FLOOD RISK ASSESSMENT

SCARBOROUGH WEST PIER

Commissioned by William Birch and Sons Ltd

Report 21037-H-RP-001-R9
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R0	27th April 2023	FIRST ISSUE - DRAFT	JSF	DW
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R3	2nd November 2023	CHANGED PROPOSED PLAN	DW	NP
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Issuing office: Mason Clark (Leeds) Refer to final page for full office details.

1 INTRODUCTION

1.1 Mason Clark Associates (MCA) has been commissioned by William Birch and Sons Ltd to compile a Flood Risk Assessment (FRA) for the proposed regeneration of the Scarborough West Pier.

1.2 This FRA has been carried out in accordance with the National Planning Practice Guidance (NPPG) for Flood Risk and Coastal Change and draws on data from the Environment Agency (EA) and the Scarborough and Ryedale Level 1 Strategic Flood Risk Assessment (SFRA), November 2021.

1.3 The Local Authority Planning Department, collaborating with the EA, are obliged to evaluate all new developments with regard for flood risk; this FRA forms part of the necessary evaluation.

2 PROJECT DEVELOPMENT

2.1 The existing site is known as Scarborough West Pier, located off Foreshore Road on the Scarborough sea front. The site currently comprises numerous historic buildings along with a public car park. The existing site layout is shown in Appendix A. The existing building uses are as follows;

Building 1: accommodates public conveniences and storage on the ground floor and offices and artists' studios on the upper floor;

Building 2: includes retail (wet fish sales) and storage on the ground floor and the harbour office and café welfare facilities on the upper floor;

Building 3: accommodates fisherman's welfare facilities and storage on the lower floor and a café, workshops and storage space on the upper floor;

Building 4: single storey structure used for fish processing activities;

Building 5: accommodates bait sheds; and

Building 6: single storey commercial kiosks fronting onto Foreshore Road, which sell wet fish, fast food and beach goods.

2.2 The proposed development involves a combination of the demolition of under-utilised buildings, the upgrade and conversion of existing buildings, new build elements and public realm improvements as summarised below:

Building 1 will be refurbished and extended to accommodate a restaurant on the ground floor and upper floors;

Building 2 will be refurbished to accommodate retail and storage on the ground floor and artists' studios and an associated gallery on the upper floor;

Building 3 will be refurbished to accommodate retail, fisherman's welfare facilities, industrial storage and café storage on the lower floor and the Harbour Masters office and café to the upper floor;

Buildings 4 will be demolished and replaced by a new bait shed building which will accommodate 31 units;

Building 5 will be demolished;

Building 6 will be demolished;

- A new building (7) will be constructed opposite Building 1 which will include replacement kiosks and public conveniences as well as the presence of a substation;
- Public realm improvements including areas of landscape planting, which introduce a shared space that promotes a pedestrian first environment; and
- Eighty one car parking bays, including accessible spaces.

2.3 The topographical levels for the site are generally flat with no substantial changes in fall. The site levels undulate from a minimum level of 3.80m AOD to 4.30m AOD. The site topographical survey is contained in Appendix A.

2.4 Intrusive ground investigations were undertaken by Solmek in March 2023.The development site is underlain by made ground at shallow depths, which makes up the levels within the existing pier structure. The strata at lower levels comprises gravely sand which sits on heavy clay. Borehole records from the intrusive investigations are contained in Appendix C.

3 FLOOD RISK CLASSIFICATION

3.1 The Environment Agency Flood Map for planning in Appendix D shows that the site is located in Flood Zone 3, which is an area with a high probability of flooding. This map shows the presence of any local flood defences but does not take the effects into account.

3.2 The Environment Agency Long Term Flood Risk from Rivers or the Sea Map is in Appendix D and shows that the long term flood risk for the site considering the effect of the flood defences is high risk. High risk means that this area has a chance of flooding greater than 3.3% each year.

3.3 The EA Long Term Flood Risk Map from surface water (in Appendix D) shows that the site is generally at low risk from surface water flooding.

3.4 The EA Long Term Flood Risk Map from reservoirs (in Appendix D) shows that the is not at risk of flooding from reservoirs.

