.00
Place Quarry Run Material	5,335	Days	£	20.00		£	106,700.00
Place Core-Loc Concrete Units	2,460	nr	£	120.00		£	295,200.00
Gang to Set Up Welfare	4	wks		£7,500.00		£	30,000.00
				Sub Total		**£**	**562,025.00**
				Fee	15%	£	84,303.75
				Total Labour & Plant		**£**	**646,328.75**
Mob / Demobilisation & Demolition							
Jack Up Barge, 90t Long Reach Excavator, Cutting jaws, Work boat, Safety boat, Flat top barge, 50t Excavator + Grab and Crew	4	Wks	£	66,000.00		£	264,000.00
Mob / Demobilisation	2	each way	£	75,000.00		£	150,000.00
Disposal	1	Sum	£	40,000.00		£	40,000.00
				Sub Total		**£**	**454,000.00**
				Fee	15%	£	68,100.00
				Total Mob/Demob & Demolition		**£**	**522,100.00**
				Sub Total		**£**	**4,644,781.00**
				Prelims	20%	£	928,956.20
				Contractors Risk	5%	£	278,686.86
				Total		**£**	**5,852,424.06**
				Total +60% OB		**£**	**9,363,878.50**

Table F1.7 – Cost estimate for replacement of North Pier with rock revetment

Description	Qty	Unit	Rate			Amount	
Materials							
6t to 10t Rock Armour	13,690	Tonne	£	60.00		£	821,400.00
1t to 3t Rock Armour	3,625	Tonne	£	60.00		£	217,500.00
Quarry Run Material	5,000	Tonne	£	45.00		£	225,000.00
Aggregate Tax	11,158	tonne	£	2.00		£	22,316.00
				Sub Total		**£**	**1,286,216.00**
				Fee	15%	£	192,932.40
				Total Materials		**£**	**1,479,148.40**
Labour & Plant (Access Road)							
Place Rock Armour	17,315	tonnes	£	25.00		£	432,875.00
Place Quarry Run Material	5,000	tonnes	£	20.00		£	100,000.00
Gang to Set Up Welfare	4	wks		£7,500.00		£	30,000.00
				Sub Total		**£**	**562,875.00**
				Fee	15%	£	84,431.25
				Total Labour & Plant		**£**	**647,306.25**
Mob / Demobilisation & Demolition							
Jack Up Barge, 90t Long Reach Excavator, Cutting jaws, Work boat, Safety boat, Flat top barge, 50t Excavator + Grab and Crew	4	Wks	£	66,000.00		£	264,000.00
Mob / Demobilisation	2	each way	£	75,000.00		£	150,000.00
Disposal	1	Sum	£	40,000.00		£	40,000.00
				Sub Total		**£**	**454,000.00**
				Fee	15%	£	68,100.00
				Total Mob/Demob & Demolition		**£**	**522,100.00**
				Sub Total		**£**	**2,648,554.65**
				Prelims	20%	£	529,710.93
				Contractors Risk	5%	£	158,913.28
				Total		**£**	**3,337,178.86**
				Total +60% OB		**£**	**5,339,486.17**

F2 Cost estimate for tidal barrier

The potential costs for a tidal barrier or barrage at Southwold have been assessed based on the cost of previous tidal barrier schemes, summarised in **Table F2.1** below.

Table F2.1– Summary of costs for example tidal barrier schemes

Example	Approx. dimensions	Contract value or estimate? (Year)	Scheme cost, 2018 (£m)	Approx. Barrier Cost, 2018 (£m)
Ipswich tidal barrier	20m navigable width	Contract value (2018)	58	28
Boston barrier	Estimated 60m wide, 25m navigable width	Estimate (2017)	103	69
Bridgwater tidal barrier	50m wide, 15m navigable	Estimate (2017)	73	37 (estimate, 50% of scheme cost)
Colne barrier	130m wide, 30m navigable	Contract value (1993)	29	29
Yare barrier	Assumed approx. 100m wide, 30m navigable width.	Estimate (1995)	136	42
River Hull tidal surge barrier	30m wide	Contract value (1980)	11	11
Barking Creek tidal barrier	92m wide, 39m wide gate	Contract value (1979)	33	Not available

The Boston Barrier is a recently completed scheme in the east of England with dimensions comparable to what would be required at Southwold. It is understood that the Boston Barrier cost estimate includes 30% optimism bias[29], therefore the cost estimate for the barrier excluding the associated works would be £52.9m without optimism bias. The Boston scheme includes lock structures and was constructed in a spatially constrained location in Boston Town Centre, whereas there are less constraints at Southwold.

Based on the Boston Barrier cost estimate, an estimated cost of £60m is assumed for Southwold, *inclusive* of 60% optimism bias.

F3 Cost estimates for works to estuary defences

Cost estimates for works to the estuary defences are based on the estimates previously developed by Black and Veatch as part of the Blyth Estuary Strategy in 2008.

The assumptions made in these cost estimates have been reviewed and revised as follows, considering previous feedback on the Strategy cost estimates (Ref. 4):

- Embankments would be raised by increasing the crest level and widening the landward side as necessary. To maintain flood protection during construction works, the existing embankments would not be removed.
- Existing defence crest levels used for the EA strategy cost estimates were reviewed against more recent survey data. There were limited differences between these levels, so the data from the EA strategy has been used for consistency and ease of comparison.

[29] *Optimism bias is an uplift applied to infrastructure cost estimates to account for the recognised tendency for early cost estimates to be overly optimistic. Optimism bias of 30% is the accepted factor for detailed design- stage cost estimates. Optimism bias of 60% is the accepted factor for concept-stage cost estimates, and is therefore the appropriate factor for this project.*

- New defence crest levels based on water levels from tidal modelling results for each option. Consistent defence level applied to each flood compartment.
- No freeboard allowance included in new defence crest levels, based on stakeholder preference.
- Defence crest level increased to allow for settlement of 75mm over 50 years.
- Landward slope of embankments assumed to be 1:3, based on current design guidance and expected geotechnical design requirements.
- Crest width of embankment minimised, reduced to 2m.
- Geotextile assumed to be required, as we are constructing on top of the existing bank structures.
- Assume grass seeding rather than turfing, cost rate reduced by 50%.
- Assume rock armour used for toe protection rather than sheet piling, cost rate reduced to reflect this.
- No works will be required to the North Wall within 50 years.
- Habitat compensation costs not included, as compensatory habitat has already been secured by the Environment Agency.
- No change to assumed allowances for Access and Mobilisation (15%), Labour and Plant (15%), Contingencies (0%), Contractors' overheads (20%), Contractor's profit (5%).
- Engineering costs reduced to 8% of construction costs, based on expected design costs for straightforward embankment design.
- Client costs reduced to 3% of construction costs, as local authority costs for project management would be less than Environment Agency costs.

All cost estimates have been updated to present day values using the Output Price Index for Public Works (OPI) (Ref. 13), as set out in **Table F3.1**.

Table F3.1: Multipliers applied to account for inflation

	Date	Output Index	Index multiplier
Base date for original EA Strategy cost estimates	Q2, 2004	136	-
Date used for EA Strategy cost estimates	Q2, 2007	153	1.13
Date used for Southwold Harbour Investment Plan	Q4, 2020	186.9	1.37

The item rates used in the EA Strategy cost estimates were all based on rates taken from the 2004 edition of the SPON'S Civil Engineering and Highway Works Price Book. The updated rates with OPI inflation applied have been compared against the present-day values from SPON'S (Ref. 11), as set out in **Table F3.2**. This shows some rates to be higher than the inflated rates, but with the cost of imported fill material being less than the inflated rate. When the 2020 SPON'S rates are used to calculate the total option costs rather than the inflated 2004 rates, the resulting estimate for the initial capital cost is about 2% higher. Therefore, the cost estimates based on the previous 2004 rates are used, for ease of comparison with the EA Strategy cost estimates.

Table F3.2: Comparison of item costs

	Item description	Unit	2004 Rate (£)	2004 Rate + inflation to 2020 (£)	2020 Rate	Notes
1	Excavation – foundations / topsoil; not exceeding 0.25m	m^3	1.25	1.71	3.54	
2	Filling - imported; embankments	m^3	10.74	14.71	12.82	
3	Geotextile - slope 10-45 deg.	m^2	2.70	3.70	5.39	
4	Turfing - slope 10-45 deg.	m^2	4.00	5.48	-	Rate reduced by 50%, assuming seeding rather than turfing.
5	Site clearance; general site vegetation	Hectare	795.70	1090.11	1358.17	
7	Land Purchase Costs	m	0.653	0.89	-	
8	Mini Piles (erosion protection)	m	320.97	439.73		Mini-pile rate used for specific sections of exiting piled defence.
9	Rock Toe	m	90.25	123.62		Rock toe assumed for erosion protection (lower cost than piles).

Table F3.3 summarises the costs for the various estuary management scenarios. Costs were assessed for a 1 in 5-year return period standard of protection (20% AEP) and for a 1 in 100-year return period standard of protection (1% AEP), allowing for climate change based on a medium emissions scenario (UKCP18 scenario RCP4.5, 50 percentile). Sensitivity to a wider range of climate change scenarios was also assessed for the 'Raise Estuary Defences' option.

Table F3.3: Summary of cost estimates for estuary management options

Option	Materials	Contractor's Costs[30]	Engineering & Client Costs[31]	Optimism Bias (60%)	TOTAL
Raise all estuary defences (20% AEP)	£ 3,813,449	£ 1,472,348	£ 566,854	£ 3,511,591	**£ 9,364,242**
Raise north banks only (20% AEP)	£ 1,700,185	£ 627,043	£ 241,411	£ 1,541,183	**£ 4,109,822**
Raise all estuary defences (1% AEP)	£ 5,882,988	£ 2,300,164	£ 885,563	£ 5,441,229	**£ 14,509,945**
Raise all estuary defences + narrow channel[32] (1% AEP)	£ 5,540,696	£ 2,163,247	£ 832,850	£ 5,122,076	**£ 13,658,869**
Raise all estuary defences + spillway (1% AEP)	£ 5,647,027	£ 2,205,780	£ 849,225	£ 5,221,219	**£ 13,923,250**
Raise north banks only (1% AEP)	£ 2,524,404	£ 956,731	£ 368,341	£ 2,309,686	**£ 6,159,162**
Raise north banks only + narrow channel (1% AEP)	£ 5,808,634	£ 2,270,422	£ 874,113	£ 5,371,901	**£ 14,325,070**

[30] Contractor's costs include labour & plant, mobilisation/demobilisation, preliminary items & overheads, and contractor's risk & profit.

