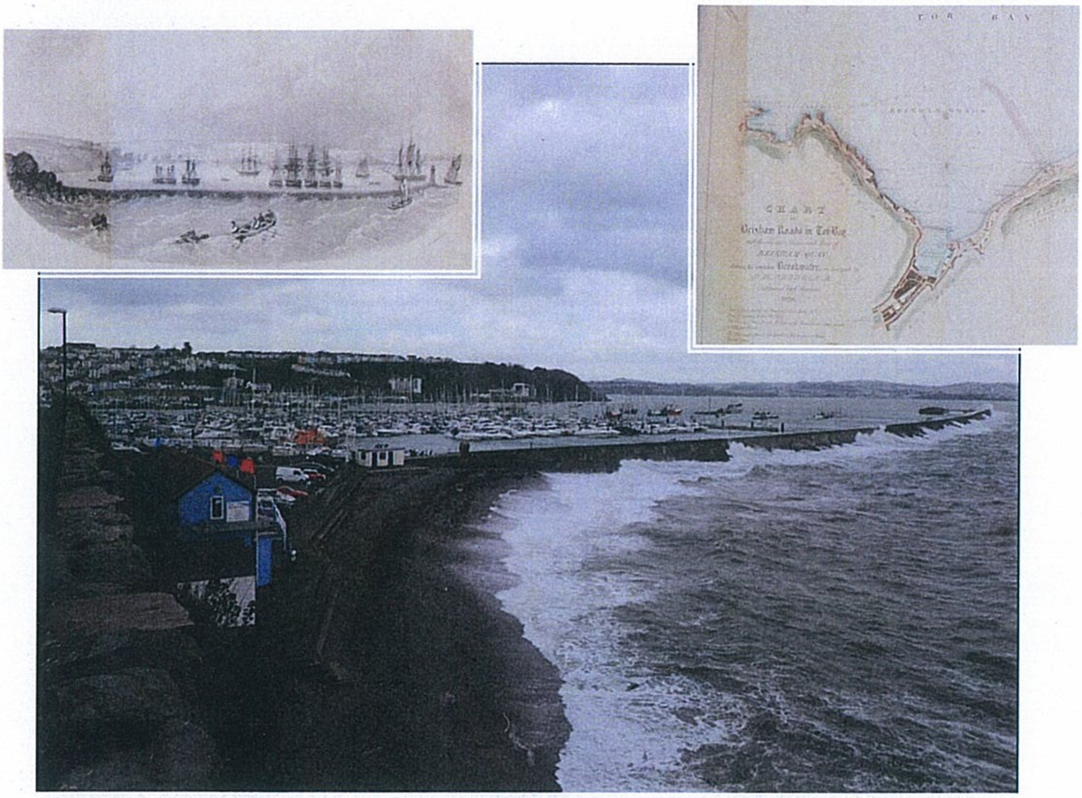


Brixham Harbour Northern Arm Breakwater

Concept Design Report

Torbay Development Agency

May 2011
Final Report
9W2488

ROYAL HASKONING
thinking in
all dimensions

A COMPANY OF

ROYAL HASKONING

HASKONING UK LTD.
COASTAL AND RIVERS

Stratus House
Emperor Way
Exeter, Devon EX1 3QS
United Kingdom
+44 (0)1392 447999 Telephone
01392 446148 Fax
info@exeter.royalhaskoning.com E-mail
www.royalhaskoning.com Internet

Document title	Northern Arm Breakwater Concept Design
Document short title	Brixham Harbour Northern Arm Breakwater - Concept Design Report
Status	Final Report
Date	May 2011
Project name	Brixham Regeneration Phase 3
Project number	9W2488
Client	Torbay Development Agency Keith Humphreys

Drafted by	Howard Rushton	
Checked by	David Carter	
Date/initials check	………………….	Date/initials check
Approved by	Hamish Hall	
Date/initials approval	………………….	Date/initials approval

EXECUTIVE SUMMARY

Torbay Development Agency is investigating the construction of a Northern Arm Breakwater to enclose the open water area of the outer harbour at Brixham. The proposed breakwater's purpose is to provide:

i) calmer wave conditions in the harbour to protect existing commercial and leisure activities (e.g. fish unloading, mooring);
ii) to facilitate development of leisure uses, specifically to include the substantial expansion of marina facilities; and
iii) to respond to the aspirations of the local community to provide a properly enclosed and safe harbour in all weather conditions.

The purpose of this report is to present the investigations and work undertaken to prepare outline designs for this structure. The work included:

- Numerical modelling of wave conditions in the harbour before and after construction of the proposed breakwater
- Consultation with harbour users
- Environmental Impact Assessment (an Environmental Scoping Report)
- Selection of a baseline option (alignment / layout for the breakwater and method of construction)
- Cost estimates
- An assessment of potential funding opportunities

The selected baseline option is for a single rock armour breakwater, extending north east from the slipway adjacent to AstraZeneca towards the disused fuel jetty on Victoria Breakwater.

Numerical modelling of the wave conditions after construction of the baseline option has shown that wave conditions within the proposed enclosed harbour are slightly higher than the target conditions. However, wave conditions are within the range that enables the proposed expansion of marina facilities and provides protection to existing recreational and commercial vessels.

The estimated capital and design costs for the baseline option range from £25 million to £38 million. The high uncertainty in the cost estimate is primarily due to the design being based on limited site investigation. A marine site investigation would provide additional data on which to refine the designs and costs. The estimated costs for this investigation are £100k - £160k.

CONTENTS

Appendices

Appendix A – Figures / Drawings
Appendix B – Minutes of Consultation Meetings
Appendix C – Consultees Responses to Wave Modelling
Appendix D – Breakwater Design
Appendix E – Geotechnical
Appendix F – Health and Safety
Appendix G – Wave Modelling
Appendix H – Environmental Scoping Report
Appendix I – Option Costs

1 AIMS AND OBJECTIVES

1.1 Torbay Council is considering the construction of a Northern Arm Breakwater within Brixham Harbour to enclose the open water area of the outer harbour (see Figure 1.1).

Figure 1.1 Aerial Photo of Brixham Harbour showing the Location of the Northern Arm Breakwater

Source: USGS
Source: NASA, NGA, USGS
Source: ESRI, i-cubed, USDA FSA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGP

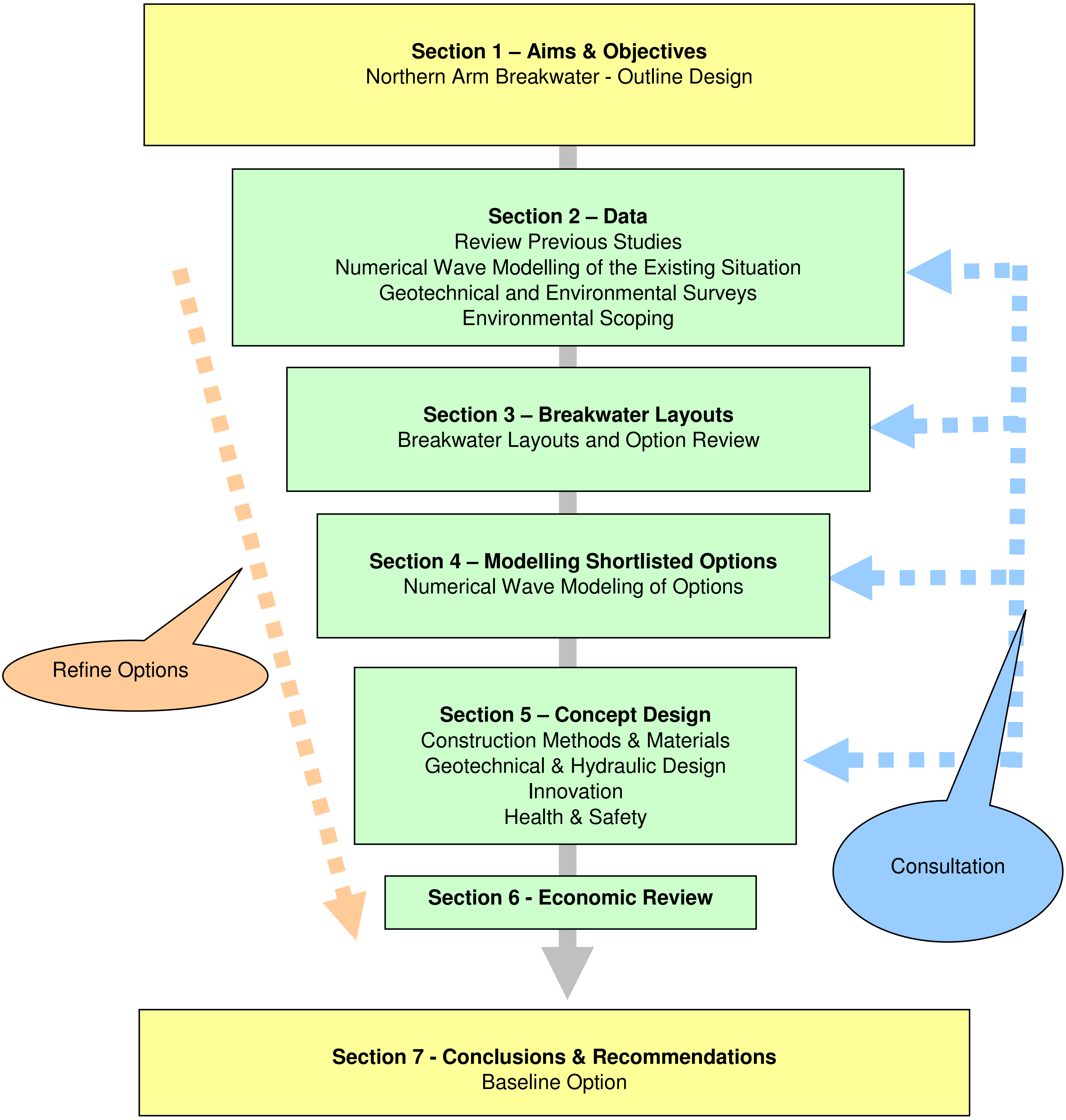
1.2 The proposed breakwater's purpose is to provide:

i) calmer wave conditions in the harbour to protect existing commercial and leisure activities (e.g. fish unloading, mooring);
ii) to facilitate development of leisure uses, specifically to include the substantial expansion of marina facilities; and
iii) to respond to the aspirations of the local community to provide a properly enclosed and safe harbour in all weather conditions.

1.3 This report presents the process (refer Figure 1.2) of selecting a baseline option for the breakwater in relation to layout, design, environmental impact and cost. Sources of potential funding are also explored.

1.4 The outline design was an iterative process with a number of feedback loops between data collection, modelling, consultation, environmental assessment and outline design and refining the options

Figure 1.2 Outline Design Flowchart



2 DATA

2.1 Previous Studies

A number of previous studies have been carried out relating to the Northern Arm Breakwater, the key documents are listed below:

- Victoria Breakwater, Brixham, Geotechnical Investigation Report, 2011, Yeandle Geotechnical / Case Consultants
- Brixham Regeneration – Northern Arm Breakwater, Design Evaluation and Cost Assessment of Option C, 2008, Halcrow
- Brixham Northern Arm Breakwater, Outline Design Report, 2006, Hyder
- Brixham Environmental Statement, 2006, Hyder
- Brixham Harbour Regeneration, Numerical Modelling, Breakwater Design Applications, 2005, Hyder
- Brixham Harbour Regeneration, Brixham Harbour Numerical Model Set Up Report, 2005, Hyder
- Brixham Harbour Regeneration Strategy, Site Investigation Factual Report, 2000, Scott Wilson

2.2 Design Criteria

2.2.1 The key design criteria for the breakwater relate to improving wave climate conditions inside Brixham Harbour with the breakwater in place. The target criteria for wave conditions have been established from the Yacht Harbour Association document, A Code of Practice for the Design, Construction and Operation of Coastal and Inland Marinas and Yacht Harbours, 2007. The desired wave heights are 0.3m (annual significant wave height (Hs)) and 0.4m (50 year Hs).

2.2.2 For comparison, an alternative standard is the Australian Standard (AS3962) Guidelines for design of marinas. This is not as stringent and gives a range of values dependant on the orientation of berthed vessels. The 50 year Hs is 0.75m for head seas, 0.50m for oblique seas and 0.31 for beam seas (for moderate conditions).

2.2.3 In addition, the breakwater design has to allow safe navigational access and egress for vessels using the harbour, maximise the water area available inside the harbour for subsequent use and development (e.g. marina expansion).

2.2.4 Other design considerations include durability, a minimum design life of 50 years, the degree to which the structure will settle and the breakwater's potential use for vessel berthing and cargo handling (i.e. on its lee side and crest).

2.2.5 It is proposed that the width of the fairway / entrance channel matches the existing marked fairway, this is approximately 70m. The entrance has been modelled as 80m wide at MHWS, this will reduce at low tide due to the slope of the breakwater. There are a number of different details that could be investigated for the roundhead at the entrance to the breakwater including steeper slopes, use of concrete units, installation of a short length of vertical wall etc to minimise the entrance width while providing acceptable entrance conditions.

2.2.6 The breakwater's cost is a key design consideration. The breakwater itself is anticipated to generate little direct revenue to support its construction and maintenance. It would, though generate substantial economic benefit and revenue generation within the Harbour and Torbay

2.2.7 In addition, the breakwater's design has taken into account a number of environmental criteria such as:

i) the presence of designated sites, for example the Lyme Bay and Tor Bay Candidate Special Area of Conservation (cSAC) and Brixham Battery Scheduled Monument
ii) features such as the Harbour Holes (sea caves) and AstraZeneca's outfall discharge
iii) the need to maintain sufficient water circulation and flushing such that hydrodynamic conditions, sediment transport patterns and water quality are not adversely affected (see Section 2.6 and 2.7).