3.5 The EA Long Term Flood Risk Summary (in Appendix D) shows that the site is not affected by groundwater flooding.

3.6 The Scarborough SFRA (November 2021) classifies the site as being in 'Indicative Flood Zone 3B'. An extract from the Scarborough SFRA map is contained in Appendix E.

3.7 The SFRA defines Flood Zone 3B as 'where no detailed modelled 20-year flood extent exists, then Flood Zone 3a has been used as a proxy – this is hatched to show the difference. This is conservative and developers would need to refine in a detailed site assessment.'

3.8 In order to refine the flood risk categorisation for this site the Environment Agency's Coastal Design Sea Levels - Coastal Flood Boundary Extreme Sea Levels (2018) data set has been used as a basis to define the 20 year flood level, which according to the description above will define the extents of Flood Zone 3B. The extract below shows this data set overlaid onto base mapping, it indicates 3 nodes in the area surrounding of Scarborough West Pier, Table 1 summarises the sea levels for relevant return period.

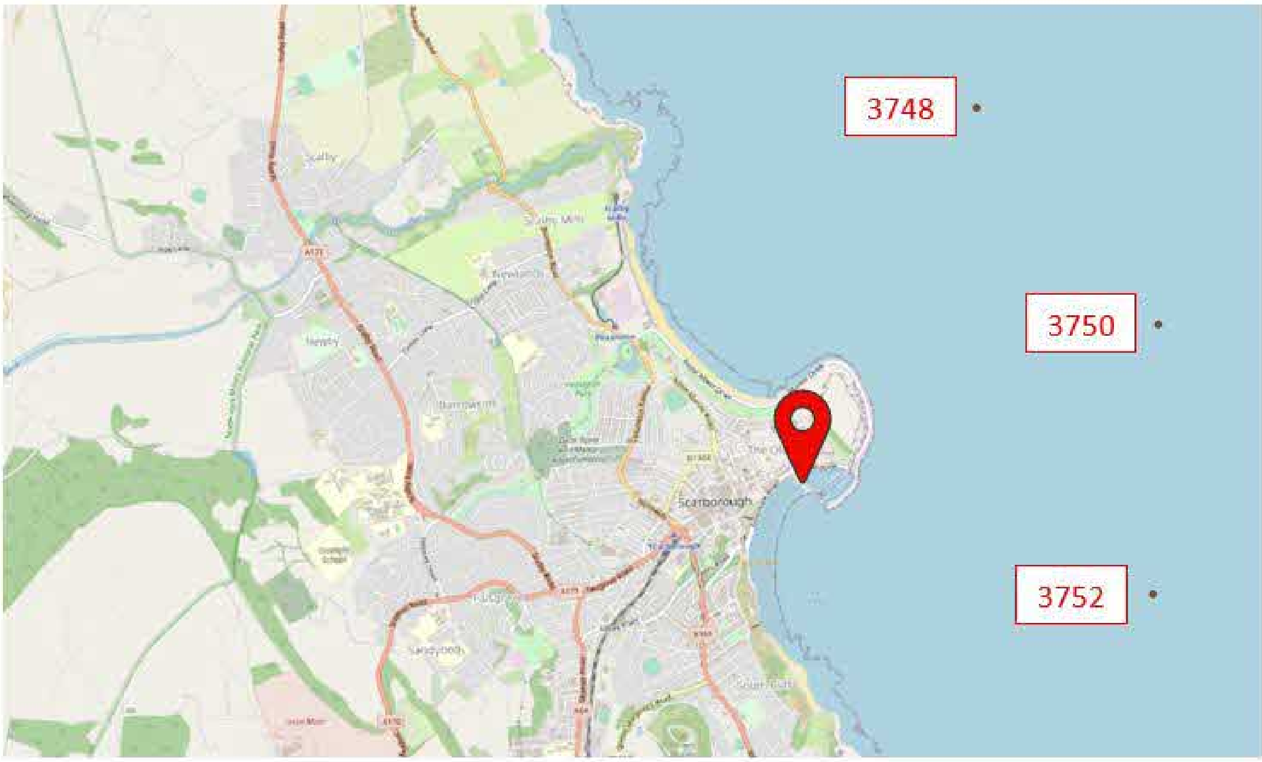

Figure 1 – EA data set - Coastal Design Sea Levels - Coastal Flood Boundary Extreme Sea Levels (2018) Node Locations

Node Chainage	Sea Level (mAOD) and Return Period (1 in x years)			
	1 in 1	1 in 20	1 in 200	1 in 1000
3748	3.39	3.80	4.16	4.43
3750	3.39	3.81	4.16	4.44
3752	3.39	3.81	4.17	4.44

Table 1– Sea levels taken from the EA data set for the relevant nodes.