[31] Engineering and Client costs include site investigations, engineering design, consent process incl. associated studies, construction management and supervision and other associated costs to East Suffolk Council.

[32] Costs do not include for works to construct the rock groyne to narrow the channel. With the narrow channel, the upstream defence crest level is slightly less, so the embankment costs are lower than without the rock structure to narrow the channel.

F4 Cost estimate for spillway

A cost of £10 million has been assumed for the proposed spillway option, *inclusive* of 60% optimism bias. This estimate is based on experience of relevant projects to construct sluice structures of a similar size and is considered to be appropriate for this optioneering stage of the project. The cost estimate includes:

- excavation of the existing embankments;
- construction of wing walls to support the sluice gate;
- construction of a reinforced sill forming the base to the spillway, against which the sluice gates would be closed;
- supply and installation of the sluice gates; and
- associated electrical works.

A more detailed cost estimate could be prepared based on an outline design of a proposed structure if this option was to be taken forward.

F5 Cost estimate for works to reduce flood risk to the Harbour

Cost estimates for works to reduce flood risk to the harbour are set out in Table F5.1, based on the following assumptions:

- Works to raise the level of the harbour road would be undertaken over approximately a 20m width of the road.
- The present level of the Harbour Road is conservatively assumed to be +1.0m ODN on average along its 1060m length.
- A road level of 3.10m ODN would be required for a 1:100 year standard of protection, allowing for climate change to 2070.
- A road level of 2.65m ODN would be required for a 1:5 year standard of protection, allowing for climate change to 2070.
- Unit costs for flood walls and embankments are based on the current Environment Agency Cost Database (Ref. 12).
- Costs do not include for relocation or flood resilience measures to the various boat sheds and other structures located along the harbour road, or to replace or adapt the existing pontoons. Further consideration is needed of how best to undertake works to raise the road to minimise the need to relocate these buildings.
- Additional resilience measures may be needed to businesses and properties in the harbour in the future. Property level flood protection measures to the properties in the Blackshore could cost £50,000 on average, depending on the extent of internal works that are required. These costs are not included in the table below.

Table F5.1: Cost estimates for works to reduce flood risk to the harbour

Option	Embankments	Flood walls and flood gates	Sub-total	Optimism Bias (60%)	TOTAL
H2: Raise Harbour Road (1:5 SOP)	£2,060,863		£2,060,863	£1,236,518	**£3,297,380**
H3: Raise Harbour Road (1:100 SOP)	£2,552,215		£2,552,215	£1,531,329	**£4,083,544**
H4a: Raise Harbour Road plus concrete flood walls (1:100 SOP)	£1,069,296	£2,130,569	£3,199,865	£1,919,919	**£5,119,784**
H4b: Raise Harbour Road plus glass and concrete flood walls (1:100 SOP)	£1,069,296	£3,944,417	£5,013,713	£3,008,228	**£8,021,941**
H5: Raise Harbour Road (1:5 SOP) + Blackshore Flood Walls (1:100 SOP)	£2,060,863	£638,544	£2,699,406	£1,619,644	**£4,319,050**

Annex F1 – Contractor Briefing Information

Note / Memo

HaskoningDHV UK Ltd.
Water

To:	Van Oord
From:	David Cramp
Date:	24 August 2020
Copy:	Tim Burgess, Amy Savage, Euan Hobson
Our reference:	PB9485-RHD-ZZ-XX-NT-Z-0001
Classification:	Project related
Checked by	Click or tap here to enter text.

Subject: **Southwold Harbour Study – Costing Information**

1 Introduction

Southwold Harbour is located on the Suffolk coast at the mouth of the River Blyth estuary as highlighted in Figure 1-1 below.

Figure 1-1: Site Location

The harbour is split into 7 locations labelled on
Figure 1-2:

- North Wall
- North Pier
- Knuckle
- RNLI Station
- Walberswick Quay
- South Training Wall
- South Pier

For this costing part of the study we are interested in the South Pier.

Figure 1-2 - Southwold Harbour Location Plan

The harbour previously supported a major local fishing industry, but this commercial activity has declined and made way for an increase in recreational use of the harbour. Southwold Harbour now attracts many yachting visitors to Southwold and is a focal point for day yachtsmen. Walberswick Beach attracts summer visitors and is a 'walkers' beach throughout the year.

Despite the decline in commercial fishing the area does still support a small but active fishing industry with associated shore-based activities. The harbour is also a base for a RNLI Lifeboat.

1.1 Purpose of Study

RHDHV have been commissioned by Coastal Partnership East for East Suffolk Council to undertake a study into the current condition of the defences at Southwold harbour and potential options to improve conditions and safeguard the future use of the harbour.

1.2 Purpose of Note

The purpose of this note is to provide information for early contractor involvement (ECI) into the high level costing of options to repair and replace the South Pier. High level costings are required for the following options:

1. Replace the South Pier with a Rock Breakwater
2. Replace the South Pier with a Concrete Unit Breakwater
3. Replace the South Pier with a like for like solution
4. Repairs to the South Pier

1.3 Note Layout

The note is split into the following sections:

- **Section 2 South Pier Details** – Describes the existing structure, currant condition and expected life expectancy.
- **Section 3 Site Conditions** – Introduces the conditions at the site.
- **Section 4 Options** – Details the options of which high level costing information is required.

2 South Pier Details

2.1 Structural Details

The South Pier is comprised of three or four different types of structure having undergone a number of repairs over the last 90 years. Fundamentally however, the South Pier consists of a 417m long continuous reinforced concrete structure with a face (on the north side of the Pier) of either reinforced concrete planks or steel sheet piling making up the harbour wall, supported by pairs of raking piles connected with concrete longitudinal and cross members. The nature and condition of this face varies depending on location. In places, the raking piles are surrounded by rock armour, intended to reduce scouring according to the 1990s design drawings. An example cross-section drawing of one part of the South pier is included in Figure 2-1.

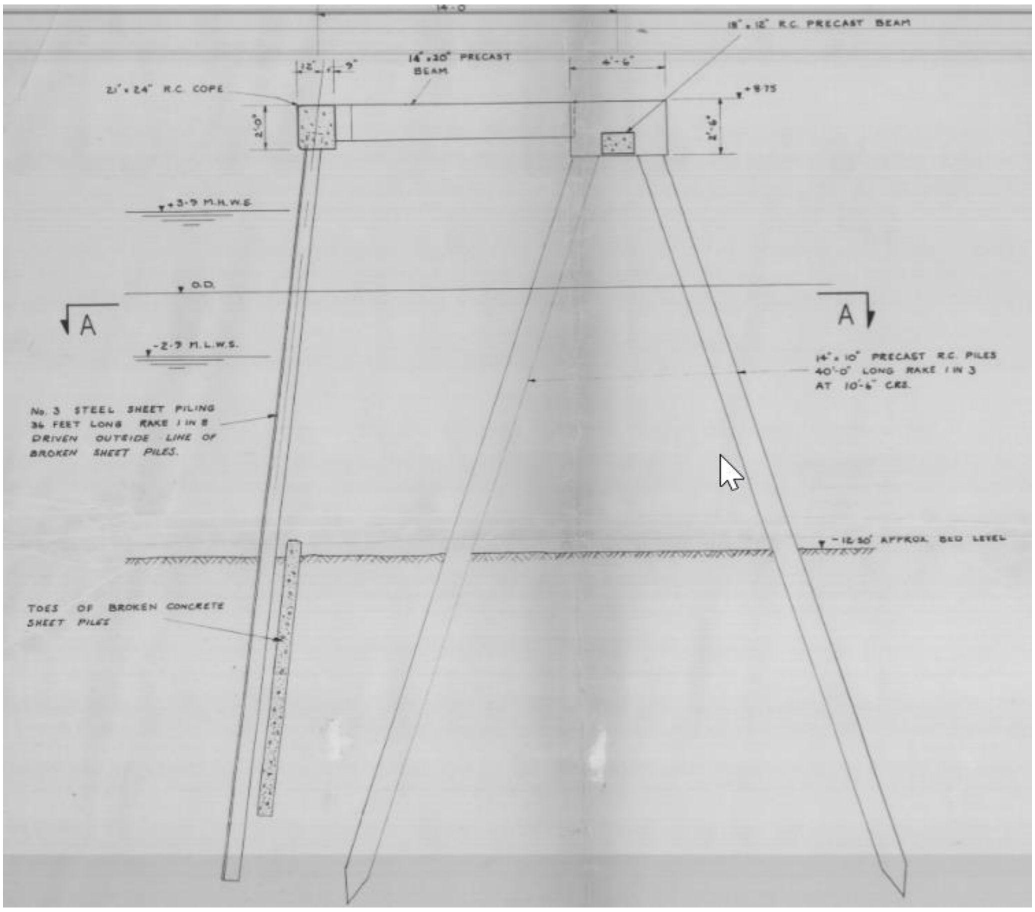


Figure 2-1 – Example cross-section of South Pier (Length C – dimensions and levels in feet and inches)

The easternmost section of the pier, Length A (Figure 2-2), is made up of box piles at each crossmember interlocked with sheet piles driven in front of the concrete planks. The box piles are shown on historic drawings to be filled with concrete above the seabed level. The planks have been cut off at -0.3m AOD (Figure 4). The rear concrete beams to Length A have also been replaced at some point. The joints between these box piles and the crossmembers have been repaired in the past.
An original length of the pier remains inland of these box piles (Length B), which is still in relatively good condition.

Length C, immediately inland of Length B, is made up of steel sheet piles driven in front of the concrete planks which had been cut off at -0.3m OD (Figure 2-2). Newer raking piles, beams and crossmembers have been added here too. This structure differs slightly from the original design in that the rear beams are below the cross members rather than in line with the cross beams.