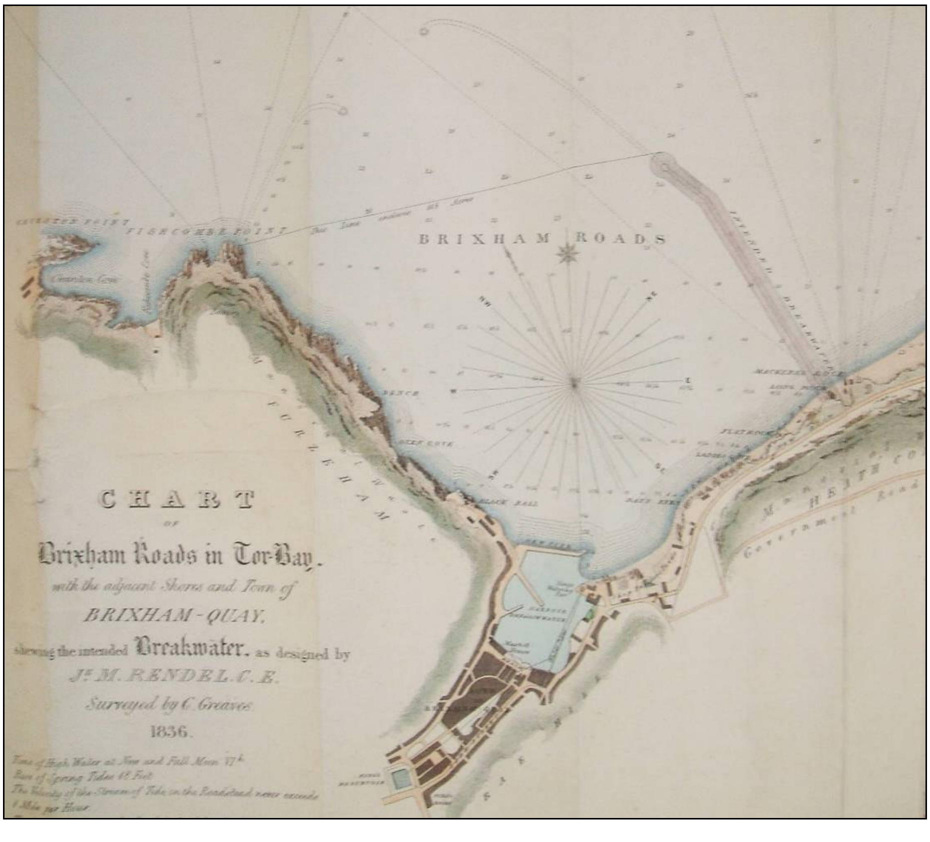
2.3 Historic Data

2.3.1 To inform outline design of the Northern Arm Breakwater we have undertaken a search of historic documents and plans of the Victoria Breakwater. The Breakwater appears to have been constructed in three phases, the first 1400 feet started in 1843, a further 600 feet in 1909 and the final 1000 feet in 1912.

2.3.2 We have obtained additional information from local sources and from the Devon Record Office, the 1837 plan is included in Figure 2.1:

- Brixham Roads in Torbay and Brixham Quay with Intended Breakwater. QS/DP/133 1837 (Figure 2.1)
- Torbay and Brixham Deep Sea Harbour of Refuge and Docks QS/DP/208 1846

Figure 2.1 Brixham Roads in Torbay and Brixham Quay with Intended Breakwater, 1837



2.4 Consultation

2.4.1 Consultation was an essential part of the outline design process. TDA were aware that there were a number of local views regarding the possible effects of the proposed breakwater and wished to take into account local knowledge pertinent to both the outline design and operating conditions in the harbour.

2.4.2 In addition, it was important to gather Stakeholder knowledge on the local wave climate and establish a broad consensus on the suitability of the different wave conditions tested and subsequently establish confidence in the models ability to replicate existing conditions, prior to its being used to test alternative proposed breakwater options and layouts. Local observers have a wealth of tacit knowledge of the local marine climate and wave conditions within the existing breakwater and as such it was very important to learn from the local marine professionals and the broader community.

2.4.3 The following is a list of the Stakeholders who were consulted. Their attendance at meetings and the contributions that they made to assist the design process, were much appreciated :-

Keith Humphreys	Torbay Development Agency
Paul Labistour	Brixham Harbour Master
Kevin Mowat	Executive Head of Tor Bay Harbour Authority and Tor Bay Harbour Master
Peter Brown	Vigilance Sailing Trawler
Jerry Carter	Marine and Towage Services Group Ltd
Paul Churchill	RNLI “Vigilance”
David Ham	RNLI
Mark Criddle	RNLI
Bob Curtis	Brixham 21, advisor to Harbour Committee and former Pilot
Dave Hodgetts	Brixham 21
Tom Savage	Brixham Yacht Club
Nick Henderson	Brixham 21 and Chair of Regeneration Committee, Brixham Town Council
Cllr Robert Horne	Torbay Council and Chair of Harbour Committee

2.4.4 Below is a schedule of the Stakeholder Meetings that were all held in the Brixham Harbour Master’s Office (Appendix B includes the Minutes of Consultation Meetings):-

First Stakeholders’ Meeting	26th November 2010
Second Stakeholders’ Meeting	6th January 2011
Third Stakeholders’ Meeting	4th February 2011
Fourth Stakeholders’ Meeting	17th March 2011

2.4.5 Further meetings were also held with representatives of Astrazenica’s Brixham Environmental Laboratory which is located at the southern end of Freshwater Quarry. As well as discussing the possible impact of the breakwater, the locations of the seawater intakes and outfalls were confirmed.

2.5 Still Water Levels

2.5.1 Design Still Water Levels, used for outline design of the geometry of the breakwater were obtained from the Hyder (2006) and are provided in Table 2.1.

Table 2.1 Still Water Levels

Tide Levels	Level (m CD)
Highest Astronomical Tide (HAT)	5.4
Mean High Water Springs (MHWS)	5.0
Mean Sea Level (MSL)	3.0
Mean Low Water Springs (WLWS)	0.9
Lowest Astronomical Tide (LAT)	0.1
Design Water Levels	
Extreme Water Level (1 in 1 Year)	5.74
Extreme Water Level + Sea Level Rise (1 in 1 year)	5.99
Extreme Water Level (1 in 100 Year)	6.53
Extreme Water Level + Sea Level Rise (1 in 100y year)	6.78

2.5.2 Hyder (2006) used 5mm per year for sea level rise due to climate change. This equates to approximately 250mm over the next 50 years. This has been adopted for this preliminary design stage. It is noted that this is lower than the current Department for Environment Food and Rural Affairs (DEFRA) guidance used for the appraisal of flood and coastal defence schemes of 360mm. However the more recently published UK Climate Projections (UKCP09) provides a range of projections based on different climate change scenarios.

2.5.3 During the course of this study the Environment Agency have made available revised predictions for sea levels around the coast, *Coastal flood boundary conditions for UK mainland and islands Environment Agency, February 2011*. We understand that the revised predictions will be slightly lower (approximately 400mm) than the 1 in 100 year water level quoted above, however, confidence levels are also associated with the results to illustrate the uncertainty in the predictions at various locations around the coast.

2.5.4 It is considered that the changes to predicted extreme still water levels and allowances for climate change are not significant in terms of development of an outline design. The values quoted in Hyder (2006) have been used. The sensitivity of the design to these parameters should be reviewed again at detailed design.

2.6 Existing Wave Conditions

2.6.1 As part of this commission Royal Haskoning have developed a numerical model of Brixham Harbour using MIKE21-SW (Spectral Wave Model).

2.6.2 Originally the intention had been to develop the model prepared by Hyder Consulting in 2005 (using MIKE21-BW (Boussinesq Wave Module)), however there were problems in using this model:

- Harbour users had commented that they did not feel that the wave model was representative of the existing condition (predicted wave heights were too low).

- Upon re-running the model we could not replicate the conditions presented by Hyder. It was discovered that during Hyder's commission it was agreed to increase the input wave conditions at the Victoria Breakwater to make the wave heights more representative. Subsequently the wave heights from the model had been factored up (by a value of approximately 2.0) to prepare the plots and results.

2.6.3 The project team agreed that to have confidence in the model results (both internally and externally) a new model should be prepared. This was enabled by developing Royal Haskoning's existing model of Tor Bay in MIKE21-SW.

2.6.4 New estimates of offshore wave conditions were also prepared, as these were not available from the Hyder model. The offshore wave conditions used as an input to the model are provided in Appendix G.

2.6.5 A key aspect of the consultation with harbour users was their agreement that the existing wave conditions were representative before proceeding with modelling of options. A 1 in 1 year wave condition was modelled from a number of different directions, these conditions were circulated by email and discussed at the consultation meeting on 4th February 2011. A comparison of all the 1 in 1 year wave conditions is provided in Figure 2.2 and Table 2.2.

2.6.6 Specific Questions raised by stakeholders at the meetings are summarised in Appendix C.

2.6.7 Two critical wave conditions were identified (Plots for the existing situation are included in Figure 2.3 and Figure 2.4):

i) Wind waves from 300^0
ii) Swell waves from 120^0

Figure 2.2 Location of model output points

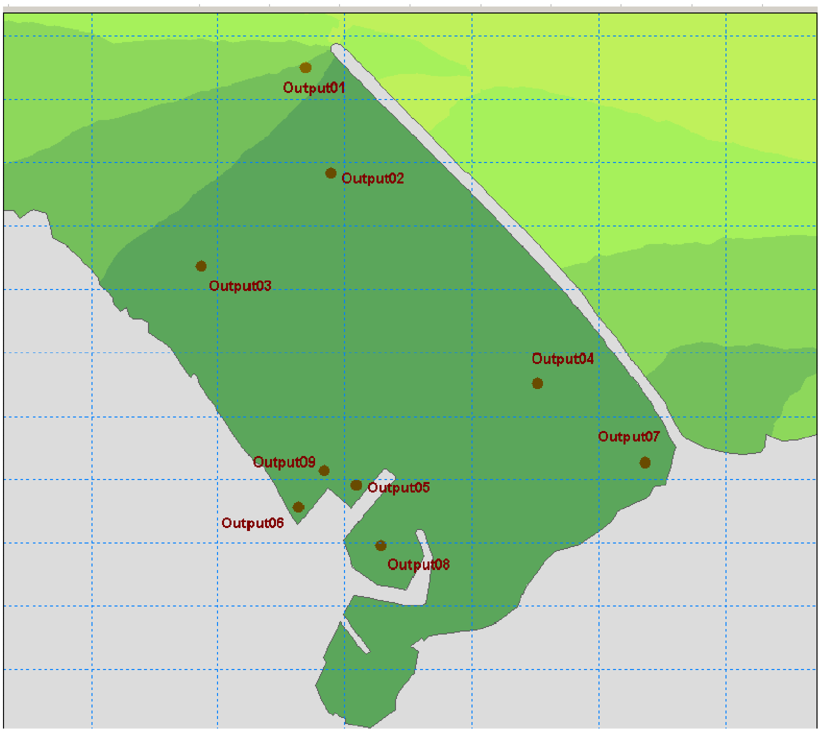


Table 2.2 Summary of modelled 1 in 1 year wave conditions

Output Points	Wave Direction and Wave Height (m)					
	330˚	30˚	60˚	90˚	**120˚	150˚
1	0.57	1.72	1.76	0.58	0.79	0.88
2	0.48	0.90	0.88	0.46	0.63	0.68
3	0.54	1.21	1.19	0.49	0.71	0.76
4	0.47	0.65	0.61	0.36	0.48	0.52
5	0.58	0.92	0.93	0.48	0.70	0.73
6	0.57	0.89	0.92	0.46	0.70	0.73
7	0.44	0.53	0.51	0.30	0.40	0.45
8	0.31	0.42	0.41	0.20	0.29	0.32
9	0.54	0.83	0.84	0.44	0.63	0.65

** Although the results are marginally less than the results from 150^0 this is reversed for the 1 in 100 year event where the 120^0 condition is higher.