3.9 Nodes 3750 and 3752 are closest to the development site and have therefore been used to determine the 20 year flood level which will define flood zone 3B. These nodes indicate that the extreme water level the 5% Annual Exceedance Probability (AEP) even has a level of 3.81m AOD.

3.10 The site levels are generally above 3.81m AOD (there are some very localised external areas at 3.8m to the rear of building 1. The Finished Floor Levels (FFL's) for the existing buildings 1, 2 and 3 are 4.180, 4.085 & 3.850 respectively. The extents of the site falling below the extreme 1 in 20 flood level is shown in Figure 2 below with a scale drawing contained in Appendix F;

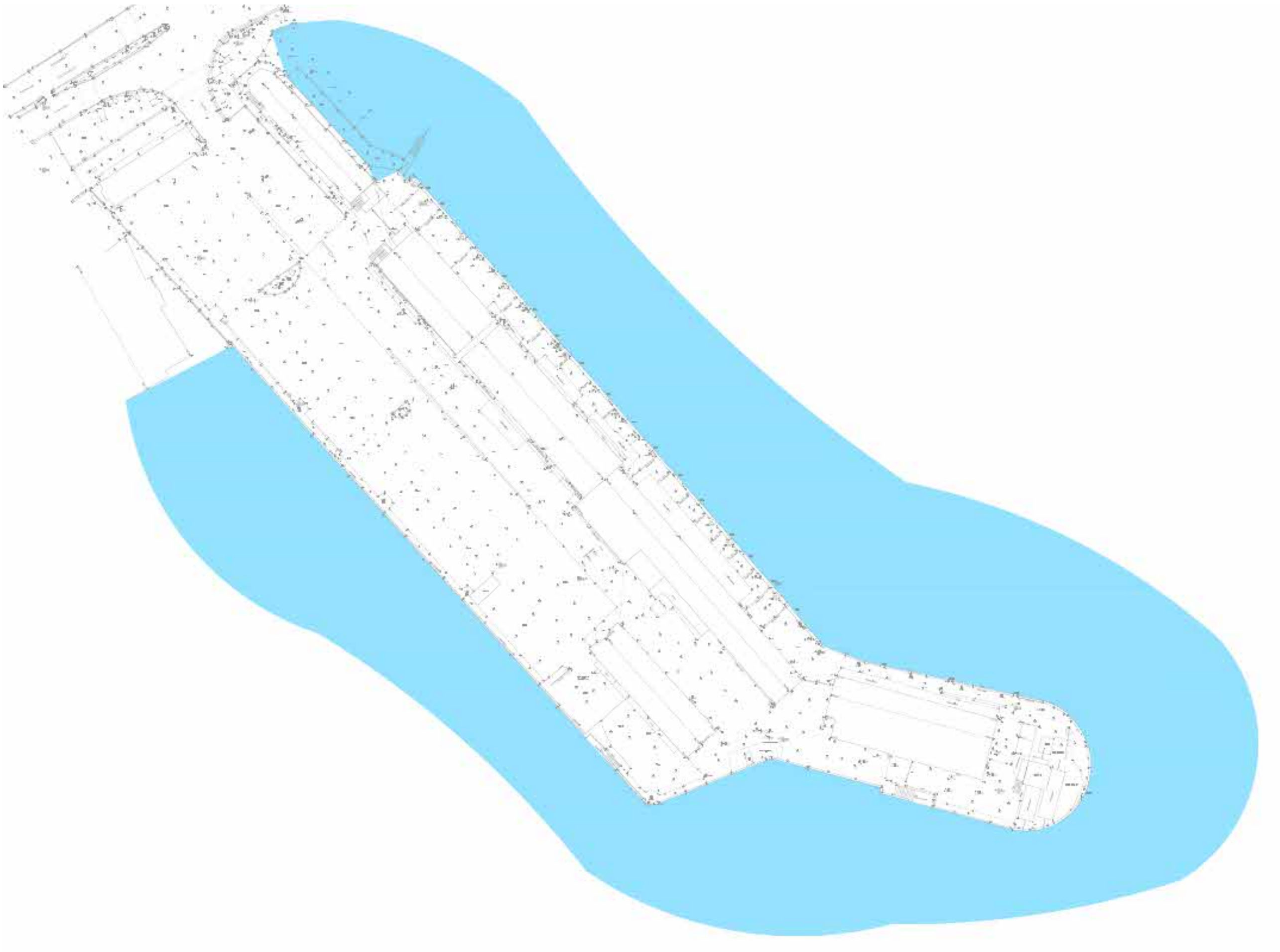

Figure 2 – Interpreted extents of Flood Zone 3B around site perimeter

3.11 Based on the above analysis it is considered appropriate to classify the development site to be in Flood Zone 3A.

3.12 The Environment Agency have been consulted on the above methodology and have confirmed that the development can be assessed as being in Flood Zone 3. A copy of the EA response is contained in Appendix D. The consultancy firm who completed the original SFRA have been commissioned by North Yorkshire County Council to complete a pre planning application appraisal (Appendix L) which confirms the site could be classed as outside Flood Zone 3b.

Sequential Test

3.13 Please refer to Appendix K for the full Sequential Test.

Exception Test

3.14 The site development comprises elements of retail, office and artists' studios which can be classified as less vulnerable development. The industrial elements of the development are associated with the fishing industry so can therefore considered to be water compatible.

3.15 Table 3 from the NPPG, shown below, indicates that both the less vulnerable and water compatible elements of the development are permissible in Flood Zone 3A and will not require an exception test.

Flood risk vulnerability classification (see table 2)		Essential infrastructure	Water compatible	Highly vulnerable	More vulnerable	Less vulnerable
Flood zone (see table 1)	Zone 1	✓	✓	✓	✓	✓
	Zone 2	✓	✓	Exception Test required	✓	✓
	Zone 3a	Exception Test required	✓	×	Exception Test required	✓
	Zone 3b functional floodplain	Exception Test required	✓	×	×	×