Length B2 is the remainder of the structure inshore of Length C up to the entrance to Dunwich Creek, and is similar in construction to Length B.

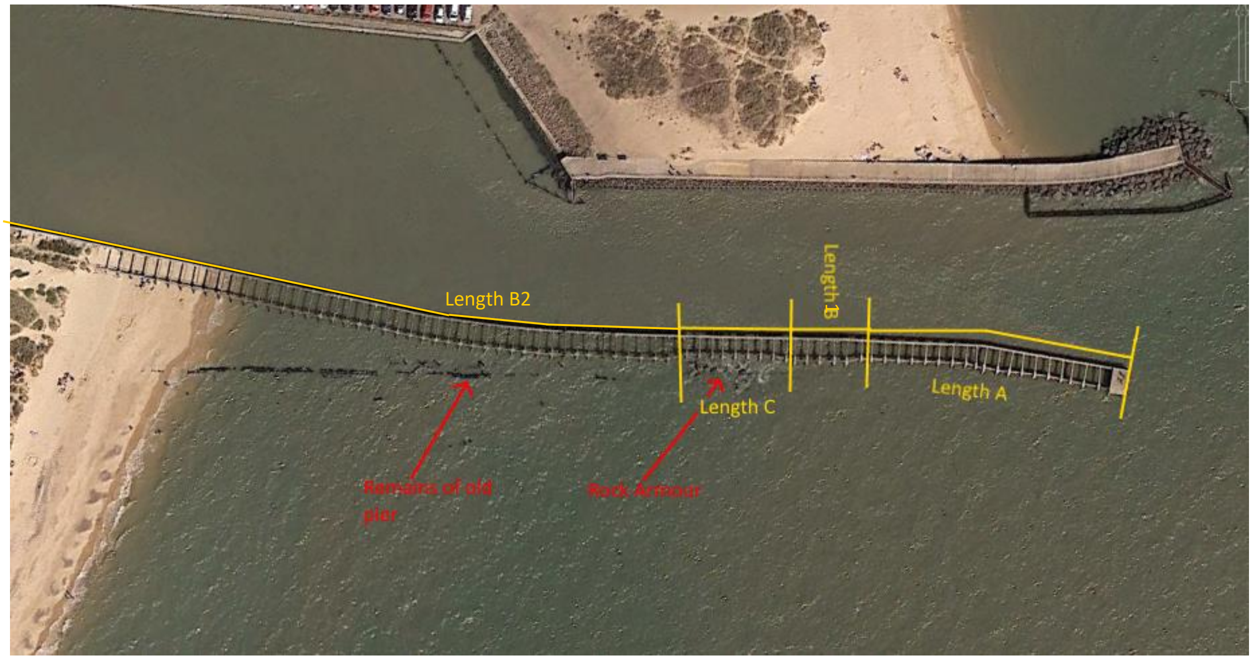


Figure 2-2 - Map of South Pier with marked Lengths A-C

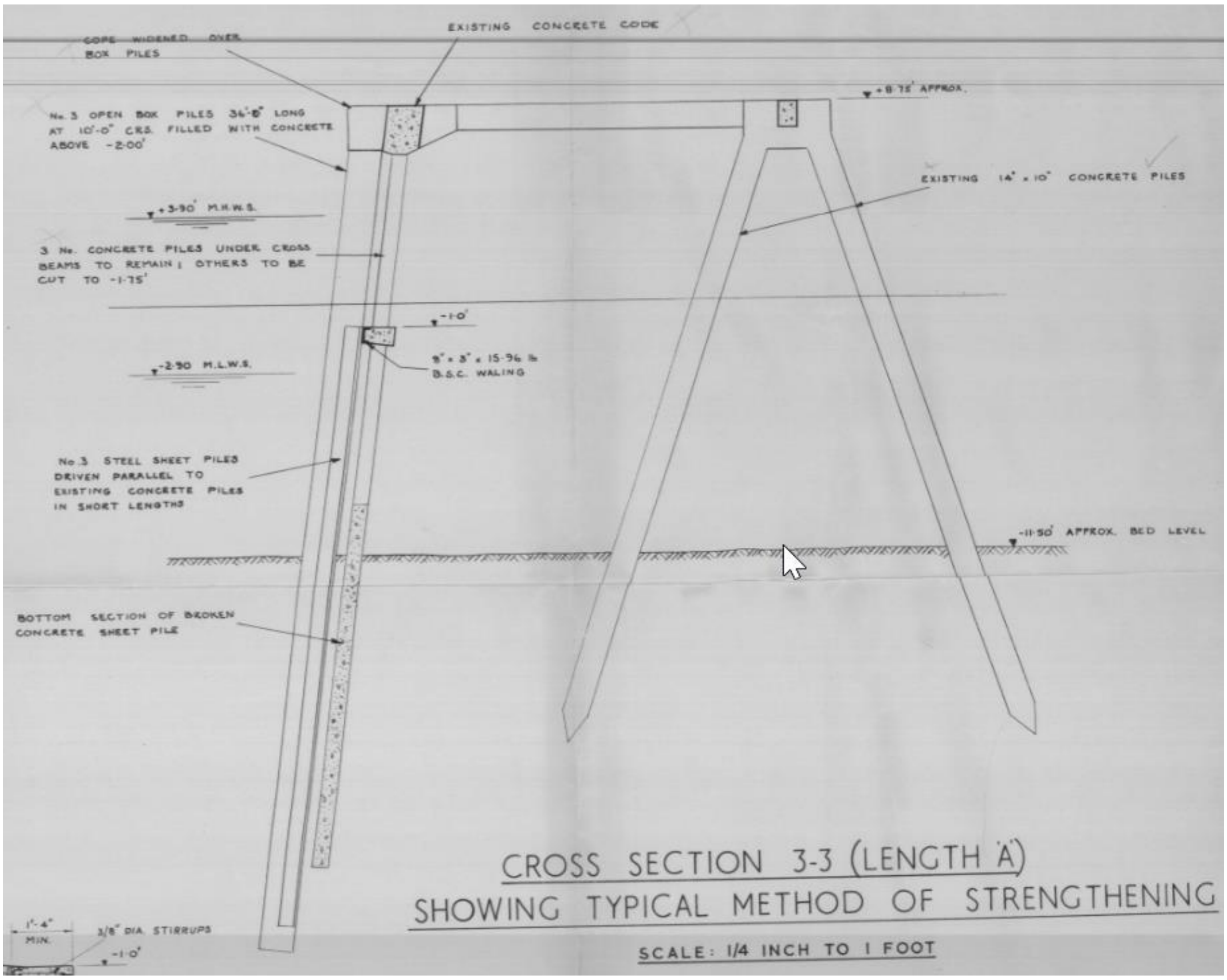


Figure 2-3 – South Pier Length A, Section 3-3 (dimensions and levels in feet and inches)

2.1.1 Summary of Condition Assessment

The majority of the structure was in a moderately good condition overall considering previous estimates of life expectancy.

The concrete part of the structure does not appear to be at the end of its life. Whilst a few areas have failed, and rebar is exposed in small, localised areas, generally there aren't any signs of imminent failure that might have been expected given the structure had a predicted life of 5-10 years 24 years ago.

Most raking piles look to be in good condition. The narrow crossmembers are typically the part of the structure in worst condition, with exposed rebar and signs of corrosion to approximately 20% of these. Much of the cracking in the concrete appears to be due to failure of previous poor-quality patch repairs.

The sheet steel piles in Length C extend above low water into the splash zone. Consequently they have suffered from significant corrosion, and are supporting little to none of the front beam. This beam is cantilevered off the piles behind and would appear to be the most 'at risk' part of the structure. In the event of a storm surge event this beam is liable to be driven upwards, which could lead to the crossmembers or rear piles failing and a length of this front beam collapsing into the harbour.

Length A of the South Pier is generally considered be less vulnerable than Length C. The more substantial box piles have been installed around the original concrete structure, with the additional lower level steel sheet piles typically located below low water level and according to the original drawings supported by a waling at the top and the old concrete planks lower down. As such the sheet piles do not appear to have corroded in the same way as the sheet piles to Length C. Whilst visibility of these piles was limited during the inspection, the section continues to be well aligned and the upper edge of the sheet piles did not appear to be corroded to the extent of the Length C sheet piles (Figure 7).

One of the box piles around the harbour mouth (number 8 counting the seaward end inland) is not supporting the beam above it. Closer inspection suggests that this pile is likely to have been struck by a vessel resulting in a dent at the low tide waterline. This damage is also causing the top beam to be cantilevered off the rear piles and may be subject to failure in a storm surge as above.

2.1.2 Areas of Interest

Box pile number 8 (Figure 2-4**)** has been damaged, possibly hit by a vessel at some point, and is no longer supporting the beam above which is simply cantilevered off the raking piles behind and the adjacent box piles. (Figure 2-5).

A section of planks has been replaced with steel sheet piles (Length C) however these have corroded severely (Figure 2-6). This front beam section is no longer supported properly and is cantilevered off the rear raking piles. The damage to this structure in the past appears to have been slowed with mounds of rock that have been used to block openings in the pier face from the rear (Figure 2-6).

A rear longitudinal beam at piles 35-36 has failed completely (Figure 2-6).

There is a minor issue with scouring around the planks at piles 66-67 (Figure 2-7) where a scour hole has formed on the beach side of the structure (Figure 9).

The west end of the pier, level with Walberswick dunes and inside Walberswick Quay, has also developed some holes between the planks leading to scour in these regions (Figure 2-7)**.** This is before the section where the main planks have been cut down to allow water exchange.

Approximately 20% of the rear piles, beams and connecting cross members have exposed rebar (Figure 2-8).

Potential failure has occurred in the front beam at piles 115-116 (Figure 2-8)

A joint has begun to fail / a crack has formed on the front beam between piles 121 and 122 (Figure 2-9).

Figure 2-4 - Box Pile 8 failure

Figure 2-5 - Length C corroded steel sheet piles and unsupported front beam.