Figure 2.3 Existing Condition, Swell, 120 Deg (1in 1yr)

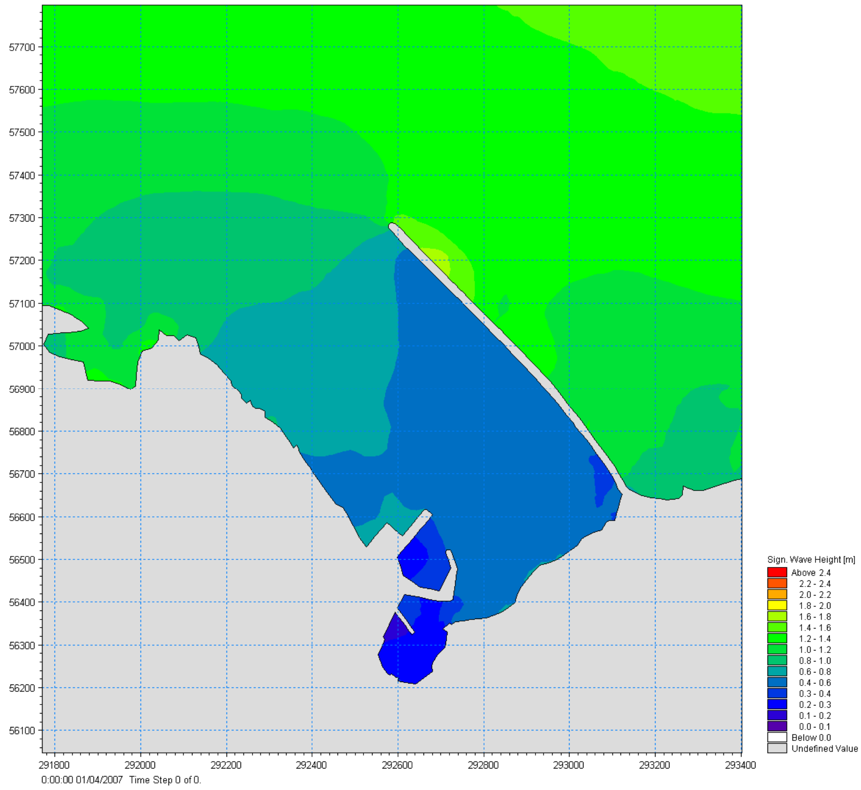
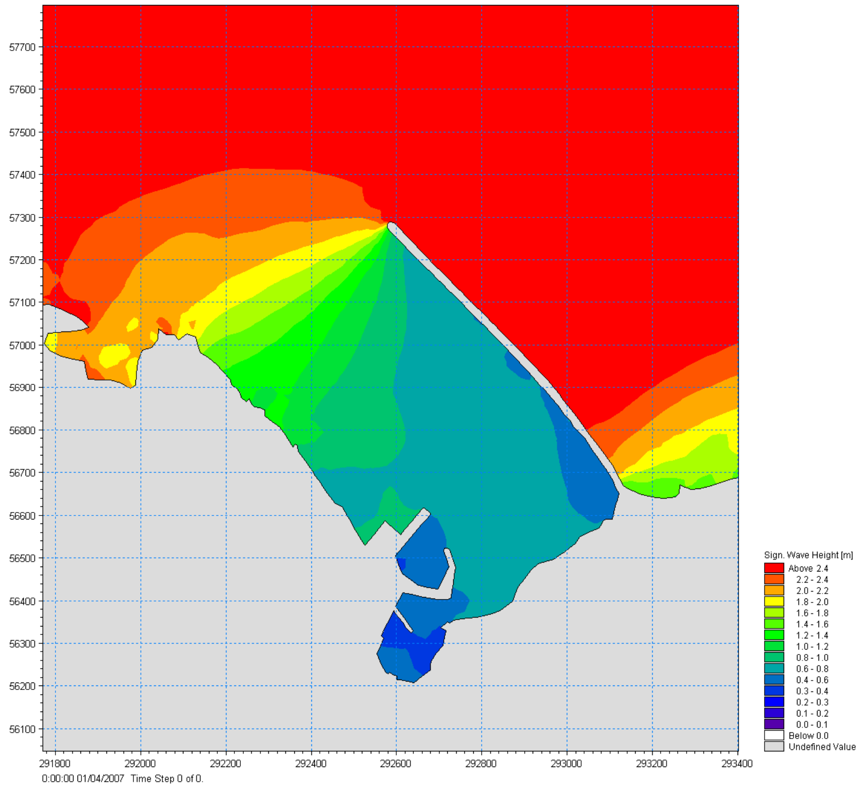


Figure 2.4 Existing Condition, Wind, 30 Deg (1in 1yr)



2.7 Tidal Currents and Water Quality

2.7.1 Tidal circulation in Tor Bay was established by South West Water Services Ltd, Torbay Marine Scheme, Oceanographic Overview, 1994 which collated available data at the time.

2.7.2 Hyder undertook an assessment of tidal currents and water quality as part of the Environmental Statement prepared in 2006. A hydrodynamic (MIKE21-HD) model of Brixham was prepared and calibrated using water level and current data collected by AstraZeneca in 1987, supplemented by data from South West Water Services in 1992. The model of the proposed situation included an extension to Victoria Breakwater and a piled wave screen, along a similar alignment to the options considered for this study.

2.7.3 The conclusion of the hydrodynamic modelling was that the effects on local hydrodynamics of the proposed breakwater were considered to be for the most part largely insignificant:

- Although the orientation of the flowfields within the harbour are rotated by 45º the existing flow speeds are very low and the post-construction flow speeds are not significantly higher.
- The constriction posed by the presence of the breakwater at the entrance to the harbour increased maximum flow speeds from an existing 0.03m/s on the flood tide and 0.05m/s on the ebb tide to post-construction values of 0.1m/s and 0.2m/s, respectively. However, this is not expected to adversely affect navigation or mooring of vessels.
- Further south towards the Fish Quay and the MDL's existing floating wave screen, there is no significant difference between the existing and post-construction flowfields.
- No change in water levels in the harbour is predicted.

2.7.4 Although the baseline option identified by this report has a slightly different layout and orientation to that proposed by Hyder and there are differences in the wave model, this does not affect conclusions drawn by the hydrodynamic model discussed above.

2.8 Sediment Transport

2.8.1 Hyder undertook an assessment of sediment transport as part of the Environmental Statement prepared in 2006. Their calibrated hydrodynamic (MIKE21-HD) model was used in conjunction with particle size analysis to determine the potential for changes in sediment transport due to construction of the proposed Northern Arm Breakwater. The conclusions of this assessment were:

- The increase in flow speed at the new, narrower harbour entrance may cause local resuspension of bed sediments depending on the structure of the bed. However, it is considered unlikely that significant erosion will occur in the harbour entrance.
- Except for an initial adjustment of the seabed at the new harbour entrance, it is considered unlikely that any significant change in the sediment transport regime of Brixham Harbour will occur as a result of the proposed works.
- The proposed works do not increase the flow speeds in the harbour sufficiently at any location to cause resuspension of bed sediment.

- The reduction of flow speeds at some locations within the harbour could cause a local increase in deposition of suspended sediment. However, as the suspended sediment concentration is low, there is very little material that could fall out of suspension and therefore this reduction in flow rate should not lead to significant siltation.
- The predicted post-construction reduction in wave heights in the harbour means that the near-bed orbital velocities due to waves will be reduced, thus reducing the likelihood of resuspension of bed sediment by waves. Passage of marine vehicles may induce near bed velocities sufficient to cause resuspension of bed sediment as with the present layout.

2.8.2 Although the baseline option identified by this report has a slightly different layout and orientation to that proposed by Hyder and there are differences in the wave model, this does not affect conclusions drawn by the hydrodynamic model discussed above.

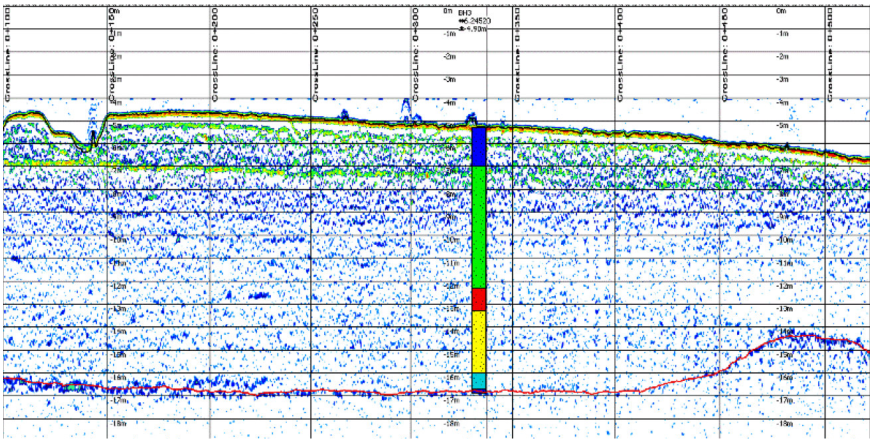
2.9 Geotechnical

2.9.1 Site investigation has been carried out previously as part of earlier studies for Torbay Council/ Torbay Development Agency, the following geotechnical reports have been received and reviewed:

- Victoria Breakwater, Brixham, Devon Geotechnical Investigation Report, Case Consultants (Yeandle Geotechnical), January 2011.
- Brixham Regeneration Scheme, Freshwater Quarry, Site Investigation Report, Frederick Sherrell, November 2010
- Brixham Northern Arm Breakwater, Outline Design Report, Hyder Consulting Ltd, February 2006
- Brixham Harbour Regeneration Strategy, Site Investigation Factual Report, Scott Wilson, April 2000

2.9.2 As part of this study a geophysical survey has been carried out to confirm the depth of rock head across the site. The results of the geophysics survey are included in Appendix E, this shows the sediment thickness (between bed level and rock head) across the site, refer Figure 2.5 (also refer Figure 5.1).

Figure 2.5 Extract from Geophysics Report (showing approx 12m thickness of sediment nr proposed breakwater roundhead



2.10 Environmental

2.10.1 A number of consents will be required prior to construction and operation of the Northern Arm Breakwater, including marine licences and planning permission. In order to support the consents applications processes, Environmental Impact Assessment (EIA) is required under the Marine Works (Environmental Impact Assessment) Regulations 2007 (as amended from April 2011) and, potentially, the Town and Country Planning (Environmental Impact Assessment) (England and Wales) Regulations 1999 (as amended).

2.10.2 An EIA Scoping Report has been prepared and is included in Appendix H. The EIA Scoping Report presents the results of a study to determine the issues on which the EIA should focus and the information to be included within the resulting Environmental Statement (ES). Torbay Development Agency will submit this to the Marine Management Organisation (MMO) and, potentially, Torbay Council as part of the TDA's requests for Scoping Opinions.

2.10.3 Scoping comprised a series of tasks to identify the potential environmental issues associated with the proposed Northern Arm Breakwater development:

- site visit to gain an overview of the development's location and the study area's principal environmental features;
- collation of existing environmental information by searching of relevant databases and literature;
- liaison and iterative feedback between the concept design team and the environment team;
- small-scale studies and surveys including a towed video seabed survey to identify habitats and macro-fauna and flora, Phase 1 terrestrial habitat survey, and a desk-based archaeological assessment;
- identification of the potential environmental issues arising as a result of the proposed development;
- consultation with key consultees; and
- preparation of this *EIA Scoping Report*.

2.10.4 Environmental factors have been incorporated into the design process and the selection of the preferred option in relation to the alternatives (see Section 3).

2.10.5 The existing environmental conditions, potential impacts and key activities to be carried out during the EIA stage are set out for each environmental parameter:

- Coastal Processes
- Water and Sediment Quality
- Marine Ecology
- Terrestrial Ecology and Ornithology
- Fisheries
- Geological Environment
- Archaeology and Heritage
- Landscape and Visual Amenity
- Transport
- Noise and Vibration
- Air Quality
- Navigation and Moorings
- Recreation and Amenity
- Human Environment

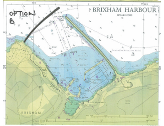
3 BREAKWATER LAYOUTS

3.1 Long list of options

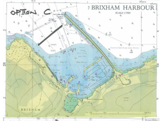
3.1.1 A long list of options were developed by the project team during a design workshop on 2nd December 2010. Harbour stakeholders were consulted on these options through a series of workshops and their views have been fed into the concept design process.

3.1.2 The long list of options was discussed during the second consultation meeting with harbour users on 6th January 2011. Nine options for the Northern Arm Breakwater's position were initially identified and considered during the process of determining a concept design. These options are summarised below:

Option A: Curved breakwater running north-east from Battery Point and wrapping around Victoria Breakwater

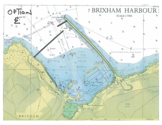


Option B: Straight breakwater running north-east from Battery Point and terminating to the north of Victoria Breakwater



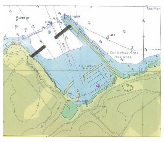
Option C: Straight detached breakwater running north-east from AstraZeneca's laboratories and terminating approx 70m from the disused fuel jetty

Option D: Straight breakwater running north-east from AstraZeneca's laboratories and terminating approx 70m from the disused fuel jetty, also an extension to the Victoria breakwater running north-west

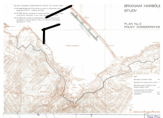


Option E: Straight breakwater running north-east from AstraZeneca's laboratories and terminating approx 70m from the disused fuel jetty, also an extension to the Victoria breakwater running west-south-west

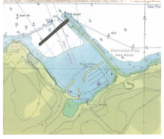
Option F: Straight breakwater running north-east from AstraZeneca's laboratories and terminating approx 70m from the disused fuel jetty



Option G1: Straight breakwater running north-east from AstraZeneca's laboratories to the middle of the harbour also an extension to the Victoria breakwater running west-south-west (entrance channel located between the two breakwaters)



Option G2: Similar to option G1 but with an overlapping breakwater to improve wave climate



Option H: Straight breakwater running south-west from the end of Victoria Breakwater terminating approx 100m from AstraZeneca's laboratories

3.1.3 The stakeholders and TDA's concept design team considered a number of criteria for refining viable options for the Northern Arm Breakwater's position. These criteria are identified in Section 2 and summarised in Table 3.1. The initial constraints map is shown in Figure 3.1.