Key: ✓ Development is appropriate.
× Development should not be permitted.

4 CRITERIA FOR ASSESSMENT

4.1 The Environment Agency Flood Map for Planning (Appendix D) indicates that the site is located in Flood Zone 3, which is an area with a 1% AEP probability of flooding from rivers or 0.5% AEP from the sea.

4.2 To allow for climate change, selected parts of the guidance by the Environment Agency "Flood Risk Assessments: Climate Change Allowances" has been included as below. This document provides guidance on anticipated changes in peak river flows, peak rainfall and sea level rise as a result of climate change which are applicable to the site. The guidance was last updated on 27th May 2022.

Peak River Flow Climate Change Allowance

4.3 The climate change allowances for peak river flows are given for each river basin district. The range of allowance categories: Central, Higher Central and Upper End are divided into three timeframe periods.

4.4 The guidance recommends the allowances category or categories for consideration which are based on the flood zone and vulnerability classification for the development. The site is located in Flood Zone 3, with a less vulnerable land use. It is recommended that both the central allowance and higher central allowances are assessed.

4.5 The site is located in the Derwent Humber Management Catchment district with an anticipated lifespan of 40 years for the refurbished buildings, retails kiosks and toilet block. The applicable climate change allowance is therefore:

Central: 17%

Higher Central: 22%

Peak Rainfall Intensity Climate Change Allowance

4.6 The anticipated increase in rainfall intensity is given for small and urban catchments and affects the surface water flood risk. There are three time categories and two allowance categories for reference. All flood risk assessments should consider a range of impact from the Central and Upper End allowances.

4.7 Basing the development on an anticipated lifespan of 40 years gives the following allowances for consideration:

Central: 20%.

Upper End: 35%

Sea Level Climate Change Allowance

4.8 The allowance for sea level changes due to climate change is given for areas across England. The guidance states that both the Higher Central and Upper End allowances should be used for assessment.