Figure 2-6 - 35-36 rear longitudinal beam failure

Figure 2-7 - Scour Hole in South beach at piles 66-67

Figure 2-8 - Exposed rebar and failure of front beam at piles 115-116

Figure 2-9 - Scour holes from failed front planks

2.1.3 Life Expectancy and Recommendations

The condition of the structure and the predicted sources of failure are essentially unchanged from the reports from the 1990s. The condition of most of the existing concrete structure is unlikely to have changed much since that time. It is therefore considered likely to last another 15-20 years if the unsupported and cantilevered sections are repaired.

Length C has essentially failed and could collapse within the next 5 years. Failure could risk damage to adjacent parts of the structure. This section should be repaired as soon as possible.

The steel sheet piles to Length A of the South Pier are not considered to be at high risk of failure at present based on the above water inspection, and therefore the residual life of 15-20 years for the overall structure is applicable in this area. It is recommended that the condition of this part of the structure continues to be monitored, with a diving inspection undertaken of the below water section if any change is observed. It may be cost-effective to plan such an inspection at the same time as the repairs to Length C.

Reinforced concrete can be patched or replaced at those locations where the rebar is exposed (approximately 20% of the structure). However, this may not be cost effective as it would not improve structural stability.

If necessary, considering the aims of the scheme, scour holes could be filled after the gaps in the planks and piles have been repaired.

This assessment is based only on the inspection of the present condition of the structure and does not consider additional risks due to scour of the bed of the entrance channel.

3 Site Conditions

The following section introduces the existing conditions at Southwold Harbour.

3.1 Bathymetry

A bathymetric survey was undertaken in 2020. The results of the 2020 survey are shown in Figure 3-1 and Figure 3-1: 2020 bathymetric survey data

in metres above Ordnance Datum (m OD). A comparison between the 2020 bathymetric survey and a bathymetric survey undertaken in 2013 is shown in Figure 3-3.

The South Pier to be replaced / repaired spans approximately 270 metres from the edge of the existing coastline. From the survey the following depths have been approximated:

- 100m landward length @ -2m OD
- 170m seaward length @ -5.5m OD

The relationship between Chart Datum (CD) and Ordnance Datum (OD) at Southwold is OD = CD -1.75.