Table 3.1 Key Criteria Considered for the Breakwater Location

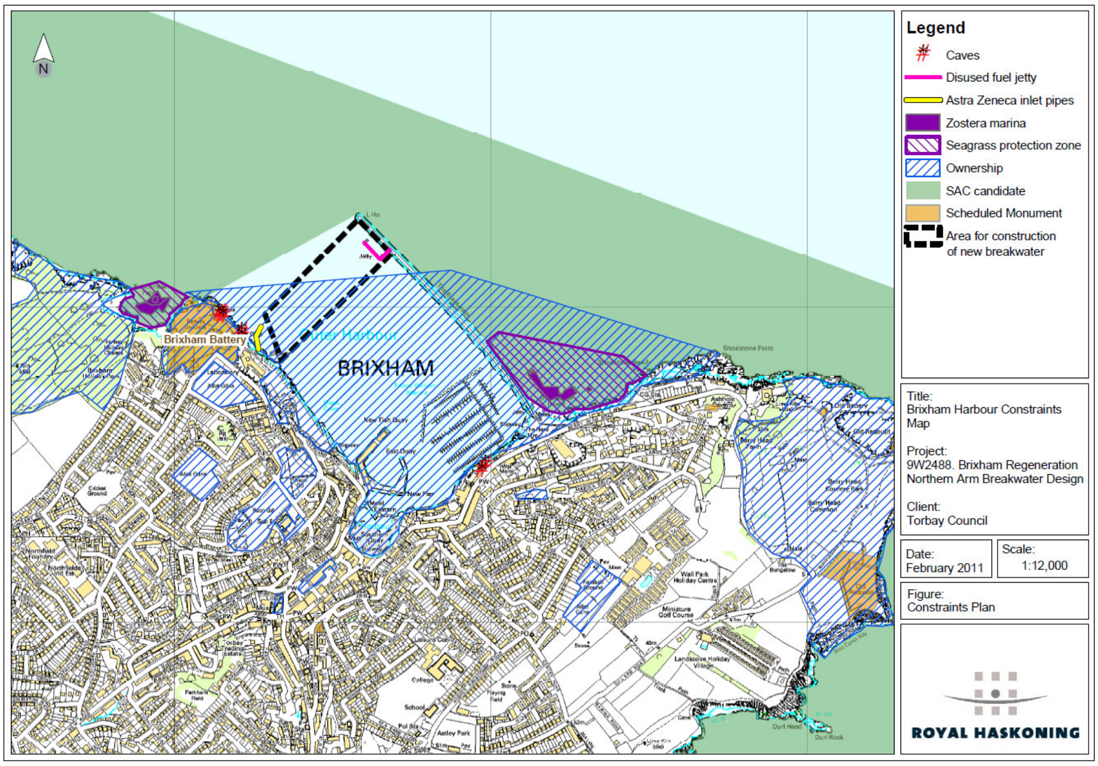
Engineering / Design Criteria	Environmental Criteria
▪ Wave climate in Brixham Harbour ▪ Maximisation of enclosed harbour area ▪ Safe navigation at harbour entrance ▪ Useable harbour area ▪ Presence of disused jetty towards the seaward end of the Victoria Breakwater ▪ AstraZeneca sea water inlet and outfall ▪ Access for maintenance works ▪ Cost	▪ Brixham Battery Scheduled Monument ▪ Lyme Bay and Torbay cSAC boundary ▪ Sea caves in Brixham Harbour (i.e. Harbour Holes) ▪ Water circulation and flushing in Brixham Harbour to maintain water quality and sediment transport patterns ▪ Access for the public (pedestrians)

3.1.4 The findings of the workshop and subsequent design team work (including further consideration of environmental issues) lead to the refining of the options for the breakwater's concept design, the key advantages and disadvantages of each option are summarised in Table 3.2.

Table 3.2 Summary of Breakwater Location Shortlisting

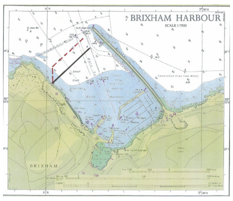
	Layout Option								
Key Advantage / Disadvantage	A	B	C	D	E	F	G1	G2	H
Maximises enclosed harbour area	Y	Y	N	N	N	N	N	Y	N
Good Wave Protection	Y	Y	N	Y	Y	Y	N	Y	N
Good Navigation	N	Y	Y	Y	N	Y	Y	N	N
Within limit of Brixham Harbour	N	N	Y	N	Y	Y	Y	Y	Y
Outside footprint of Lyme Bay and Torbay cSAC	N	N	Y	N	Y	Y	Y	Y	Y
Does not require new land connection around the Brixham Battery Scheduled Monument	N	N	Y	Y	Y	Y	Y	Y	Y
Does not enclose AstraZeneca's inlets and outlets	N	N	Y	Y	Y	Y	Y	Y	Y
Good water quality	N	N	Y	N	N	N	N	N	N
Lower Cost	N	N	Y	N	N	Y	Y	N	N
Shortlisted	N	N	N	N	Y	Y	N	Y	N

Figure 3.1 Initial Constraints Maps showing the Key Criteria Considered for the Breakwater Position

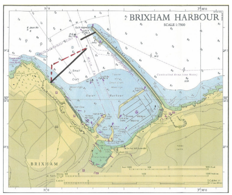


3.2 Shortlisted Options

3.2.1 The nine options were shortlisted into three, Option E, Option F and Option G2. These were further rationalised into two layouts, Option 1 and Option 2:



Option 1 – Is close to Option F from the initial options, a straight breakwater with its root adjacent to the AstraZeneca Laboratory



3.2.2

Option 2 – Is a combination of Option E and Option G2, an overlapping breakwater, the main breakwater located as Option 1 but with an extension to Victoria Pier creating an overlap.

3.2.3 Variations of these options were also considered with a cranked (or dog-leg in the breakwater to maximise the enclosed area of harbour.

3.2.4 The two options were modelled using the numerical wave model to predict the impact on wave conditions after construction (refer Section 4). The numerical model showed that after construction Option 2 achieves the target wave climate. The wave climate for Option 1 is slightly higher than the target wave climate.

3.2.5 During the consultation meeting on 4th February 2011 it was agreed to use Option 1 as the baseline option as it provides better navigational conditions at the entrance of the harbour and it is lower cost than Option 2.

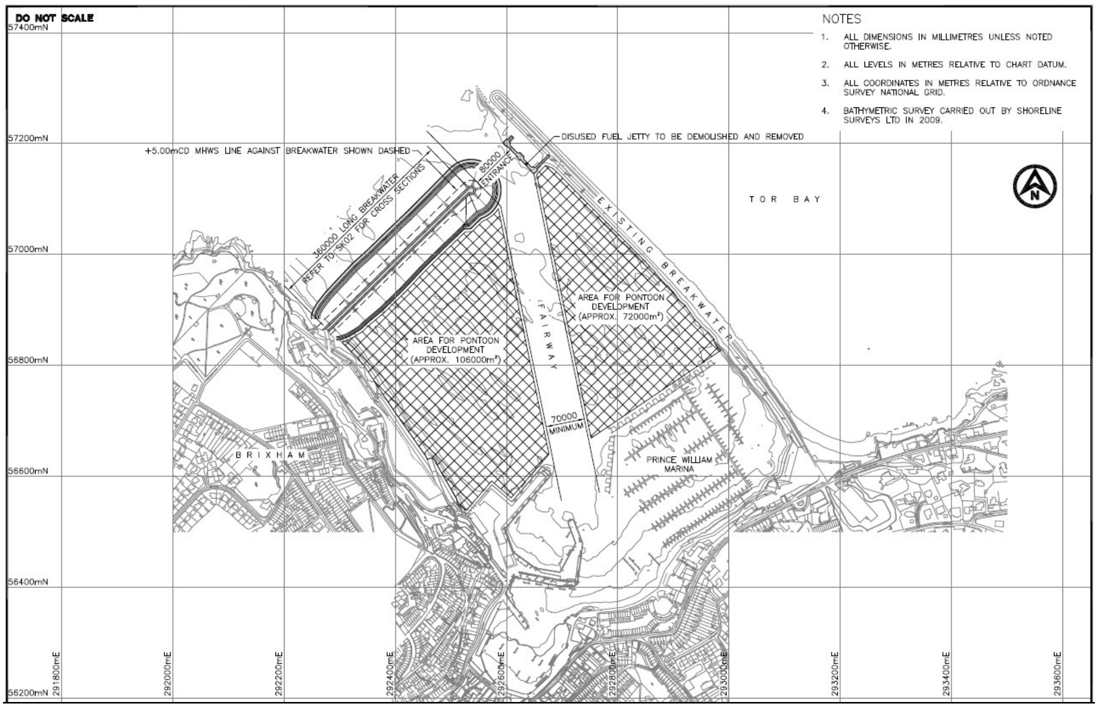
3.2.6 The decision as to whether the breakwater is straight or cranked will be determined based on the benefit that the additional area of enclosed harbour provides, compared to the additional cost for a longer breakwater in deeper water. It was noted, however that the cranked breakwater changes the entrance conditions and allows more wave energy to enter the harbour resulting in a higher wave climate than a straight breakwater that terminates opposite the disused fuel jetty.

3.2.7 The possibility of using the new breakwater in conjunction with the Victoria Breakwater to provide protection from sea level rise was raised by the consultees. This could possibly be achieved by installing a lock gate between the two breakwaters at some point in the future. This is not considered to be feasible because the Victoria Breakwater itself is a permeable (rock) structure. The cost of creating an impermeable barrier around the whole of Brixham Harbour would be extremely high.

3.2.8 During discussions with the harbour master at the Stakeholder meetings it was decided that should an option similar to Option 1 be progressed, demolition of the disused fuel jetty should be a requirement of the works. This would minimise the navigation hazard posed by having the entrance channel / fairway running alongside this jetty. If the fuel jetty was left in place an additional clearance would be required so that the fairway does not run along a vertical structure (this would in turn mean that the entrance would need to be wider allowing more wave energy into the harbour).

3.2.9 Option 1 has been been selected as the baseline option based on the results of the work undertaken for this study. Selection of this option does not preclude selection of an alternative option by the Council or a Developer at a later stage if another option is deemed to be the best solution in the prevailing circumstances.

Figure 3.2 Breakwater Layout - Baseline Option



3.2.10 The area of enclosed harbour that would be suitable for pontoon development is as follows (refer Figure 3.2):

Oxen Cove and Freshwater Quarry	10.6 ha
North of Prince William Marina	7.2 ha

3.2.11 The increased area that would be made available if the breakwater was cranked is approx 1 ha (at Oxen Cove and Freshwater Quarry).

3.2.12 This needs to be balanced with the existing swing moorings that would be displaced. Based on the 2011 mooring plan provided by the harbour master Table 3.3 provides a vessel size distribution.

3.2.13 There are a total of 234 vessels on existing moorings within the harbour (refer Table 3.3). Approx 30 of these are within the footprint of the proposed breakwater and would need to be re-allocated elsewhere within the harbour. Dependant on the scale and location of any pontoon development some or all of the remaining 204 vessels would need to be allocated space within the new marinas. For comparison the Prince William Marina has 500 berths. It was also noted that there is currently a waiting list for moorings at Brixham.

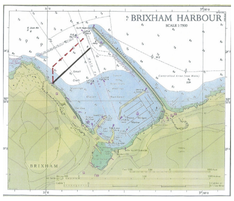
Table 3.3 Vessel Size Distribution, vessels currently on swing moorings

Vessel Length (ft)	Vessel Length (m)	No	%
< 20	< 6	41	18
20 - 30	6 - 9	106	45
30 - 40	9 - 12	55	24
40 - 50	12 - 15	12	5
50 - 70	15 - 21	17	7
100	21-30	3	1
	Total	**234**	**100**

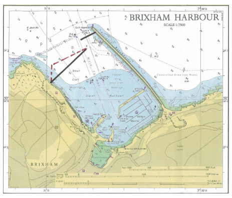
4 NUMERICAL WAVE MODELLING OF SHORTLISTED OPTIONS

4.1 Shortlisted Options

4.1.1 Once there was agreement that the wave conditions were a reasonable representation of the existing situation, the model was run for a number of different breakwater options:



- Option 1A - Straight breakwater (solid black line), rock both sides
- Option 1C - Straight breakwater (solid black line), (sensitivity run) rock seaward side, vertical wall harbour side
- Option 1D - Cranked breakwater, (dashed red line), rock both sides



- Option 2 - Overlapping breakwaters (solid black line), rock both sides

4.1.2 The target wave conditions have been adopted from the Yacht Harbour Association Code of Practice. This specifies that:

- The significant wave height (Hs) for normal annual conditions must not exceed 0.3m and the maximum period of 2 seconds
- For designers using conditions created by storms of an occurrence of 1 in 50 years – the waves should not exceed Hs of 0.4m and a period of 2.5 seconds.

4.1.3 The predicted wave conditions for Option 1 slightly exceed the target wave conditions for waves from 30^0 for both the 1 in 1 year and 1 in 50 year events (refer Table 4.1). The majority of the harbour is below 0.4m criteria for waves from 120^0. For waves from 30^0 the majority of the harbour is within the 0.4m to 0.6m band.

4.1.4 The predicted wave conditions for Option 2 are below the target wave conditions throughout the enclosed harbour (due to the overlapping breakwaters which prevent a larger amount of wave energy from entering the harbour). The results are summarised in Table 2.3. (The sensitivity run 1C is not included in the table below but the results are included in the full set of model outputs in Appendix G).

Table 4.1 – Model Output Summary (1 in 50 year return period)

	Option and Wave Height (m)			
Output Point & Wave Direction	Existing Hs (m)	1A Hs (m)	1D Hs (m)	2 Hs (m)
2 (120^{0})	0.75	0.42	0.53	0.14
3 (120^{0})	0.82	0.13	0.25	0.04
4 (120^{0})	0.58	0.29	0.31	0.12
9 (120^{0})	0.69	0.22	0.37	0.07
2 (30^{0})	0.93	0.73	0.72	0.20
3 (30^{0})	1.24	0.24	0.53	0.15
4 (30^{0})	0.67	0.43	0.4	0.21
9 (30^{0})	0.87	0.49	0.58	0.23

Red shading denotes exceedance of preferred standard

4.1.5 Although the wave climate for Option 1 is slightly higher than the target conditions, the exceedence is relatively small. It may be possible to reduce the wave climate further by installing floating breakwaters (upgraded pontoons), however, floating breakwaters are generally most suitable for wave periods of 4 seconds or less, the wave periods at Brixham are 7 seconds or greater.