4.9 The proposed development has a design life of 40 years, climate change and other associated allowances have been calculated on the basis that the design life will end in 2065, with construction being completed by 2025.

4.10 The data presented in Table 1 in section 3 provides sea level data from 2017 with an allowance for storm surge. Climate change requirements and allowances for offshore wind speed and extreme wave height need to be accounted for. The site is located in the Humber catchment, the recommended climate change allowances are presented in Figures 3 & 4 below;

Area of England	Allowance	2000 to 2035 (mm)	2036 to 2065 (mm)	2066 to 2095 (mm)	2096 to 2125 (mm)	Cumulative rise 2000 to 2125 (metres)
Humber	Higher central	5.5 (193)	8.4 (252)	11.1 (333)	12.4 (372)	1.15
Humber	Upper end	6.7 (235)	11 (330)	15.3 (459)	17.6 (528)	1.55

Figure 3 – EA climate change guidance sea level rise

Applies around all the English coast	2000 to 2055	2056 to 2125
Offshore wind speed allowance	5%	10%
Offshore wind speed sensitivity test	10%	10%
Extreme wave height allowance	5%	10%
Extreme wave height sensitivity test	10%	10%

Figure 4 – EA offshore wind speed and extreme wave height guidance

4.11 The applicable climate change allowances have been assessed against the 2017 year 0.5% AEP baseline scenario. The higher central scenario will determine the design flood level, with access to and from the site being assessed against the upper end scenario. The design flood level with appropriate climate change allowances is presented in Table 2 below;

	Climate change allowance for sea level rise			10% off shore wind speed allowance	10% extreme wave allowance	2017 0.5% AEP baseline water level	2065 0.5% AEP water level + climate change
	2017 - 2035	2036 to 2065	Total sea level rise to 2017-2065				
Higher Central	99mm	252mm	351mm	35mm	35mm	4.170m AOD	4.591 AOD
Upper End	120mm	330mm	450mm	45mm	45mm	4.170m AOD	4.710 AOD

Table 2 – Climate change allowances on sea level

Impact upon Development

4.12 The impact of climate change upon the development considering the above stated allowances is considered within Section 5.

5 SOURCES OF FLOODING

5.1 Flooding from Rivers, Watercourses and the Sea

Flood Mapping

5.1.1 The Environment Agency Flood Map for Planning in (Appendix D) indicates that the site lies within Flood Zone 3 . A Flood Zone 3 classification indicates that a site is at a high risk of flooding from rivers in 1 in 100 year event and or the sea in a 1 in 200 year event.

5.1.2 The Environment Agency Long Term Flood Risk Summary for Rivers and the Sea in (Appendix E) indicates that the site is at high risk of flooding.

5.1.3 The Environment Agency Flood Map for Planning (Appendix D) indicates the risk of flooding without defences whereas the Flood Risk Summary indicates the risk of flooding when defences are operational. The difference between the maps indicate that the defences offer some improvement in flood risk.

5.1.4 The Environment Agency have been consulted and have provided their available flood risk assessment data which includes the historic flood map. The historic flood map indicates that part of the site was affected by flooding during the east coast tidal events in both December 2013 and January 2017.

5.1.5 As outlined in Section 3 the Scarborough SFRA flood maps indicate that the site is located in Indicative Flood Zone 3B.

The SFRA defines Flood Zone 3B as 'where no detailed modelled 20-year flood extent exists, then Flood Zone 3a has been used as a proxy – this is hatched to show the difference. This is conservative and developers would need to refine in a detailed site assessment.'

5.1.6 In order to refine the flood risk categorisation for this site the Environment Agency's Coastal Design Sea Levels - Coastal Flood Boundary Extreme Sea Levels (2018) data set has been used as a basis to define the Flood Zone 3B extents and which shows that, with the exception of a very localised area of external paving, the site is located in Flood Zone 3A.

5.1.7 A Wave Overtopping Assessment has been completed by Royal HaskoningDHV reference: PC5767-RHD-XX-ZZ-TN-Z-0001, appended within Appendix N.

5.1.8 Based on the assessment, the design flood level for the site has been calculated to be 4.510m AOD for a 0.5% AEP event plus appropriate allowances for climate change. The development site levels vary between 3.80m and 4.38m AOD, which indicates that the site could be subject to flooding between 0.130m and 0.710m in depth.