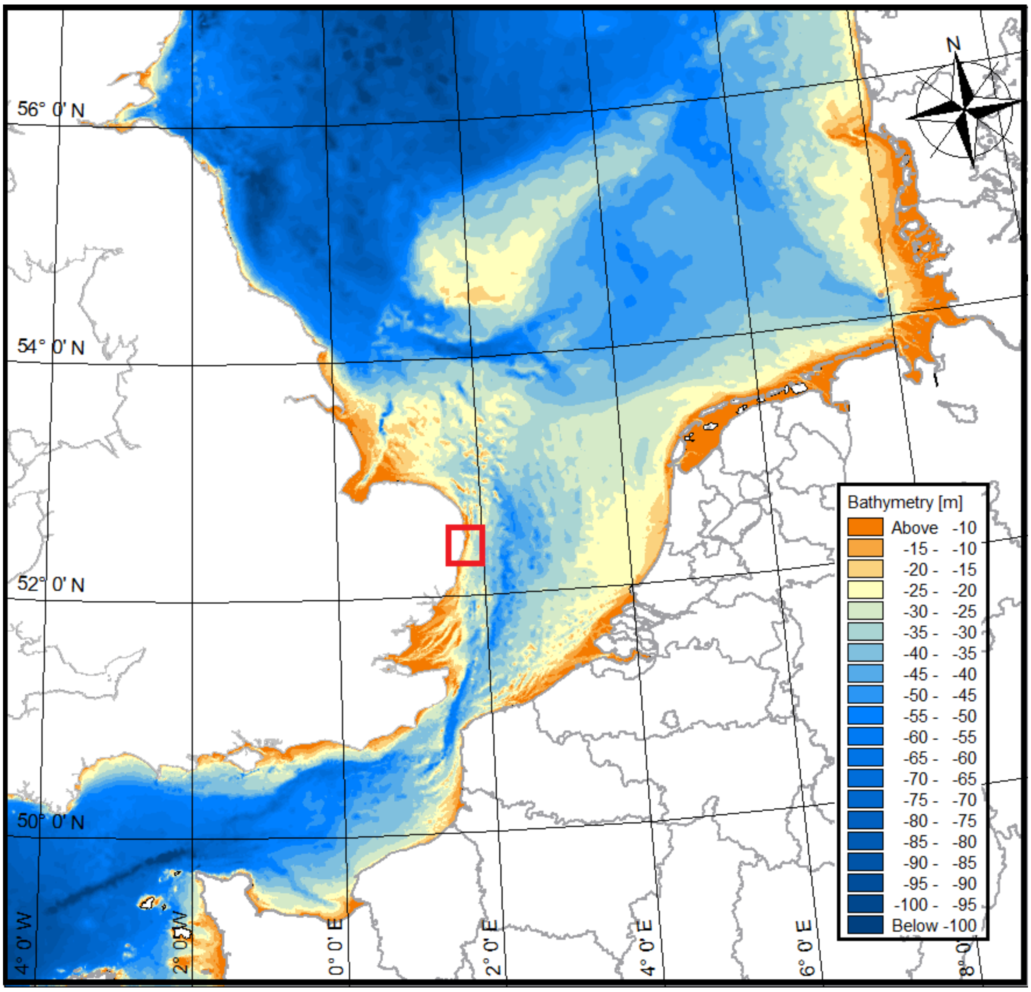


Figure 3-1: 2020 bathymetric survey data

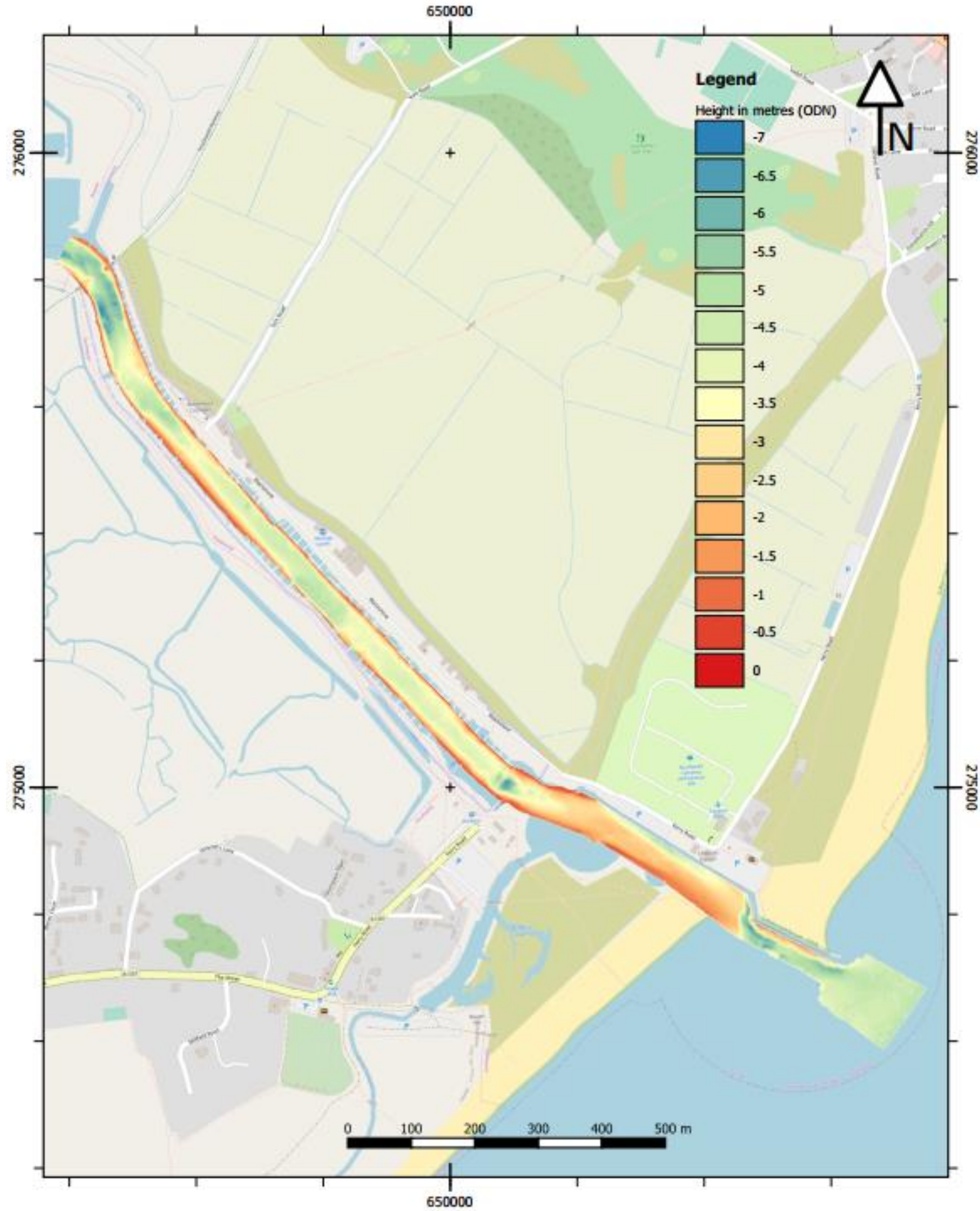


Figure 3-2: 2020 bathymetric survey channel data

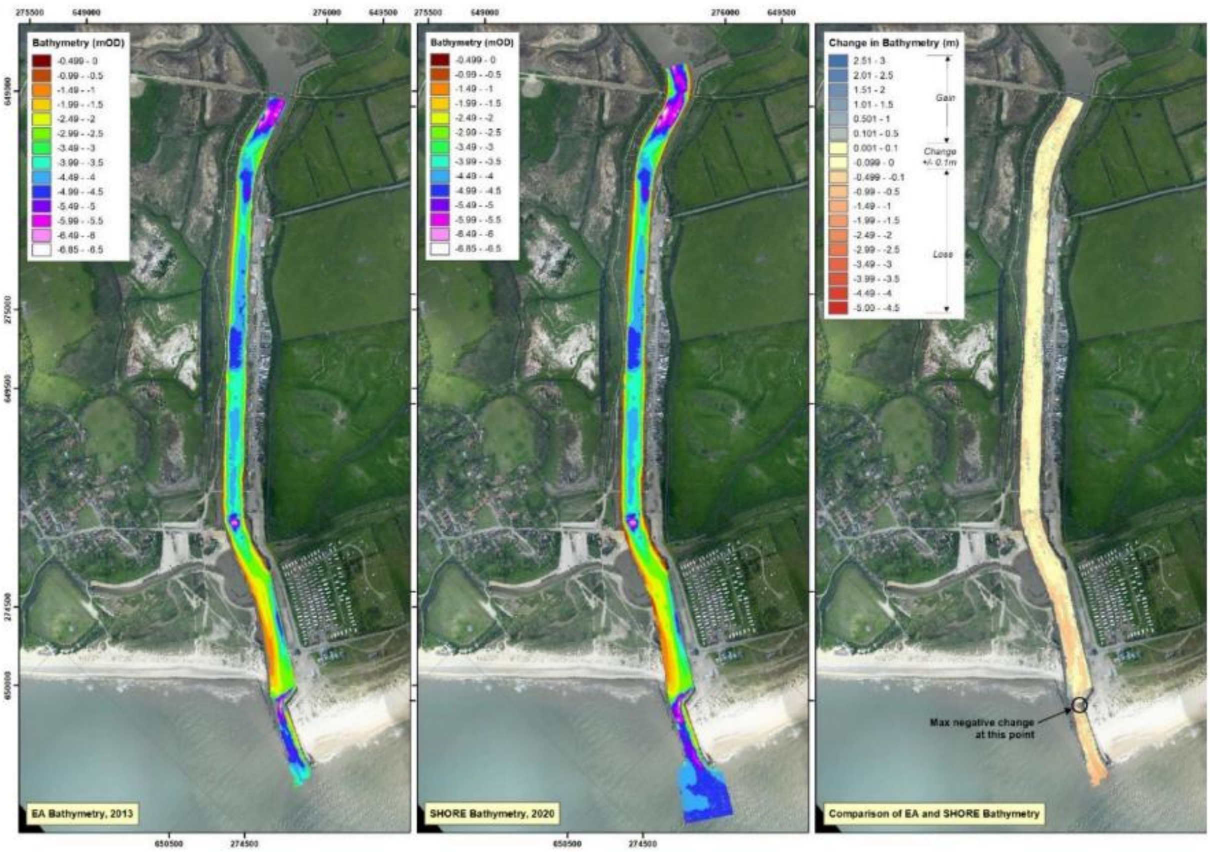
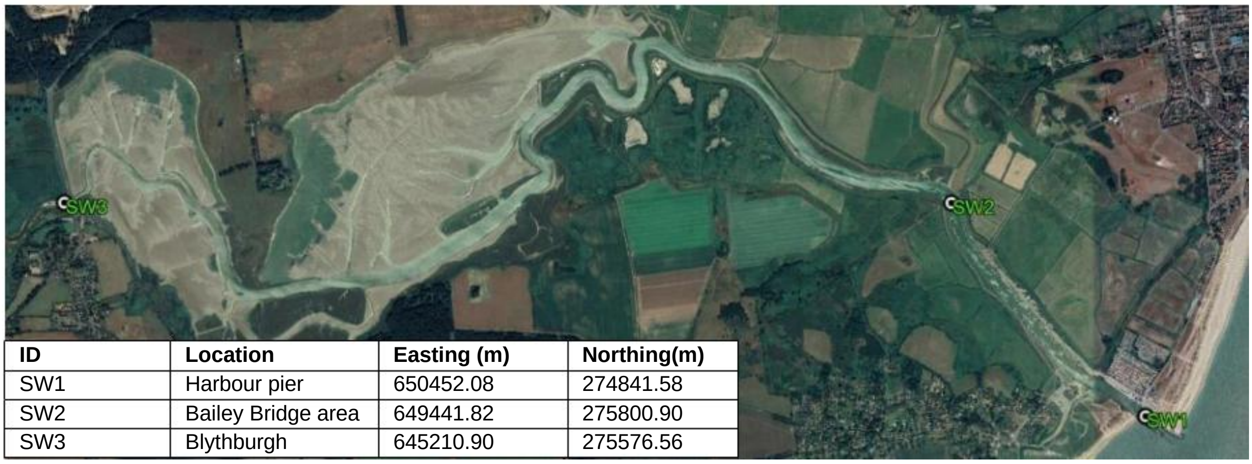


Figure 3-3: Comparison between the 2103 and 2020 bathymetric survey

3.2 Water Levels

Water level measurements were recorded at three locations (SW1, SW2 and SW3) along the Blyth river. Measured water levels relative to ODN (ODN which is approximately mean sea level) are shown in Figure 3-5 to **Error! Reference source not found.**.



ID	Location	Easting (m)	Northing(m)
SW1	Harbour pier	650452.08	274841.58
SW2	Bailey Bridge area	649441.82	275800.90
SW3	Blythburgh	645210.90	275576.56

Figure 3-4: Water level measurement locations

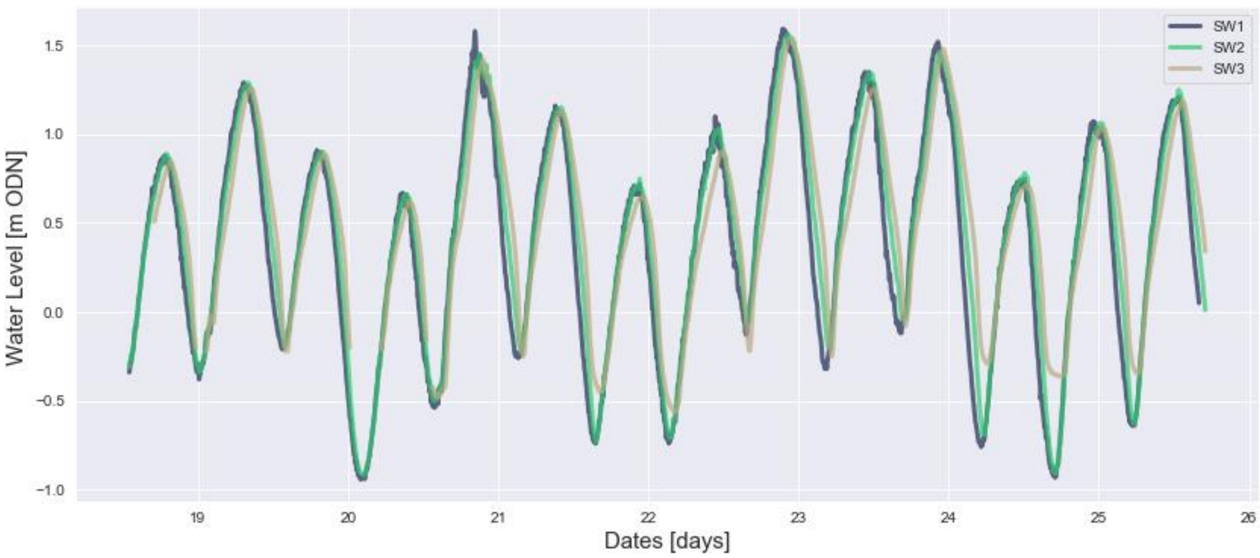


Figure 3-5: Water level timeseries of the three locations, relative to ODN. Harbour Pier (SW1), Bailey Bridge (SW2) and Blythburgh (SW3).

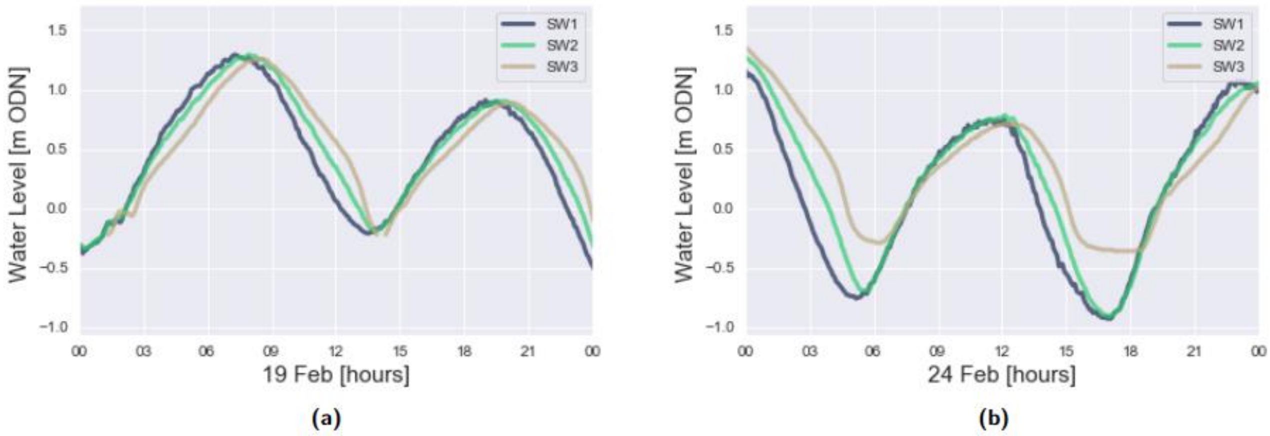


Figure 3-6: Single day time series of water level elevation for three water level locations (a – Neap tide; b-Spring tide)

Water levels at Southwold, including extreme water levels, have been extracted from the United Kingdom Climate Predictions 2018 (UKCP 2018) from Lowestoft (20km north) and Felixstowe (45km south) with an interpolation made between the two locations to derive the conditions at Southwold. The water levels were based on the RCP 8.5 scenario (high emission scenario) and are provided in Table 3-1.