4.1.6 The Yacht Harbour Association guidelines are more stringent than other international guidance in relation to acceptable extreme wave heights. For example the Australian Standard, gives a Hs of 0.75m is permissible (for head seas, moderate conditions) as discussed in Section 2.2. It is considered that although the wave climate exceeds the target conditions for Option 1, this is acceptable for and the safe operation of a marina.

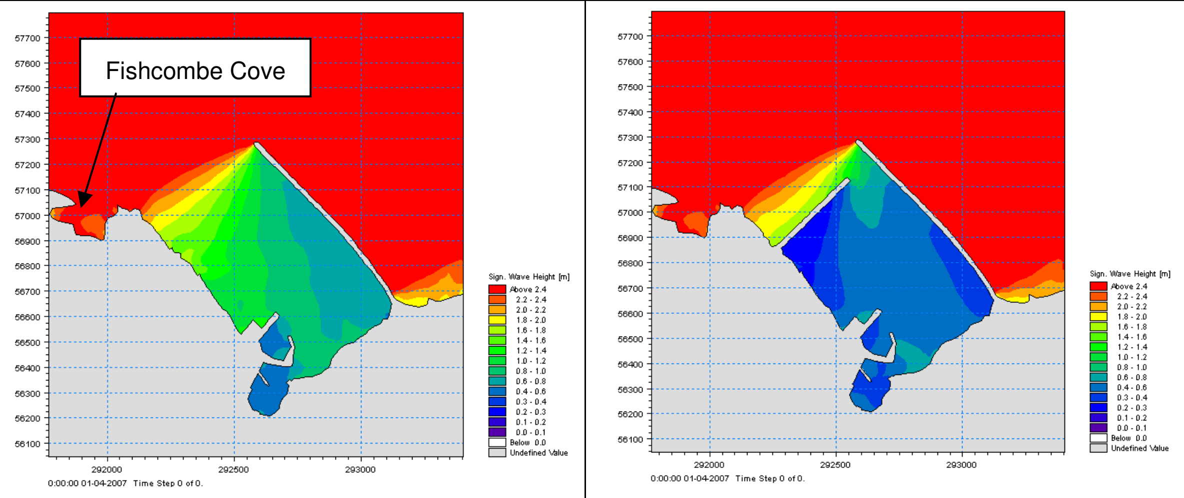
4.1.7 There is no evidence that the proposed breakwater significantly increases / worsens the wave climate at the entrance to the harbour via reflection between the Northern Arm and Victoria Breakwater (refer Figure 4.1 and Appendix G).

4.1.8 There is no significant reflection towards the cSAC and Fishcombe Cove, (refer Figure 4.1, A and B).

Figure 4.1 – Existing and Proposed Situation 1 in 50 year return period

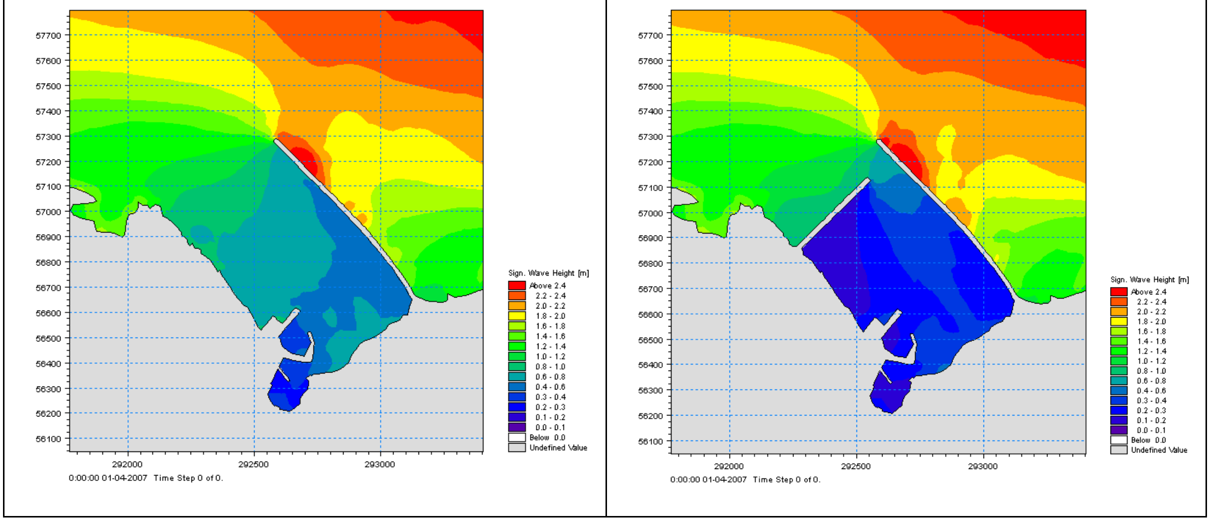
A) EXISTING SITUATION, WIND WAVE, 30 DEG

B) OPTION 1, WIND WAVE, 30 DEG



C) EXISTING SITUATION, SWELL WAVE, 120 DEG

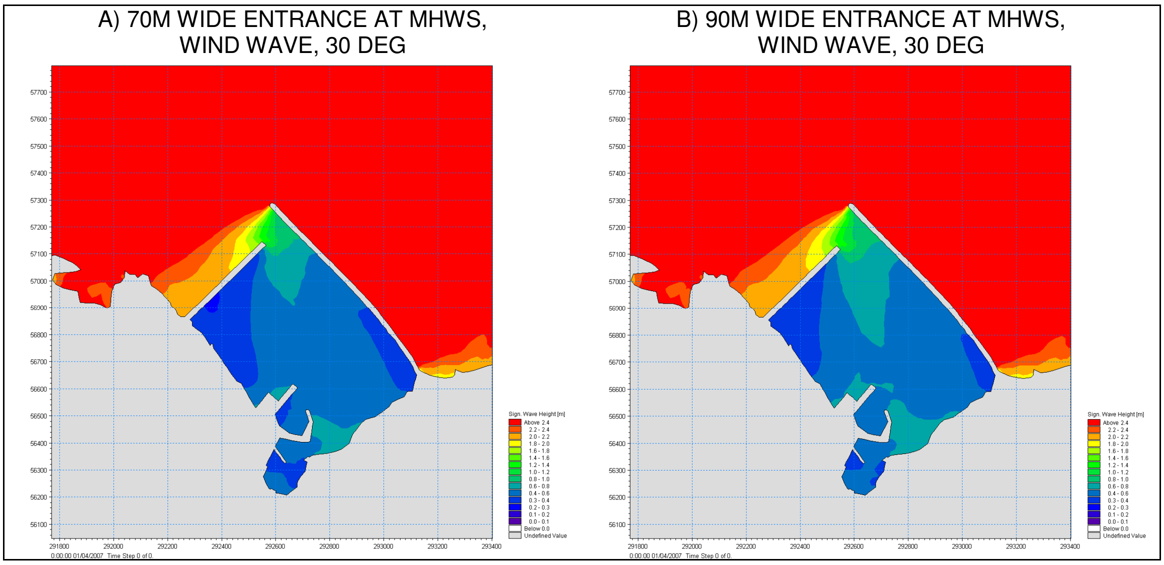
D) OPTION 1, SWELL WAVE, 120 DEG



4.2 Sensitivity of Harbour Entrance Width

4.2.1 Sensitivity of the width of the harbour entrance was undertaken by running two scenarios, one with a 70m width and one 20m wider, the results are shown in Figure 4.2 (for a 1 in 100 year return period event). There is a slight increase in wave heights within the enclosed harbour, although this is mainly concentrated to the fairway / entrance channel.

Figure 4.2 – Sensitivity of entrance width 100 year return period



A) 70M WIDE ENTRANCE AT MHWS, WIND WAVE, 30 DEG

B) 90M WIDE ENTRANCE AT MHWS, WIND WAVE, 30 DEG

5 CONCEPT DESIGN

5.1 Introduction

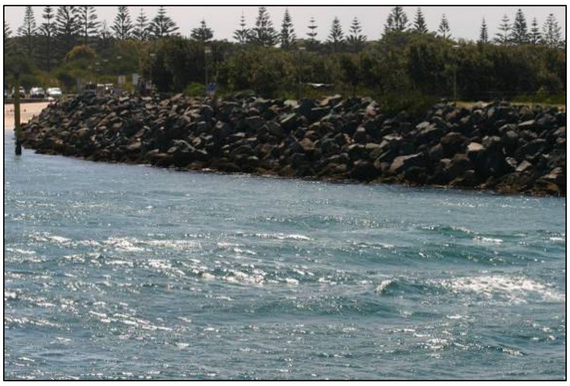
5.1.1 Breakwater design is determined by a number of factors. For the purpose of this outline design the design philosophy has been divided into separate criteria:

- Construction methods / materials
- Geotechnical stability
- Hydraulic stability

5.2 Construction methods / Materials

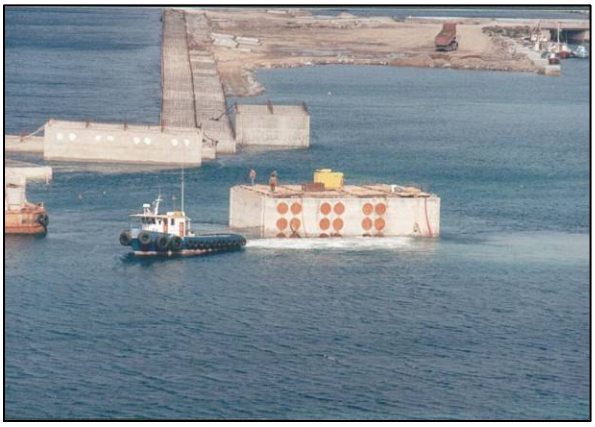
5.2.1 Three construction methods have been considered for the proposed breakwater:

i) rock armoured breakwater, with concrete crest.



ii) steel sheet piled cofferdam (with rock scour protection on the exposed face)

iii) (concrete caissons / blocks with rock scour protection on the exposed face)



5.2.2 A piled wave screen (one of the options proposed by Hyder) was not taken forward for the following reasons:

- the slatted timber infill panels between piles would allow a proportion of the wave energy to pass through and it is very unlikely that a sufficient reduction in wave height would be achieved. (the options above would provide better wave conditions within the harbour)
- high reflection from vertical structure towards navigation channel, cSAC and Fishcombe Cove resulting in less safe conditions for access
- potential for scour at base of wave screen structure
- long term maintenance / durability issues associated with steel structures in the marine environment

5.2.3 The advantages and disadvantages of each option are summarised in Table 3.1

Table 5.1 Advantages and Disadvantages of different Construction Methods

Advantages	Disadvantages
Rock Breakwater	
~ Lower cost ~ Flexible, layout can be changed, extended, rock reused ~ Durability / Longevity ~ settlement can be accommodated as flexible structure ~ Good hydraulic performance (absorbs wave energy) ~ Berthing facilities are possible with floating pontoons or offset structures	~ Large Footprint ~ Settlement may occur ~ Longer construction period ~ Incremental construction possible, abortive work if damaged by storms.
Steel Sheet Piling	
~ Small Footprint ~ Designed to minimise settlement ~ Berthing against inner (vertical) face possible ~ Construction of facilities on deck possible ~ Shorter construction period	~ Durability / Longevity ~ Risk of damage during construction ~ Noise / vibration impact ~ Cost ~ Reflected Waves in Harbour ~ Visual Appearance

Caisson / Concrete Block	
~ Small Footprint ~ Shorter timeframe for construction ~ Berthing against inner (vertical) face possible ~ Construction of facilities on deck possible ~ Shorter construction period	~ Durability / Longevity ~ Possible differential settlement ~ Cost

5.3 Comparative Costs

5.3.1 Comparative costs were estimated for each option early on in the project, to narrow down the potential options. The costs considered standard breakwater construction as the assessment of ground conditions had not been carried out at this stage. The comparative options costs were are given in Table 5.2.

Table 5.2 Construction Methods, Comparative Costs

Option	Cost/m run
i) Rock Breakwater	£30k - £45k
ii) Steel Sheet Piling	£58k - £65k
iii) Caisson / Concrete Block	£62k - £70k

5.3.2 As the costs are for comparison, they cover material supply and placement only, rather than total project costs. The following items are excluded: design and supervision, dredging (e.g. for caisson option), pre-drilling piles into bedrock, piling under caissons, contingency etc.

5.3.3 It was agreed at the consultation workshop on 6th January 2011 that the baseline option in terms of initial cost, longevity, flexibility and impacts would be a rock breakwater.

5.4 Geotechnical Design

5.4.1 The Outline Design Report, Hyder 2006 summarises the ground conditions as silty sand and sand, this is also shown on Figures 4 and 5 from the Scott Wilson Report (included as Appendix B of the Hyder Report). However, having reviewed the full Scott Wilson report, the borehole logs and lab tests indicate that the material consists largely of soft clayey silts overlying limestone bedrock and the silts are up to 10metres thick in places. The parameters used for outline design are summarised in Table 5.3. The parameters are then used to determine settlement (amount and duration) and ground stability.