5.1.9 It is considered that the site is at most risk of flooding during storm surge scenarios which can generally be predicted, and appropriate mitigation measures as outlined in Section 6 can be installed prior to such events taking place.

Summary

5.1.10 The site is located in an area at high risk of flooding therefore mitigation measures will need to be installed which are discussed in Section 6.

5.2 Flooding from Surface Water

Flood Mapping

5.2.1 The EA Long Term Flood Risk Map from surface water (in Appendix E) shows that the site has a very low risk from long term surface water flooding, which is a chance of 1 in 1000 each year.

Sensitivity to Climate Change

5.2.2 The peak rainfall intensity climate change allowance influences flooding from surface water, which shows an allowance for climate change of between 25% - 35%. This could change the flood risk from very low to low risk.

Summary

5.2.3 The site is currently at very low risk from surface water flooding, however with a consideration for climate change this could change to low risk over the lifetime of the development.

5.3 Flooding from Groundwater

5.3.1 The EA Long Term Flood Risk Maps (in Appendix E) only shows the risk of groundwater flooding when it is an issue for the site. As there is no indication of flood risk from groundwater shown on the long term flood risk maps the site is not affected by groundwater flooding.

Summary

5.3.2 As there is no indication of flood risk from groundwater shown on the EA long term flood risk maps the site is not affected by groundwater flooding.

5.4 Flooding from Sewers

5.4.1 Flooding from sewers is often linked to flooding from surface water. The risk of flooding from surface water is currently very low, which is a chance of 1 in 1000 each year. Therefore, the risk of flooding from sewers is thought to be very low.

Sensitivity to Climate Change

5.4.2 The peak rainfall intensity climate change allowance influences flooding from sewers, which shows an allowance for climate change of between 25% - 35%. This could change the flood risk from very low to low risk.

Summary

5.4.3 The site is at very low risk from flooding from sewers. This may change to low risk due to climate change over the lifetime of the development.

5.5 Flooding from Reservoirs

5.5.1 The EA Long Term Flood Risk Map from reservoirs (in Appendix E) shows that the site is not at risk of flooding from reservoirs.

Summary

5.5.2 The site is not at risk from reservoir flooding.

6 MITIGATION MEASURES

6.1 Finished Floor Levels

6.1.1 Environment Agency standing advice recommends that the finished floor of any new building is 300mm above the design flood level including an allowance for climate change. The development comprises both refurbishment of existing buildings within a listed building curtilage and the construction of new buildings. The constraints posed by the site topography and the proximity of the new buildings to existing structures means that it will not be possible to achieve this requirement. The recommendations for the Finished Floor Level in Appendix L, which states "It is recommended that for commercial and retail development the Finished Floor Levels are set above 4.90mAOD" along with the EA response in Appendix D have been taken into consideration. All of commercial and retail development are within existing buildings, where the FFLs are below the design flood level. To mitigate the risk of flood damage to buildings during flood event it is proposed that both flood resilient and flood resistant measures will be incorporated into the building design in accordance with the recommendations outlined in the EA document Improving the Flood performance of new buildings.

6.1.2 The surrounding external topography will be adjusted where possible to ensure that ground levels fall away from any building faces. This will ensure that water will not pond against the face of the building in either rainfall or residual flooding events.

6.2 Flood Resistant Construction

6.2.1 The elements of the development that are classed as more vulnerable will benefit from flood resistant construction up to 600mm above the FFL. The buildings benefitting from flood resistant construction are; building 1, the retail element of building 2, building 3 and Building 7.

6.2.2 The flood resistant measures include construction of a concrete retaining wall to protect all new buildings around their perimeter. Flood gates will be installed at all doors to provide flood resistance to the buildings up to 600mm above FFL.

6.3 Flood Resilient Measures

6.3.1 All buildings in the development will benefit from flood resilient construction up to 300mm above the design flood level. As outlined in Section 3, the design flood level has been determined at 4.510m AOD with appropriate allowances for climate change. A level of 4.900m AOD is suggested as a minimum level for which flood resilient construction should utilised in all buildings on the development.