Table 3-1: Southwold Water Levels

Return Period (years)	Water Level (m OD)
MHWS	1.2
MLWS	-0.9
1	2.32
10	2.81
100	3.31
100 + 50 years Sea Level Rise	3.83

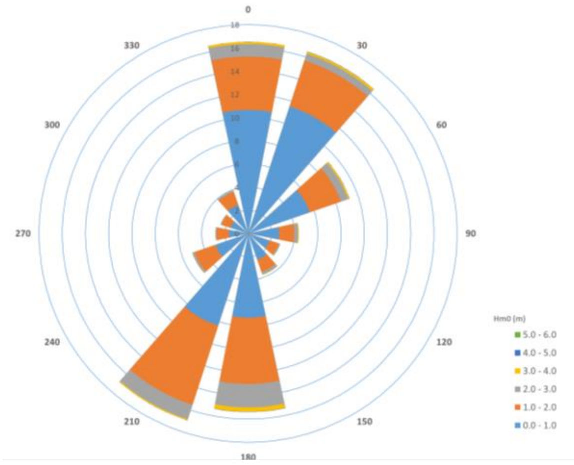
3.3 Wave Conditions

3.3.1 Offshore waves

Offshore wave data has been purchased from the UK Met Office WWIII model, at location 52.265ºN, 1.996ºE.

The offshore wave rose shows that the predominant wave directions are split between the north to north-easterly and south to south-westerly sectors, with very limited wave activity from the north east to south-east sectors.

Figure 3-7: Annual wave rose at the Met office data point (1980 – 2019)



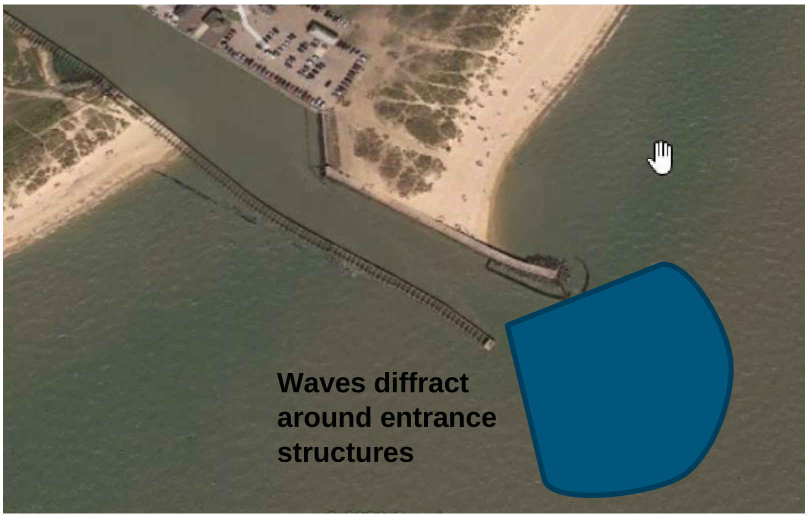
Southwold harbour is generally protected against waves from the north and north east by the North Pier. Offshore waves from the south to southwest have the most influence on the conditions in the harbour.

3.3.2 Nearshore waves and waves in entrance channel

After refraction inshore, nearshore waves approach the harbour entrance from directions between 70° and 170°.

The nearshore waves ***diffract*** or bend around the ends of the harbour entrance structures.

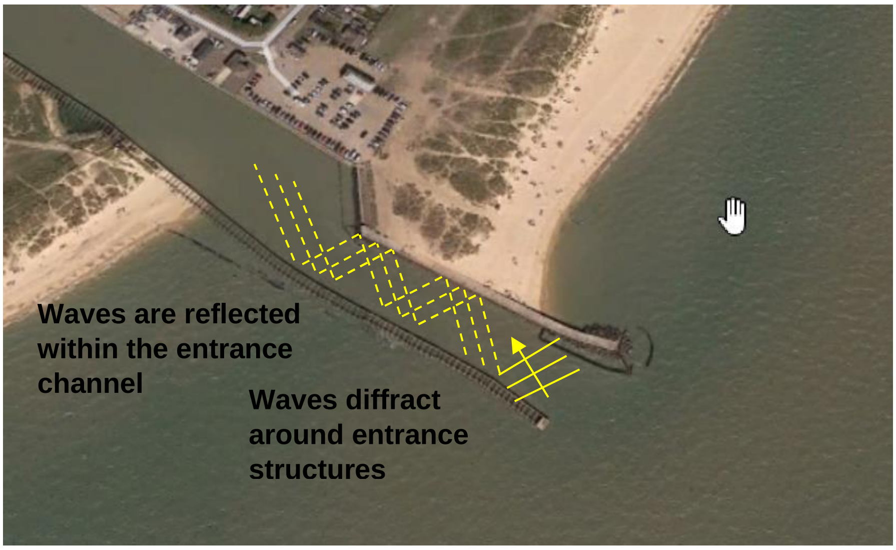
Figure 3-8: Nearshore Wave Diffraction



Waves from the north east can cause disturbed seas at the mouth of the harbour, but don't have a significant impact on conditions in the entrance channel as they can't fully diffract around the North Pier.

Waves enter the harbour at an angle to the pier structures, so they will reflect off the North and South Piers (wave reflection is greatest off smooth vertical surfaces and is reduced with rock and concrete armour units). This reflection results in a disturbed wave pattern within the harbour entrance.

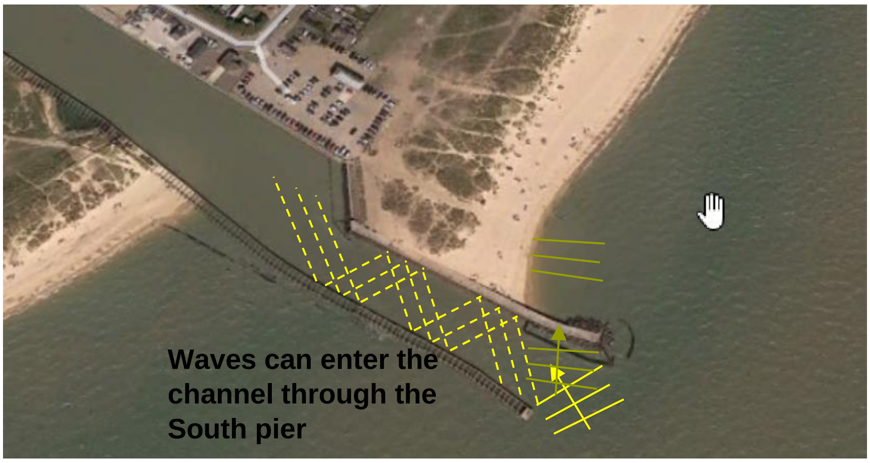
Figure 3-9: Harbour Entrance Wave Pattern



The holes in the South Pier were created to reduce wave reflection. The holes mean that there is less of a hard surface to cause reflection, and waves can also travel directly into the channel through the South Pier.

Although the waves that travel through the South Pier cause more disturbance in the entrance channel, this interferes with the reflected waves, so wave heights aren't amplified, and the channel is easier to navigate.

Figure 3-10: Waves entering through the South Pier



3.3.3 Wave Conditions for Design of Breakwater Structure

A 100 year wave condition (including 50 years of sea level rise) has been adopted for the design of the breakwater structures to replace the existing south pier. The 100 year wave conditions was extracted from the RHDHV MIKE 21 Wave Transformation Model and are provided in Table 3-2.

The 100 year wave height is 4.5 metres, while the 1 year wave height is 3.5 metres. Extracts from the MIKE 21 Wave Transformation Model are provided in Figure 3-11.

Table 3-2: Breakwater Design Conditions

Breakwater Design Conditions (100 year)	
Significant Wave Height, Hs	4.5 metres
Peak Wave Period, Tp	10 seconds
Wave Direction	180 degrees

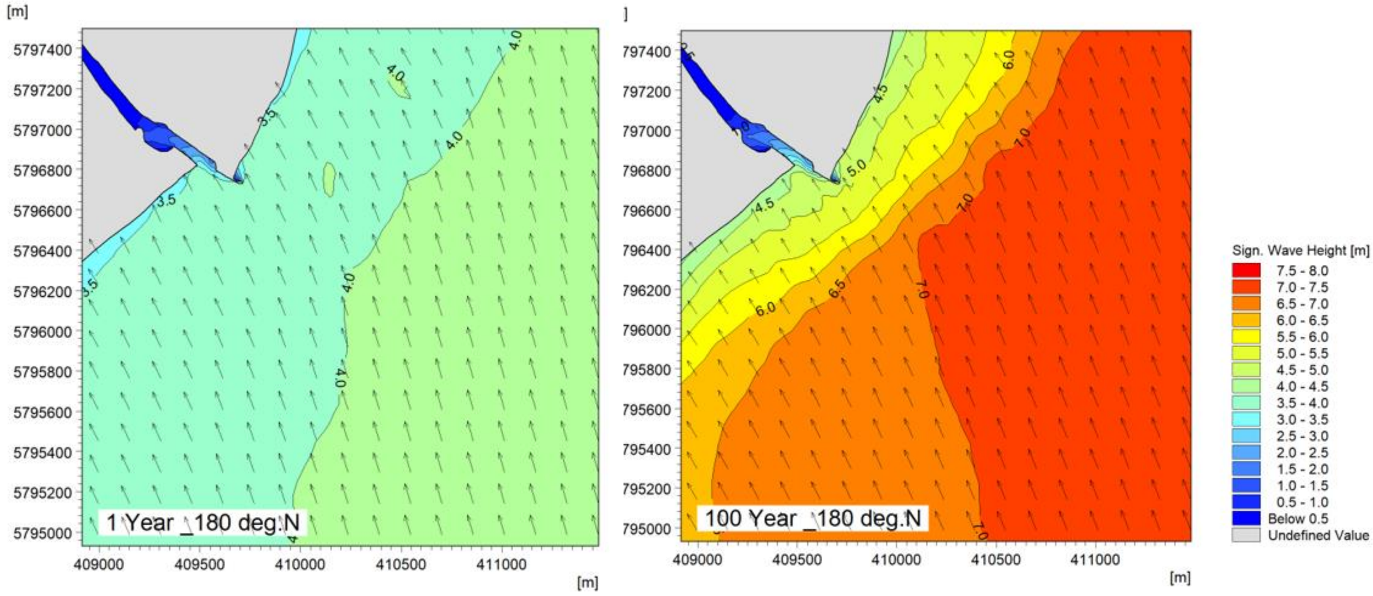


Figure 3-11: MIKE 21 Wave Transformation Model Extracts

3.4 Tidal Currents

Tidal currents reach a maximum of 1.5 m/s within the Harbour.