Table 5.3 Outline Design Parameters

Soil description	Initial Design Parameters	Description
Quarry run for breakwater	Ø' = 36˚	This is the angle of shearing resistance of the quarry run material and is a measure of the shear strength of this material proposed for the breakwater.
	γb = 20kN/m3	This is a measure of the bulk density of the fill above water level and defines the load applied to the top of the soft silty CLAY/clayey SILT from fill material placed above water that will cause the clay/silt to settle due to additional loading from the breakwater.
	γs = 22kN/m3	This is a measure of the saturated density of the fill below the water level and is higher as granular material desnifies slightly under water. It defines the load applied to the soft silty CLAY/clayey SILT from fill material placed below the water level that will cause the clay/silt to settle due to additional loading from the breakwater.
Soft silty CLAY/clayey SILT	Cu = 5kPat top of layer	This is the value of undrained shear strength of the saturated clay at the top level of the soil layer. This is a measure of how resistant the clay is to shear failure due to the applied load from the breakwater. Used in assessing the slope stability of the breakwater during and post construction.
	Cu= 15kPa bottom of layer	This is the value of undrained shear strength of the saturated clay at the bottom level of the soil layer and indicates that the soil gains in strength with depth. This is a measure of how resistant the clay is to shear failure.
	γb = 17kN/m3	This is a measure of the bulk density of the clay/silt above water level and clays have the same value below the water level hence no saturated density given. It defines the load applied to the soft silty CLAY/clayey SILT in addition to the fill material, with the load increasing with depth. This load does not cause settlement as the clay/silt has already settled over time due to this self load.
	mv = 1MN/m2	This is the Coefficient of Compressibility and defines the total consolidation settlement that will occur in the clay/silt layer due to the applied loading from the breakwater.
	Cv = 1m2/yr	This is the Coefficient of Consolidation and defines the time that the settlement, defined by **mv,** will take to occur due to the breakwater loading.
Limestone	Ø' = 35˚	Again this is the angle of shearing resistance
	γb = 20kN/m3	Again this is the bulk density.

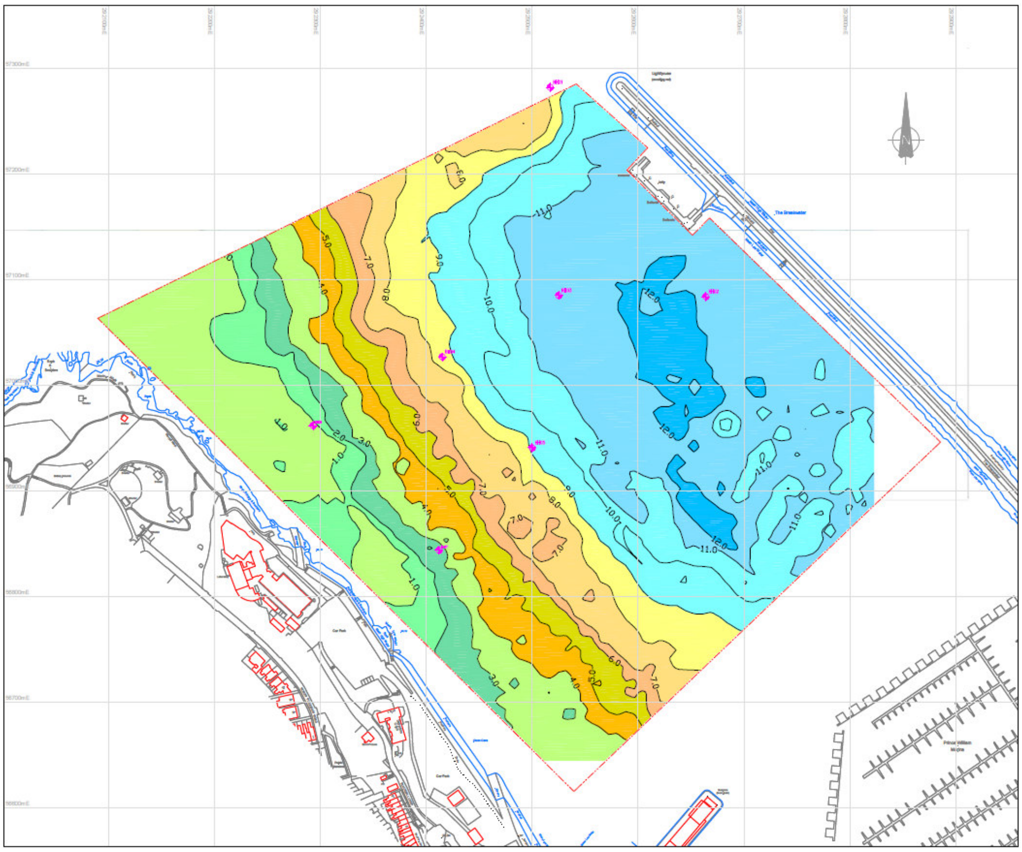
5.4.2 Based on the soil parameters derived from the limited Scott Wilson report, the breakwater would be unstable if constructed under a normal construction programme with no ground improvement methodology or staged construction (i.e all the breakwater fill placed in a single deposition). It should be noted that there has been no direct testing to determine consolidation parameters (only three undrained triaxial tests were carried out) and therefore we have made our best estimates of what these would be, based on the type of material.

5.4.3 Further geotechnical analysis could potentially show that consolidation periods are shorter that allowed for in this report hence reducing construction time, risk and cost. However, equally the investigation and analysis could confirm the concept design assumptions or find that the ground conditions are worse than assumed.

5.4.4 A geophysical survey was undertaken in March 2011 to obtain further information on the depth of marine sediments overlaying rock level, refer Figure 5.1. The Isopachyte plan generally confirms the depths to rock head assumed from the Scott Wilson Report. There are some discrepancies and these are probably due to the difficulty in distinguishing the weathered layer of rock that can be identified as soil in both boreholes and geophysics.

5.4.5 The geophysics indicates that rock head is relatively shallow over the first 150m but increases to approx 11.5m at the end of the breakwater. Moving the roundhead north (e.g. Option 2, cranked breakwater) would reduce the layer of sediment by approx 2m, therefore during detailed design it may be advantageous to orientate the breakwater to take advantage of the slightly higher rock levels (if the alignment of the entrance is changed, the effect on wave climate should be checked).

Figure 5.1 Isopachyte – Total Sediment Thickness



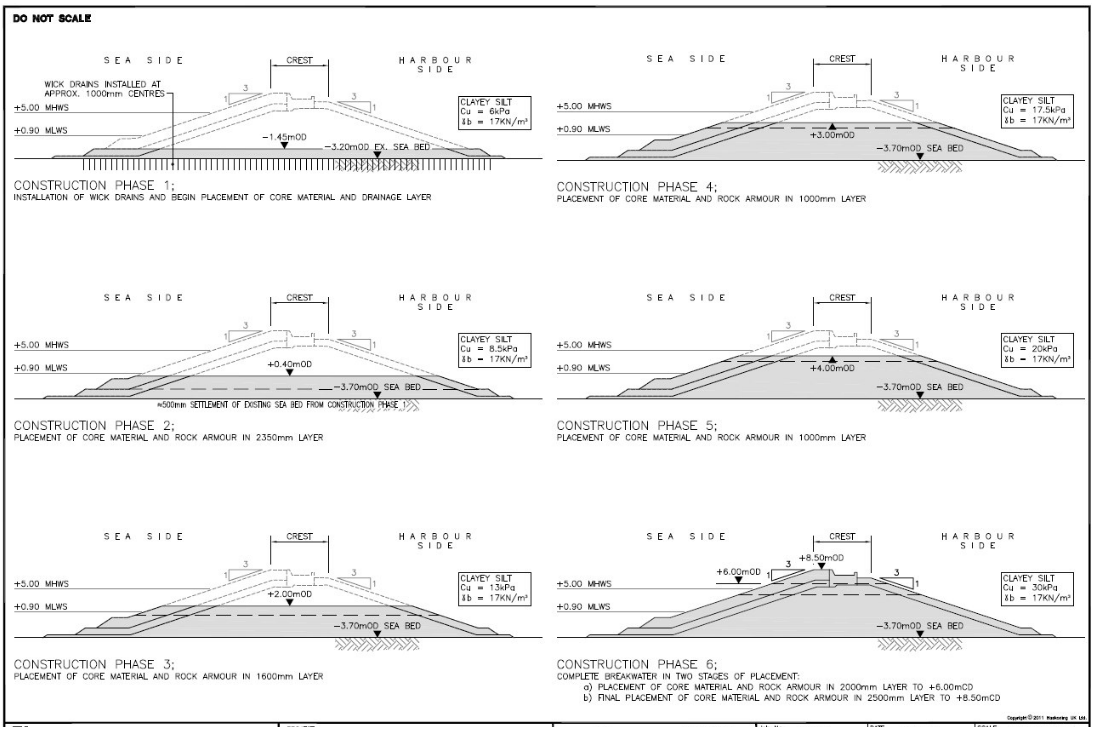
5.4.6 To achieve a stable breakwater it is necessary to construct the breakwater at a relatively shallow slope (1 in 3) refer Appendix A 9W2488_SK02_RevP1. This is shallower than required for hydraulic stability where the slopes could be 1 in 1.5 or 1 in 2, refer Appendix A 9W2488_SK01_RevP1.

5.4.7 It will also be necessary to undertake ground improvements (such as installing wick drains to speed consolidation, which increases strength) and construct the breakwater in a staged manner, refer Figure 5.2). The options for ground improvement are as follows (in increasing order of cost):

- installation of wick / band drains,
- stone columns
- in-situ soil mixing

5.4.8 As it is lower cost and generally a quicker method of construction we have investigated installation of wick drains. Wick drains are artificial vertical drainage paths where pore water can flow, reducing the time for consolidation. Typically they are approximately 100mm wide x 15mm thick with a plastic core (which acts as a free draining channel), surrounded by a geotextile filter. The drains would be installed at approximately 1m centres. Where wick drains are installed it is also necessary to undertake construction in layers and monitor consolidation prior to placing further layers.

Figure 5.2 Staged Construction



5.4.9 Long term settlement of the breakwater is expected to be between 2.5 and 3 metres due to the presence of the thick layer of soft marine sediments.

5.4.10 A staged construction method is obviously slower than a standard construction programme for a breakwater on good quality soils and will therefore add to the overall cost of the works. This can be mitigated by optimising the construction programme and plant utilisation during the works to minimise mobilisation / demobilisation costs and the amount on plant on site at any given time.

5.4.11 As detailed above and in the discussion of project costs and funding opportunities (Section 6), the cost of the proposed breakwater is highly dependant on the ground conditions. It is recommended that before undertaking any further studies or detailed designs a more detailed marine site investigation is carried out. This should include the following (as a minimum):

- 15 No Cone penetration tests - 15m deep
- 6 No Cable percussion boreholes (15m deep) with rotary follow on (5m deep)
- Carry out permeability testing in the superficial deposits and rock.
- Sample collection (soils and rock) and laboratory testing

5.4.12 The costs for the marine site investigation are likely to be between £130,000 and £160,000.

5.5 Hydraulic Design

5.5.1 The following standards and technical guidelines are used in the design of the breakwaters:

- BS 6349 – British standards for Maritime Structures, 1991
- CIRIA C683 – The Rock Manual – The use of Rock in Hydraulic Engineering (2nd Edition), 2007

- CEM – Coastal Engineering Manual, US Army Corps of Engineers, 2002
- EurOtop – Wave Overtopping of Sea Defences and Related Structures, Assessment Manual, 2007

5.5.2 The design life for the breakwater is 50 years (from the brief). The structure is designed to withstand a 100 year return period wave and water level event in combination with the expected sea level rise after 50 years.

5.5.3 The operational requirements for the breakwater structure may be summarised as follows:

- Pedestrian access along the crest (except storm condition)
- Maintenance road along crest
- Potential for boat mooring immediately behind the crest during summer months
- Service lighting to the roundhead

5.5.4 Based on the use of 1:3 side slopes, dictated by geotechnical stability issues, the size of the armour rock has been determined using both Hudson and Van der Meer equations. The proposed armour rock sizes are presented in Table 5.4.

Table 5.4 Rock Armour Sizes

Location	Slope (V:H)	Hudson	Van der Meer
Trunk	1:3	0.5t	0.46t
Roundhead	1:3	2.1t	1.15t

5.5.5 At this preliminary stage the following armour sizes are proposed:

- 1-3t on roundhead and seaside of outer trunk
- 0.3-1t on leeside of breakwater

5.5.6 As discussed in Section 5.4 the breakwater will be constructed in a series of layers over a period of potentially 3 years, to allow the strength of the ground to improve. The rock forming these layers will be placed by barge dumping rather than with a land based operation. However, land based operations will be possible from the crest once the structure is above the water line.

5.5.7 The core mound is made up of quarry run material which will be at risk of re-shaping during storms (to form an equilibrium profile). There is a risk that the lighter rock in the core mound will be washed away during extreme storms. It will, therefore, be necessary to place temporary protection (larger armour rock) on the front slope and crest of the core mound during the ground improvement process.

5.5.8 Alternatives to the temporary rock protection, which would reduce the extent of reworking of the mound are (refer Appendix A 9W2488_SK03_RevP1):

i) Place 0.3-1t rock armour on the front section of the core mound. This will provide additional protection to the front slope and crest of the core mound over the longer construction period. The disadvantage is that the core of the structure would be more permeable and potentially allow the transmission of waves through the upper part of the structure creating problems for boat mooring in the lee. If this is the case it may be necessary to replace rock armour near the crest with quarry run, before completing the wave wall.

ii) Place sand filled geocontainers to form the core. These geocontainers could be prepared and placed from a barge. A geotextile filter would be placed between the core and the final rock armour. These geocontainers forming the shape of the core mound would be more stable (than quarry run) during storm conditions and, therefore less susceptible to damage. The advantage of geocontainers is that the slope profile with 1 in 3 can be easily achieved and wave transmission would not be an issue.