6.3.2 Electrical equipment and sockets should be raised a minimum of 300mm above the design flood level. All equipment such as computers and TV screens should be wall mounted or on raised cabinets where practicable.

6.3.3 Solid concrete flooring or tiling should be considered instead of carpets for an easier clean up.

6.3.4 Flood resistant materials should be used inside for furniture and fittings.

6.3.5 The proposed levels for which flood resilient, and flood resistant construction is proposed for each building is presented in Appendix G.

6.4 Structural Stability

6.4.1 Standard masonry buildings are at significant risk of structural damage if there is a water level difference between outside and inside of about 0.6m or more. A water entry strategy is favoured when there are high flood water depths. Therefore, a water entry strategy is proposed, where flood water will be allowed to enter the building when it is higher than the proposed flood gates which are 0.6m. Therefore, the use of flood resilient measures should be satisfactory and to ensure structural integrity is maintained and drying and cleaning are facilitated.

6.4.2 We are unable to comment further structurally at this stage as no wave force data us available. It is noted within the assessment on page 11, "The wave approach direction for 'nearshore' output point 11 and 17 (being closest to West Pier) average from an East direction which means waves are either travelling away from, or parallel with, West Pier."

The units are also approximately 25m (varies) away from the pier mitigating further against the wave forces.

6.5 Flood Warnings

6.5.1 The development is located in both a flood alert and flood warning area. Subscription to the EA's Flood Warning Service in the area is recommended for the site. Flood Warnings are issued by the EA to specific areas when flooding is expected, and upon receipt of a flood warning immediate action should be taken. The EA aim to issue Flood Warnings at least 2 hours prior to the onset of fluvial flooding, whereas tidal flood warnings are issued based on forecast information, this could be issued anywhere between 24 to 36 hours in advance. Tidal flood warnings are triggered by a combination of forecast high water (astronomical tide level plus any additional surge), forecast wind speed, and forecast wind direction.

On receipt of a 'Flood Alert' or 'Flood Warning' from the EA, Site users should be made aware of the possibility of flooding and prepare for possible evacuation. The scaling down of activities at the Site should also be considered. On receipt of a 'Severe Flood Warning', the Site should be evacuated.

6.5.2 A Flood Warning and Evacuation Plan (FWEP) will be required during both the construction and operational phases of the development. This FWEP will inform the occupants of the Site of the detailed emergency evacuation procedures and any scaling back of operation processes required in the event of a potential flood event or breach and/ or overtopping scenario. The site owners should subscribe to EA Flood Warning Service to receive updates on flooding expected at the Site.

6.5.3 Given the location of the development it is considered that the most appropriate course of action for the site in the scenario of a predicted storm surge event would be to evacuate in the first instance, however, safe refuge above the flood level will be available in the first floors of Buildings 1, 2 and 3.

6.5.4 Information regarding 'What to do in the event of a flood?' will be included in the Site health and safety plan. All personnel entering the Site will be inducted and be aware of all health and safety procedures. In addition, site notices will include methods of evacuation and notification of dry refuge areas in the wider vicinity of the Site.

6.5.5 A site specific wave overtopping assessment has been carried out to support the application and can be found within Appendix N.

6.6 Surface Water Drainage

6.6.1 The proposed surface water drainage strategy should follow the drainage hierarchy with assessment of the feasibility for surface water disposal to the following outfalls, in order of priority;

1. infiltration
2. watercourse
3. surface water sewer
4. combined water sewer.

6.6.2 Intrusive ground investigations were undertaken by Solmek in March 2023 which show the site to be underlain by heavy clay which will preclude the use of infiltration as a means of surface water disposal.

6.6.3 Although the site is surrounded by the sea, works to the existing pier walls do not form part of the proposed works and it is therefore not possible to form a new surface water outfall into the sea.

6.6.4 Surface water from the development will drain to the existing public combined sewer within the pier as per the current scenario.

6.6.5 In accordance with requirements outlined in North Yorkshire County Council's Sustainable Drainage Systems Guidance 2022, the proposed design flow shall be restricted to a 30% reduction of the existing brownfield run-off rate.