4 Options

This section introduces the proposed options for the South Pier including estimations of material quantities required.

4.1 Rock Breakwater

Calculations were undertaken to develop the concept design of a rock breakwater to replace the existing South Pier. The calculations determined 6-10 tonne primary rock armour is required to defend against a 1:100 year design storm event.

The breakwater crest is set at +3m OD to match the existing level of the South Pier. Two layers of 6-10 tonne primary rock are to be placed at a 1:2 slope and overlay two layers of 1-3 tonne rock underlayer. A quarry run core will complete the breakwater with the core extending 5 metres past the toe of the breakwater to provide a scour apron.

The breakwater has been split into two sections:

- Seaward Section – bed level @-5m OD, spans 170m in length (Figure 4-1)

Landward Section – bed level @-2m OD, spans 100m in length (

-)

Rock quantities have been calculated in Table 4-1

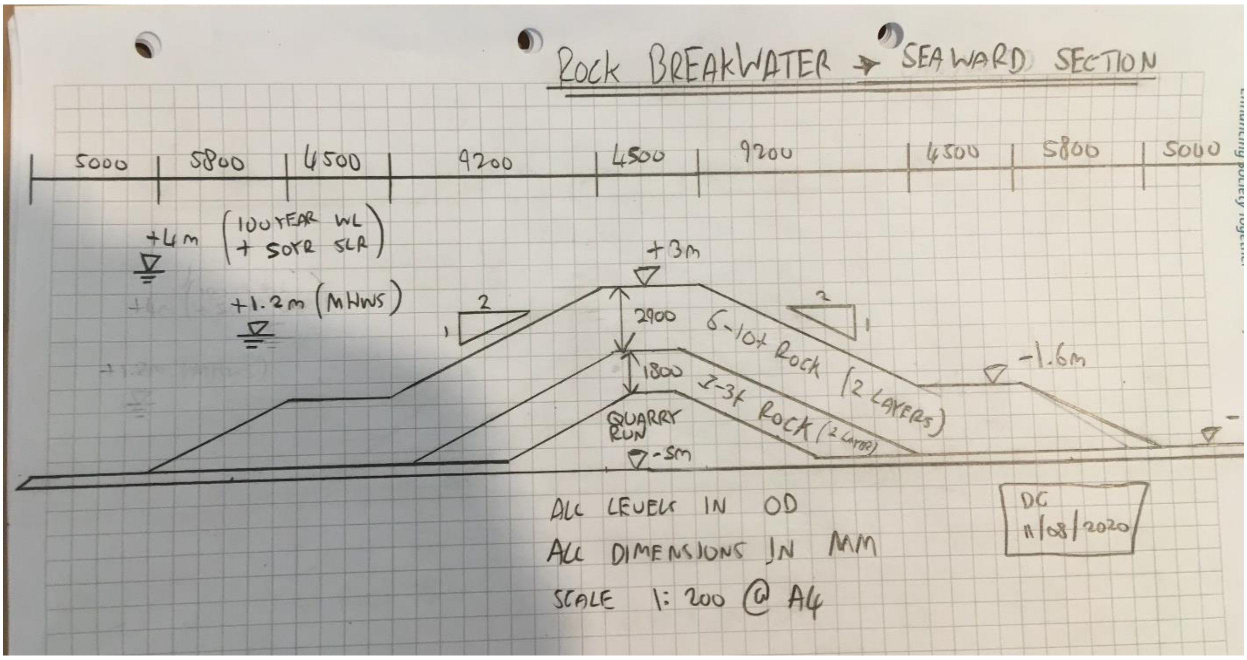


Figure 4-1: Rock Breakwater Seaward Section

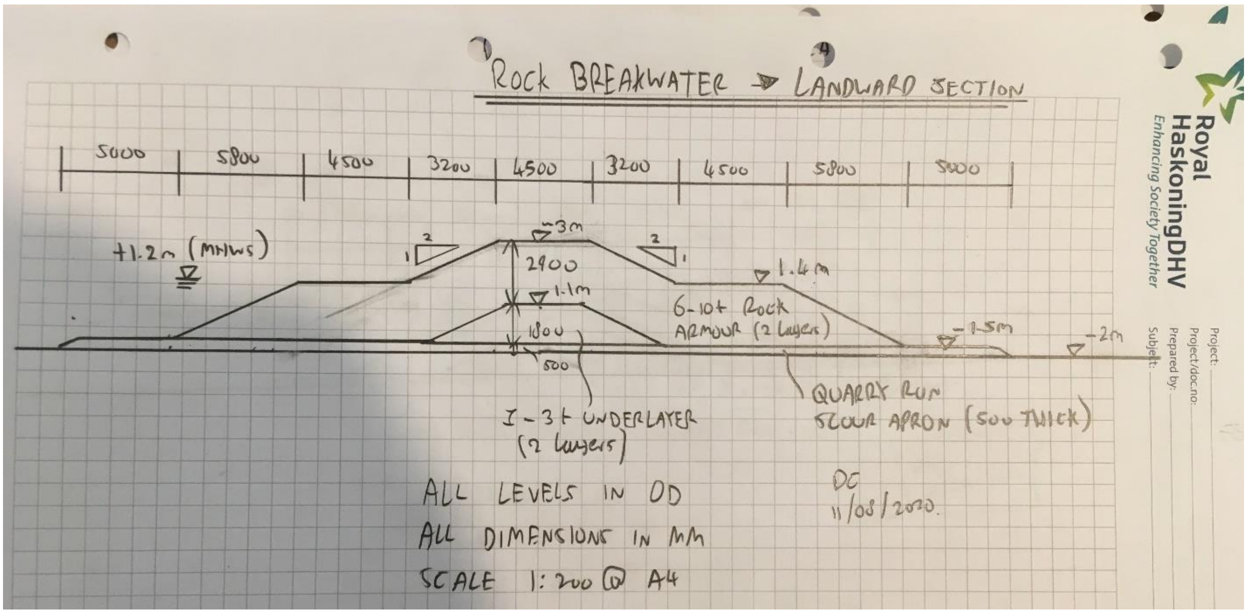


Figure 4-2: Rock Breakwater Landward Section

Table 4-1: Rock Breakwater Quantities

ROCK BREAKWATER QUANTITIES					
			Rock Volume (m3)		
Breakwater Section	Bed Level	Length (m)	6-10t Rock	1-3t Rock	Quarry Run
Landward	-2	100	8,000	1,300	2,100
Seaward	-5	170	19,380	5,950	7,990
		TOTAL	**27,380**	**7,250**	**10,090**

4.2 Concrete Unit Revetment

The availability of rock of sizes up to 10 tonnes is sparsely available from UK quarries, with rock of this size usually imported from quarries in Norway. An alternative option is to replace the primary armour layer with concrete units. The additional benefit of incorporating concrete units is they can be placed at steeper slopes to rock armour, thereby reducing the structure footprint and quantity of material required.

Calculations were undertaken to develop the concept design of a concrete unit breakwater to replace the existing South Pier. The breakwater crest is set at +3m OD to match the existing level of the South Pier. A single primary armour layer of 3m^3 Core-loc units are to be placed at a 3:4 slope and overlay two layers of 0.1-3 tonne rock underlayer. A quarry run core will complete the breakwater with the core extending 5 metres past a 3-6 tonne rock toe to provide a scour apron.

The breakwater has been split into two sections:

- Seaward Section – bed level @-5m OD, spans 170m in length (Figure 4-3)
- Landward Section – bed level @-2m OD, spans 100m in length (Figure 4-4)

Quantities have been calculated in Table 4-2.