5.5.9 Construction of the breakwater will be complicated by the requirement to install band drains and to construct the structure in a series of layers. This raises issues for the stability of the mound which will be at greater risk of damage over the extended construction period. This is likely to require temporary armour to protect the mound or alternatively consideration could be given to partly constructing the mound with armour rock or using sand filled geocontainers.

5.5.10 It is recommended that during the detailed design of the structure, physical model tests are undertaken to refine the designs and confirm:

- Stability of the primary armour
- Wave overtopping and transmission characteristics
- Sizing of the mass concrete wave wall

5.6 Possible Innovative Design and Construction Options

5.6.1 It is possible, and in some areas probable, that with additional geotechnical data and contractual and commercial incentives in any procurement Contractors will be willing to take design and construction risks that reduce the estimated construction costs considerably.

5.6.2 This sub-section looks at innovative design and construction methods that could be employed to reduce construction overheads, material costs and programme.

5.6.3 As discussed in this section the main constraints are the existing geotechnical conditions which require a staged construction process to avoid overloading the weak sediment layer. Therefore design and construction options that reduce the final loading of the permanent works on the weak sediment will speed up construction and allow greater height gain and/ or allowable load.

5.6.4 Options that reduce fill loading are:

- Lightweight core material (tyre bales, precast concrete, hollow concrete sections)
- Use of recycled aggregates for core material

5.6.5 A more radical approach would be to consider the use of bespoke cellular units (e.g. RC or fibre reinforced concrete or composites) that provide void space that is not filled. The units would have to be stepped to match the profile necessary for the rock armour to be placed.

5.6.6 Simply trying to reduce the unit cost of the fill materials by:

- Strategic procurement (linking with other schemes on the south coast to share mobilisation / demobilisation costs and rock supply costs.
- Sourcing recycled aggregates from a specific marine or near shore construction scheme in the UK or on the near European coast

5.7 Health and Safety

5.7.1 A designers CDM hazard log has been prepared during the outline design process, this is contained in Appendix F. The hazard log outlines how certain hazards have been designed out and where residual hazards exist, how these should be addressed during detailed design, construction and operation. A summary of the main hazards is provided in Table 5.5.

Table 5.5 Summary of H&S Hazards

General	Construction	Post Construction
▪ Construction Traffic	▪ Mobilisation of Plant at Oxen Cove and Freshwater Quarry	▪ Public access onto new structure (overtopping, handrailing)
▪ Navigation	▪ Working over & under water	▪ Settlement of roadway / footpath
▪ Unexploded Ordnance	▪ Staged construction	▪ Lighting (ambient, navigational)
▪ Services strike	▪ Failure of Ground	
▪ Demolition		

6 PROJECT COSTS

6.1 Project Costs

Costs have been previously estimated for the Northern Arm Breakwater by Hyder (2006) and Halcrow (2008). The last estimate was £17M (Q3 2008) for a similar configuration to the baseline option.

6.1.1 During this study project costs have been estimated with advice from two contractors, Cofra (a specialist geotechnical contractor) and Dean and Dyball (the principal contractor for the recent works at Brixham Fish Quay and with recent experience of breakwater works in the south west).

6.1.2 The costs are based on a number of assumptions but include:

- Prelims
- Mobilisation / demobilisation
- Marine SI
- Allowance for settlement
- Construction of the breakwater (including installation of wick drains)
- Allowance for services
- Allowance for demolition of fuel jetty
- Professional Fees (e.g. detailed design, Environmental Statement, Consents and Site Supervision)
- 20% for contingency and risk

6.1.3 The range of project costs is presented in Table 6.2. The uncertainty is due to the unknown ground conditions. The Conservative Estimate is the best estimate of costs if the ground conditions are as interpreted from the available information. The Optimistic Assessment is provided to demonstrate the difference on costs if ground conditions are better than can be reasonable assumed currently. Cost Case 3 illustrates the potential impact of reducing the cost of core material by reusing recycled aggregates as core material.

Table 6.2 Cost estimates

	Cost Case 1 Contractor 1 Construction Cost £M	**Cost Case 2 Contractor 2 Construction Cost £M**	**Cost Case 3 Contractor 2 Construction Cost £M**
Conservative Assessment (based on current geotechnical design parameters)	38	31	25
Optimistic Assessment (based on reduction in rock volume and construction stages)	31	25	21

6.1.4 The main difference between the current cost estimates and those prepared previously is due to the change in construction method (staged construction due to poor ground conditions) and the volume of rock required.

6.1.5 To provide a comparison, the costs for a number of recent projects are listed in Table 6.3. This table illustrates the high costs associated with constructing marine structures but it should be noted that none of these projects required ground improvement. The quantity of rock and fill material required for the Northern Arm Breakwater is approximately 340,000m^3 (including an allowance for settlement).

Table 6.3 Comparative Project Costs

Borth Coastal defences, 2011
Project Cost £12M 70,000m^3 rock 2 offshore breakwaters, 4 rock groynes shingle nourishment
Port of Workington Revetment Repairs, 2011
Project Cost £1.6M 150m long revetment (placed & delivered from land) 16,000m^3
Torquay Haldon Pier Rock Repairs, 2010
Project Cost £1M 6,500m3 rock placed by barge
Weymouth & Portland Sailing Academy, 2008
Project Cost £7M 200m long breakwater, 4,000m^3 revetment 45,000m^3 reclamation Also slipways & ramps
Portland Marina, 2007
Project Cost £27M 860m long breakwater 160,000m^3 rock Also slipways, boat hoists and marina

6.2 Funding Mechanisms - Introduction

6.2.1 The brief for this study stated that the consultant should report on possible financial mechanisms to provide funding for the breakwater in advance of the development in Freshwater Quarry and Oxen Cove.

6.2.2 Capital funding for the construction of the Northern Arm Breakwater (NAB) is not currently available from public sector funding sources in the form of grant funding from central or local government, although contributions from public sector bodies to part fund the scheme may be available.

6.2.3 To facilitate development of the harbour on both landside and waterside the Northern Arm Breakwater is required to:

- Provide Flood defence to tidal flooding from overtopping during storm events.
- Create calm water within the harbour to allow marine development to the west of Fish Market and improve the existing wave climate within the Harbour for all users.

6.2.4 The physical breakwater itself may or may not be developed and provide a source of revenue.

6.3 Baseline Conditions

6.3.1 The current harbour generates revenue (income) for the public and private sector. In general the public sector maintains the existing physical infrastructure that allows the harbour to operate. Where the private sector do maintain infrastructure, it is for their own benefit, and no other third party harbour user is reliant on private business to maintain harbour infrastructure to sustain their own activities within the harbour.

6.3.2 There is no facility or provision within the existing operation of the harbour to either keep a proportion of the revenue, or to levy extra over charges on users to create a fund to provide capital for new infrastructure or pay back borrowed capital.

Funding Baseline

6.3.3 From the baseline conditions; in the first instance assessing realistic sources of funding for the NAB will need to be based on a business case that considers the wider economic value of its presence to Brixham, Torbay and any wider area of economic influence.

6.3.4 It is considered that whether the breakwater is funded by the public or private sector a business case is a prerequisite for a decision to invest.

6.3.5 It may be possible that some funding for the NAB can be derived from the existing operation of the harbour, but this will require significant consultation with the current users to instigate.

6.4 Business Case (Required For)

6.4.1 The economic appraisal necessary for investment will differ depending on whether funding is sought from the Public Sector (prudential borrowing for example), the Private Sector or combination of the two (which would require an overarching model and appraisal and separate business cases for each party).

Public Sector Grant Funding

6.4.2 Traditional public sector investment considers the wider economic and societal benefit (socio-economic) and satisfies itself that the overall cost to the public purse will be recouped over a defined period (in many cases 50 years) in terms of both of benefits to the economy and for social policy objectives.

6.4.3 Financial models for public sector investment in Marine infrastructure are not prescribed by the DfT in the way that that the commonly used models for Road and Rail investment are; (derived benefit cost ratio BCR). Therefore any public sector investment model would need to be agreed with the funding authority be it Central Government, Torbay Council or any other body.

Public Sector Prudential Borrowing

6.4.4 Public sector prudential borrowing is different in that is requires a full economic benefit to be realised to pay back the borrowed capital. It is not however the same as a private sector model, as it allows other (generally future) Local Authority revenue streams to be capitalised to partially or fully justify the investment. An example of this would be the reduction in both revenue and capital maintenance costs of the existing Harbour's physical infrastructure as a result of the NAB, which can be capitalised annually to pay back the prudential borrowing.

6.4.5 In the case of the NAB a proportion of the capital cost, say 10% could be covered by prudential borrowing in the manner described above over a defined return period e.g. 25 years.

Private Sector – Capital Loan

6.4.6 Borrowed capital repaid to a lender over a fixed period of time. In this instance the private sector lenders would simply look at the risk of default of repayment over the loan period, and the asset value of the breakwater in terms of tangible revenue generation as collateral. This would require a very minimal business case for the lender, but would still obviously require a more detailed model for the Local Authority to indentify revenue sources for repayment.

6.4.7 If the public sector was the loan guarantor/underwriter, lenders would probably not be particularly concerned regarding the asset value/revenue to the private sector. In addition interest rates could be less than prudential borrowing rates as the public sector are considered to be the least risk debtor.

6.4.8 This source of funding could also be obtained through a design, build and finance (DBF) arrangement with a private sector Contractor who supplies the finance to fund the construction.

Private Sector Development of Real Estate and Harbour Services

6.4.9 This would require a detailed business case to consider the real estate value of any linked developments within or adjacent to the harbour in addition to any other revenue streams from services, access charges and levies that could in part or whole be directed to the developer. In this case the developer would finance the cost of the NAB themselves and have to provide investors with a business case and guarantees of repayment.

6.5 Asset Value – Direct and Indirect

6.5.1 To further develop specific options for funding and delivery of the NAB it is necessary to consider what the asset value of the NAB could be to Brixham, Torbay and it's wider economic area of influence.

6.5.2 This is necessary to monetise and aggregate the benefits for any business case where borrowed capital is required to fund the delivery of the NAB

6.5.3 Note that the capital cost of the NAB is called its 'asset replacement value' rather than is 'asset value' as the two are very rarely the same.

6.5.4 The presence of the NAB will create direct and indirect economic benefit over an area with a generally diminishing proportional benefit when moving away in simple geographical distance from Brixham. This is something of a simplification as clearly the ownership of Private Businesses, and hence the receipt of revenue and profit, is not necessarily realised in Brixham. However it is a reasonable assumption that the collection of a proportion of any benefit can be levied and collected locally from any private sector business wherever they are based.

6.5.5 Direct Benefit (Primary Effects) can be defined as:

- Development potential of the physical asset (developments on the NAB)
- An increase in adjacent land and development values that would not occur without the presence of the NAB.
- Marine development potential of certain areas of the harbour that could otherwise not be realised without the presence of the NAB
- Direct revenue generation (user/access charges) on/from the asset
- An increase in turnover and revenue of local business that has occurred due solely due the presence of the NAB
- Reduction in cost or risk exposure for existing public services or public sector bodies due to the presence of the NAB.

6.5.6 Indirect Benefit (Secondary Effects) can be defined as:

- An increase in adjacent land and marine development values on land or water that could have been developed without the presence of the NAB, but have increased in value due to its presence
- Increase in trade in existing businesses that has occurred as a secondary effect of the presence of the NAB; leisure tourism and commerce increasing due to additional trips to Brixham
- Reduction in cost for existing businesses in maintaining or replacing their existing assets by the presence of the NAB.

6.5.7 The above are not exhaustive lists, and arguments can be made that some benefits could be in either category. A simple guide is that direct benefits are benefits that could not occur without the presence of the asset, and indirect benefits are benefits that could have occurred, but were unlikely to have occurred in the short or medium term with the presence of the asset.

6.5.8 Direct and indirect benefits as listed also have the distinction that part of the monetised benefit could in theory be collected to finance the capital cost of the creation asset over time.

6.5.9 There is a third category of benefits (Tertiary Benefits) that are the ripple effects on area of development/regeneration. These are so called as the benefit is generally smaller and it is difficult to charge the beneficiary to pay the asset owner or to finance the capital cost of the asset. However they are worth stating to inform public consultations and political decisions:

- Increase in business activity in Brixham and Torbay
- Increase in number of people employed in Brixham
- Probable net reduction in unemployment in Brixham (although this is less certain)
- Increase in property prices outside the immediate area of the Harbour
- Increase in amenity benefit
- Improvement in public realm in adjacent areas of Brixham through S106 developer contributions.

6.5.10 Any business case for either public or the private sector investment will need to consider what the asset value is in terms of benefits and how the monetised benefit can be captured to finance the creation of the asset.

6.5.11 As demonstrated above the economic benefit of the NAB could be widespread and complex. The complexity involved in creating mechanisms to obtain financial contributions from beneficiaries provides a significant risk to the scheme promotee and funder.

6.5.12 It is desirable that those deriving the greatest financial benefit should be required to contribute the greatest share. The complexity of collecting the financial benefit to third parties generally increases in proportion to the diminishing level of direct and indirect benefits accrued by the third parties.