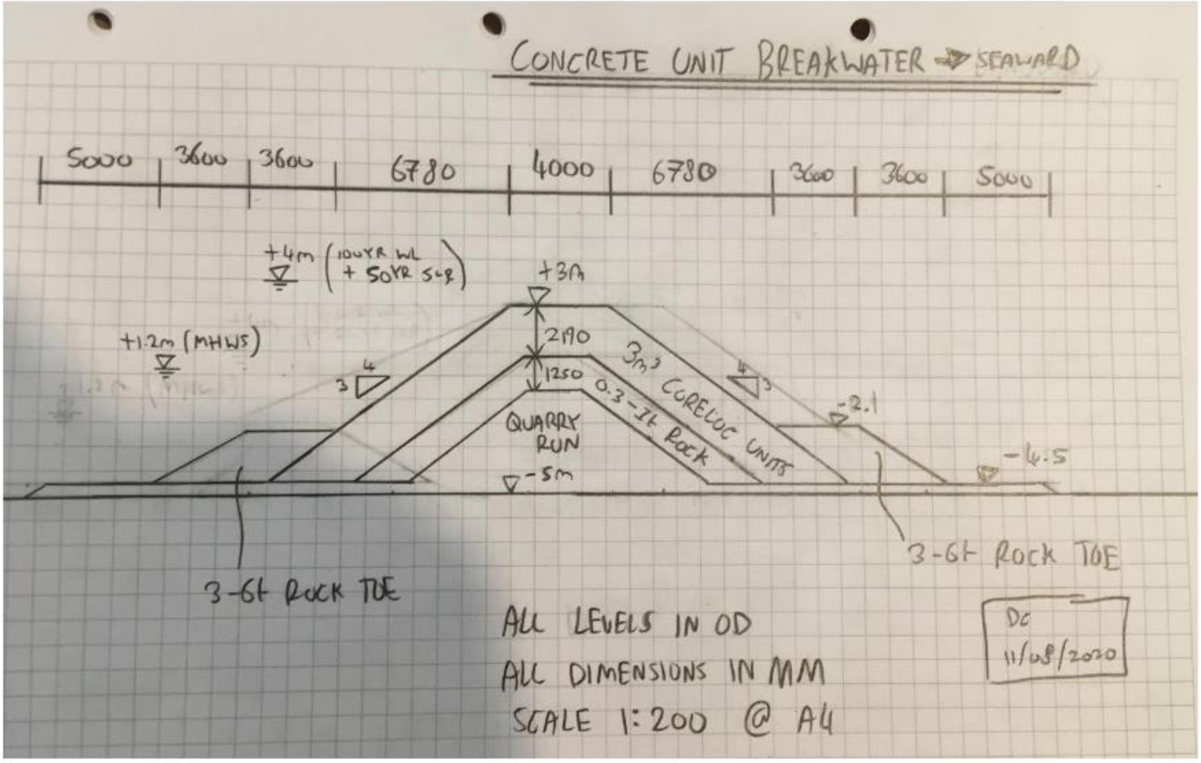


Figure 4-3: Concrete Unit Breakwater Seaward Section

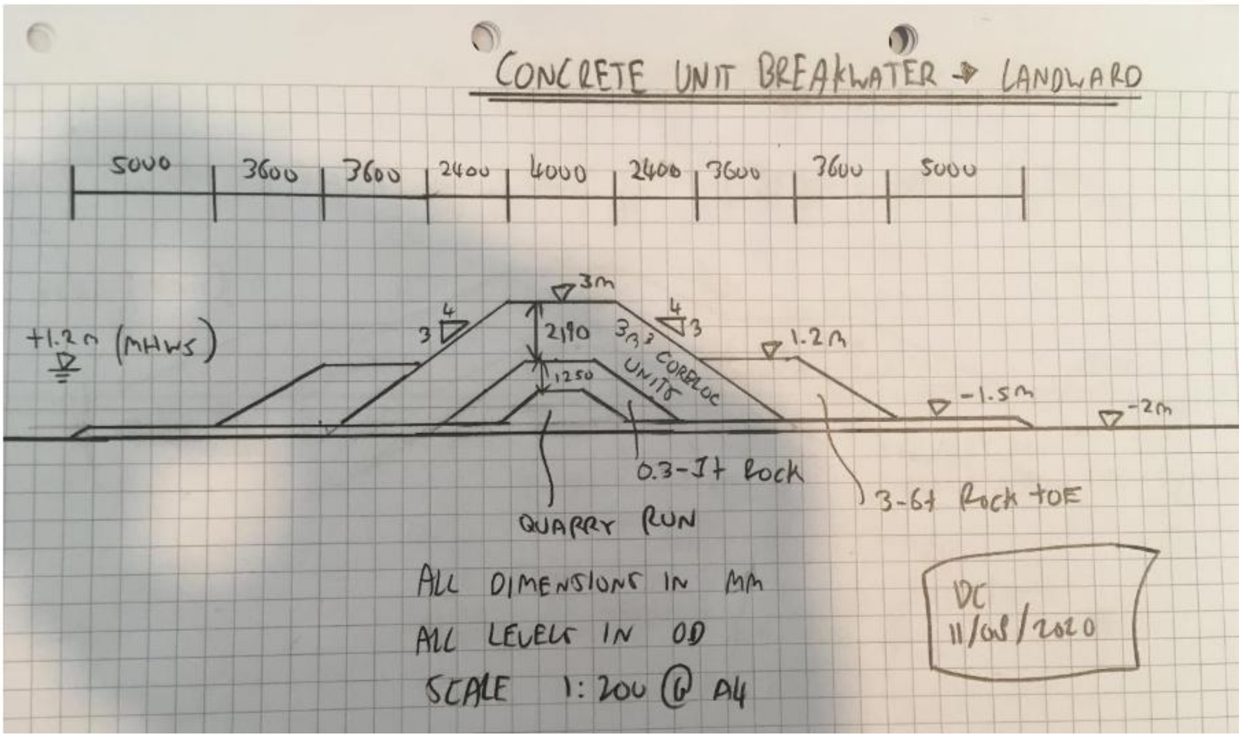


Figure 4-4: Concrete Unit Breakwater Landward Section

Table 4-2: Concrete Unit Breakwater Quantities

CONCRETE UNIT BREAKWATER QUANTITIES						
			Rock Volume (m3)			
Breakwater Section	**Bed Level**	**Length (m)**	**3m3 CORE-LOC UNITS (No of Units)**	**3-6t Rock**	**0.3-1t Rock**	**Quarry Run**
Landward	-2	100	1458	2000	1100	2000
Seaward	-5	170	3470	3400	3910	8670
		TOTAL	**4929**	**5400**	**5010**	**10670**

4.3 Like for Like Replacement

The existing South Pier is consists of a continuous reinforced concrete structure with a face (on the north side of the Pier) of either reinforced concrete planks or steel sheet piling making up the harbour wall, supported by pairs of raking piles connected with concrete longitudinal and cross members.

An estimation of material quantities was calculated based upon the cross section shown in Figure 4-5. Material Quantities are shown in Table 4-3.

Figure 4-5: Existing South Pier Structure

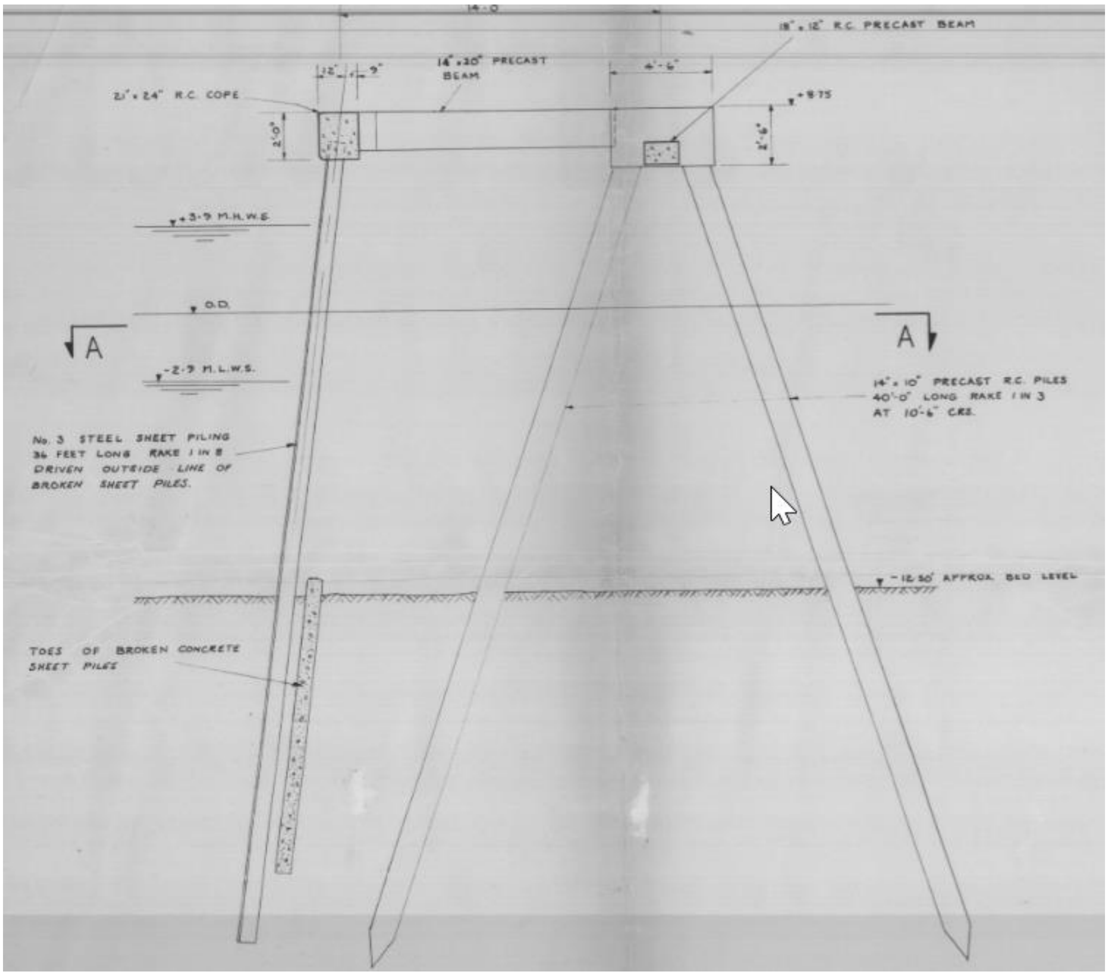


Table 4-3: Like for Like Replacement Quantities

LIKE FOR LIKE REPLACEMENT QUANTITIES (m^3)				
Steel Sheet Piles (11m long)	**Precast R.C Piles (0.35m x 0.25m, 12m long)**	**Precast R.C Beam (0.35m x 0.5m, 4.2m long)**	**Precast R.C. Capping (0.6m x 0.5m)**	**Precast R.C. Capping (0.7m x 0.35m)**
810	189	66	81	66
Assumptions				
Length of structure = 270 metres				
Cross Section applied every 3 metres = 270/3 = 90 cross sections				
Pile length = 1 metre = 270/1 = 270 piles x 3 layers = 810 piles				

4.4 Repairs to Existing Structure

The condition assessment indicated approximately 20% of the rear piles, beams and connecting cross members have exposed rebar. Along Length C (approximately 30 metres) a section of planks has been replaced with steel sheet piles, however, these have corroded severely. This front beam section is no longer supported properly and is cantilevered off the rear raking pile.

The repairs to existing structure option consists of patch repairs to the sections of exposed rebar and the replacement of the structure along Length C (approximately 30 metres). Calculated material quantities are shown in Table 4-4.

Table 4-4: Repairs to Existing Structure Option

REPAIRS TO EXISTING STRUCTURE QUANTITIES (m^3)						
Steel Sheet Piles (11m long)	**Precast R.C Piles (0.35m x 0.25m, 12m long)**	**Precast R.C Beam (0.35m x 0.5m, 4.2m long)**	**Precast R.C. Capping (0.6m x 0.5m)**	**Precast R.C. Capping (0.7m x 0.35m)**	**Precast R.C. Capping (0.7m x 0.35m)**	**Repairs to existing R.C. Concrete**
90	21	7	9	7	7	80
Assumptions						
Length of structure = 30 metres						
Cross Section applied every 3 metres = 30/3 = 10 cross sections						
Pile length = 1 metre = 30/1 = 30 piles x 3 layers = 90 piles						
20% of R.C. Concrete required repair						