6.6 Risk – Planning, Delivery and Development

6.6.1 The options for funding the NAB are directly linked to the mechanism of planning, delivery and development. In simple terms if the risks to a developer are too great or the process of delivery too complex they will not invest. Notwithstanding the Harbour Authority has permitted development rights as a consequence of pre-existing statutory consents the Local Authority may need to take some risks, highlighted in this section, to facilitate development. However it is appreciated that Torbay Council may neither have the mandate nor the appetite to take on such risks.

6.6.2 Assuming that the business case (theoretical costs and financing of the NAB) is positive for both the scheme promoter and the funder, (it is assumed that the scheme wouldn’t progress without this being the case) the commercial risks of delivery will need to be understood, mitigated and costed, by the delivery organisation and will provide the greatest barrier to realising the delivery of the NAB.

6.6.3 As the physical asset itself does not appear to have significant development value, or revenue generating capacity to the asset owner, financial contributions from other sources will need to be garnered to provide revenue to pay back capital funding.

6.6.4 The simplest model for funding and delivery is if the asset owner/deliverer[1] stands to benefit sufficient financial gain from one or more of the direct benefits listed in Section 5. In this instance they could finance the NAB themselves and limit the delivery and financing risks to planning and development of land, marine areas and other assets under their control.

6.6.5 If the business case shows that some of the indirect beneficiaries listed in Section 6.5.6 are required to contribute; this in general will require the Local Authority to provide a

---

[1] Asset owner is defined by who has undertaken to pay for the asset as deliverer, rather than who legally owns and maintains the asset as Harbour Authority for example.

mechanism for a proportion of the financial benefit to be collected and channelled to the asset owner/deliverer e.g. Planning gain, Community Infrastructure Levy (CIL).

6.6.6 Note that it is possible for private sector beneficiaries to contribute directly to the asset owner/deliverer but this presents a risk in collection. In addition charges paid to the Local Authority can be more easily accounted for as business expenses and recovered against Tax.

6.6.7 Table 6.4 shows how the options for delivery affect the funding sources and capital repayment. This is clearly simplified and variations can easily be derived to match the prevailing direct/indirect development potential.

Table 6.4 - Options for Delivery which assume that some degree gap funding will be required to deliver the breakwater

Deliverer	Planning	Funding Source (for Gap Funding)	Capital Repayment to lender
Local Authority Delivery	*Detailed Planning Application for NAB	Prudential borrowing, private capital, (from banks or other institutions). Funding delivered by Contractor (Infrastructure provider)	CIL Developer contributions, (Marine and Land based). Harbour levies and duties.
Private Sector Delivery	*Outline Planning Application for Development Area including NAB followed by DPA for NAB	Private Capital	Sales from land and marine development and going revenue from development(s)
Joint Development Agreement (SPV)	*Masterplan followed Outline Planning Application for Wider Development Area	Any combination of: Prudential borrowing, private capital, (banks or other institutions). Funding delivered by Contractor (Infrastructure provider). Shares in SPV	CIL Developer contributions, Marina and Land based. Harbour levies and duties. Sales from land and marine development and going revenue from development(s).

*Note: The Northern Arm Breakwater has been included in the Local Plan for many years and has permitted development rights

6.6.8 This section demonstrates that careful thought needs to given to how the planning and delivery of the NAB relates to the development and economic growth within Brixham and Torbay that it could stimulate. It also demonstrates that an outline business/investment case and financial model is necessary to define what the options in risk mitigation for planning, delivery and development are.

6.7 Capital Sources and Repayment Mechanisms

Table 6.5 - Potential Sources of Funding Capital

Type	Source	Comments
LA Grant	Torbay Council	Annual Government Capital Allocations to Torbay
Council Capital	Torbay Council	
Prudential Borrowing	Public Works Loan Board	
Flood Defence	Environment Agency	
Private Capital	Banks	
Private Capital	Private Capital Funds	Channelled through a third party
Private Capital	Institutional Investors	Pensions Funds
Private Capital	Developer	Capital receipts to the Council from the sale of Council owned development land.
Private Capital	Marine Developer	Capital receipts to the Harbour Authority for right to develop with the Harbour

Table 6.6 - Potential Sources of revenue for repayment of capital

Type	Mechanism	Debtor
Planning Gain	Section 106	Private Sector Developers
Planning Gain	CIL	
Tax Incremental Funding	% of Future Business Rates	Private Sector Businesses
Enterprise Zones	Reduction in business rates to encourage more business to locate/relocate	Private Sector Businesses
New Homes Bonus	Direct grant paid to Local Authorities for delivery of new homes.	Central Government (CLG)
Local Authority Maintenance Capital Revenue	Annual maintenance budgets amortised against capital asset.	Public Works Loan Board if borrowed through prudential borrowing.
Harbour Revenues	Annual contributions paid to Harbour Authority from Marine Developers	Private Sector Marine Operators
Harbour Revenues	Collection of Harbour duties and levies (e.g. from boat owners and harbour users)	Harbour Users

6.7.1 The tables above are not exhaustive but illustrate where capital funding is available from and potential sources of revenue that could used to fund repayment of any gap funding required.

6.8 Options for possible funding and delivery models

6.8.1 Until a business case is undertaken for the NAB a recommended or preferred model for funding and repayment cannot be identified. This section therefore describes a number of models that are predicated on either the wider economic benefits of the NAB and or the risks in planning and procurement.

Table 6.7 – Summary of Funding Models

Model	Key Features	Comments
Local Authority led deliver	• Majority of funding coming from public sector grant • Large proportion of economic benefit from indirect benefits requiring LA to provide the mechanism to capture	All risk with Public Sector
Private Sector led delivery	• Majority (over 75%) of funding coming from land and marine developments • Risk of planning notwithstanding that the NAB has been included in the Local Plan for many years and has permitted development rights • Risk that NAB costs and procurement passed to private sector	All risk with private sector, considered to be unlikely without either a Masterplan or Outline Planning Application (OPA) in place.
Joint LA/Private Sector delivery	• Approximately equally split between direct and indirect benefits or indeterminate split of benefits at the point of NAB construction • Facilitates risk distribution between parties best positioned to take it (Joint masterplan and OPA) followed by individual public and private sector detailed applications. • Allows development profits to be shared between public and private sector to benefit local residents outside immediate development areas.	Shared risk, preferred model when planning and funding risks are not clear.
Breakwater Trust	• Not for profit trust holding with multiple shareholders. • Repayment through public and private sector mechanisms the same as other options. • Tax efficient	Probably not practical as capital repayment sources vary and can't be levied directly as a toll.

Composite Model of Funding to Illustrate Options

6.8.2 The funding model in Table 6.8 shows median values of possible sources of capital income against an initial capital cost. The capital cost of £20m assumes that through a combination of design innovation and contractor risk, the construction cost at award of contract would be in the order of £20m.

Table 6.8 – Example Funding Model

Capital Cost	£*	Description
Cost of Breakwater	£20m	Asset Cost
Capital Funding		
Value of council owned Development Land	£6m	Based on the valuation given by Savills
Contribution from Marina Developments Ltd (MDL)	£4.55m	Contributions from Private Marina Developers to the Harbour Authority.
Flood Defence contribution from EA	£0.75m	Contribution to improved tidal flood defence generated by NAB.
Contribution from existing private sector harbour users	£1m	Contribution in lieu of improvements or replacement of existing privately owned marine assets.
Local Authority Capital	£500k	Possible contribution from Torbay Council
Total	£12.8m	
Capital Funding (Gap Funding)		
Prudential Borrowing	£2m	Borrowed against the future revenue and capital maintenance of the Harbour.
Contractor Funding	£5.2m	Capital borrowed or brought by the Contractor
Total	£7.2m	
Revenue for Capital Repayment		
Planning Gain	£3m	Over 25 years at net present value
Harbour Revenues	£3m	Over 25 years at net present value
Council Maintenance Revenue	£1.2m	Over 25 years at net present value
Total	£7.2m	

*Note: Figures are illustrative only

6.8.3 As shown by table 6.8 sources of capital funding and the repayment of gap funding are potentially available if the planning structure and repayment mechanisms can be put in place. To achieve this though will require considerable intellectual capacity and effort on behalf of Torbay Council and it is understood that there are a number of other similar potential schemes across the authority that may mean that the NAB is not an immediate priority scheme to invest this level of resources in.

7 CONCLUSIONS & RECOMMENDATIONS

7.1 Conclusions

7.1.1 This report summarises the work that has been undertaken to investigate options for Northern Arm Breakwater at Brixham. A breakwater can be constructed to provide an adequate level of protection to the enclosed harbour to enable enhanced marina development.

7.1.2 The capital cost of the breakwater is likely to be between £25 million and £38 million, the range of costs is due to the uncertainty in ground conditions.

7.1.3 The costs are very high because the ground is poor, which means the breakwater is a very expensive wave reduction feature. Additional site investigation will result in improved information and understanding of the ground conditions and may result in the possibility of refinements to the outline design

7.1.4 The scoping report has not identified any likely significant environmental effects that would provide a barrier to the project. A number of mitigation measures and controls would be required by consenting bodies.

7.2 Recommendations

7.2.1 A business case / wider economic study should be undertaken to estimate the benefits to Brixham, Torbay and the wider region.

7.2.2 It is recommended that a marine site investigation is carried to confirm project costs should the project be taken forward.

7.2.3 Some further numerical modelling is recommended to determine the optimum layout and entrance alignment during detailed design, this will also ensure that construction costs are minimised. The model should also be updated to include any additional wave measurements that are available for calibration purposes.

7.2.4 A physical model is also recommended when a preferred option is identified, to refine the geometry of the breakwater in order to reduce construction costs.

7.2.5 Alternative methods of construction could be investigated. Possible options include using geocontainers, precast concrete, hollow concrete sections, immersed caissons, and use of recycled material for the breakwater core. A staged tender process could be considered to identify a shortlist of contractors and then develop these ideas further.

7.3 Next Steps

The table below summarises a suggested staged approach to delivery of the NAB and associated development

Table 7.1 – Summary of next steps

Stage	Description	Commentary
1	Preliminary Business Case	An economic analysis of the proposed development of Brixham Harbour and Brixham Town based on existing Masterplan and Torbay Council Local Plan and emerging LDF. The work could be carried out by officers with a small piece of consultancy work for development/investment analysis and some soft market testing with developers. If the case was positive consideration could be given to move to the next stage
2	Geotechnical Investigation	Output to refine cost of NAB. If the capital cost of the Breakwater is the same or reduced from current budget estimate consideration could be given to progress to stage 3.
3	Select Development Partner(s)	A simple procurement exercise, including engagement with Local Enterprise Partnerships to select a private sector development partner or consortium, to take forward the necessary development to fund the NAB
4	Detailed Business Case	This would need to be comprehensive piece of work undertaken by TBC and the Development Partner that builds on the preliminary business case. The work would determine in more detail what development should be put forward for planning permission and ensure that it could generate the funding necessary to pay for the NAB. It would also determine which parties take forward detailed planning application and NAB procurement and set timescales and commit parties to paying funding into the project at defined points. If the case was positive consideration could be given to move to the next stage
5	Outline Planning Application	This would be a joint submission to cover all of the development. If successful a development agreement could be agreed to formally commit parties to the development.
6	Detailed Planning Applications	Detailed planning applications for; NAB and other commercial and residential developments, recognising that the Northern Arm Breakwater is in the Local Plan and has permitted development rights.
7	Procurement of Breakwater	Procurement of D&B Contractor for detailed design and construction the Breakwater. This would indentify an actual cost for the NAB.
8	Final Business Case	Formal sign off development agreement between TBC
9	Let contract to construct breakwater	Let contract to design and build NAB.

Stages 2 and 3 are interchangeable if the preliminary business case for stage shows considerable economic benefit rather than a marginal benefit.

7.4 Project Risk Log

7.4.1 The project team have developed a project risk log that should to be reviewed as the project progresses.

Table 7.2 Project Risk Log

No.	Risk	Mitigation
1	Negative / marginal cost benefit analysis	This report was commissioned by the Torbay Development Agency to identify the risks to inform Council and/or a developer when preparing a Business Case. A number of recommendations have been made within this report to further define these risks.
2	Ground conditions differ from currently known	We have made a reasonable assessment of the ground conditions (based on the limited information available). Additional site investigation is recommended before proceeding further
3	Staged Construction, storm event during construction	There is always the risk that a storm event could occur during construction, in this case the risk is compounded by construction over 2 / 3 winter seasons and that the breakwater will be left 'exposed' until it is complete. Two alternatives have been identified to minimise chance of scour / washout: i) protecting the front of the mound with 300 – 1000kg rock or ii) using geocontainers as core material. Also mitigate during procurement by appropriately setting the contractor / client weather risk.
4	Construction duration, impact on funding	Staged construction means that the breakwater could take approx 3 years to construct, this may have implications on the timing of funding as the breakwater would need to be constructed before development of Oxen Cove and Freshwater Quarry.
5	Wave conditions within the enclosed harbour not adequate	Numerical modelling has shown that wave conditions are slightly higher than that recommended by the YHA, however the wave conditions are considered to be adequate to allow development of marinas.
6	Insufficient control & monitoring during construction, failure of structure	Monitoring and timing is critical for staged construction of an embankment / breakwater. Experienced contractors should be sought and supervision must be tightly controlled

7	Programme, changes to legislation / design criteria	Awareness that conclusions and recommendations contained within this report and the Environmental scoping report are relevant today. There may be changes in legislation or design criteria in the interim
8	Material costs fluctuation	Awareness that material costs can fluctuate significantly above or below the rate of inflation due to supply and demand