6.6.6 The existing catchment of the site positively draining to the existing public sewer has been assessed based on information contained on the topographical survey and drainage survey for the site. The existing area draining to the public sewer has an area of approximately 0.45ha which produces a run off of 63/s based on a brownfield run-off rate of 140 litres/second/hectare (l/s/ha). Applying a 30% reduction to the existing run off rate results in a restricted flow of 44 l/s. A copy of the survey is contained in Appendix H, with the existing surface water drainage assessment contained in Appendix I.

6.6.7 The proposed surface water network will be designed to accommodate all flows for a storm event of up to 1 in 100 years return period with a 40% allowance for climate change. Due to limited green space usable for above ground SuDS features it is proposed that surface water flows will be contained below ground in modular attenuation tank as well as an oversized drainage channel.

6.6.8 The surface water drainage network has been modelled using MicroDrainage software, and which has been used to determine the surface water attenuation requirements. The required storage volume for a storm event up to 1 in 100 years (plus 40% climate change has been calculated to be $119m^3$.

6.6.9 Surface water flows from area of the pier subject to redevelopment will be restricted by means of an orifice plate/hydrobrake prior to connection into the public sewer.

6.6.10 Surface water run-off from parking areas will be treated by a by-pass oil separator prior to connection into the public sewer.

6.6.11 The proposed discharge rate of 44 l/s is subject to approval by Yorkshire Water.

6.7 Foul Drainage

6.7.1 The existing site is served by a separate foul drainage network which outfalls into the public sewer within the pier. All new foul connections will also be connected into the existing public combined sewer.

6.7.2 Peak flows from new foul connections are estimated to be 7.3 l/s. Calculations are provided in Appendix I.

7 CONCLUSIONS

7.1 The existing site is known as Scarborough West Pier, located off Foreshore Road on the Scarborough sea front. The site currently comprises numerous historic buildings along with a public car park.

7.2 The proposed development is for the refurbishment the existing buildings along with the construction of new retail kiosks and bait shed. The car parking area will also be enhanced to provide an area of public realm.

7.3 The development site is located in Flood Zone 3 according to the EA flood map for planning and is at high risk of flooding.

7.4 The Scarborough SFRA shows the site to be in Indicative Flood Zone 3B which is defined as 'where no detailed modelled 20-year flood extent exists, then Flood Zone 3a has been used as a proxy – this is hatched to show the difference. This is conservative and developers would need to refine in a detailed site assessment.'

7.5 The Environment Agency's Coastal Design Sea Levels - Coastal Flood Boundary Extreme Sea Levels (2018) data set has been used as a basis to define the 20 year flood level, and thereby the Flood Zone 3B Extents. This shows the development site to be generally in Flood Zone 3A.

7.6 The site is currently at very low risk from surface water flooding and sewer flooding, however with a consideration for climate change this could change to low risk over the lifetime of the development.

The site is not shown to be at risk from any other sources of flooding.

7.6 The site could be subject to flooding to a depth of 0.710m in places during the design flood. The scheme design will employ both flood resistant and flood resilient measures to mitigate the effect of such events.

7.7 A Flood Warning and Evacuation Plan (FWEP) will be required during both the construction and operational phases of the development. A place of safety will also be provided on the first floor of buildings 1, 2 and 3.

8 SCOPE

8.1 This report has been commissioned by William Birch and Sons Ltd to assess the probability of flooding of the proposed developments at the Scarborough West Pier. This report is based upon the data referred to and is an assessment of the likelihood of the site flooding from the various sources discussed. Due to the variable nature of flooding, it is possible that future flooding scenarios will be different to past scenarios.

8.2 This report shall be for the private and confidential use of William Birch and Sons Ltd, for whom the report is undertaken, and their immediate advisors in connection with the proposed development. It shall not be reproduced in whole, or in part, or relied upon by third parties for any use whatsoever without the express written authority of Mason Clark Associates Ltd.

8.3 Mason Clark Associates Ltd shall have no liability for any use of the report other than for the purpose for which the report was originally prepared.

9 LIMITATIONS

9.1 All comments and proposals contained in this report, including any conclusions, are based on information available to Mason Clark Associates during investigations. The conclusions drawn by Mason Clark Associates could therefore differ if the information is found to be inaccurate or misleading. Mason Clark Associates accepts no liability should this be the case, nor if additional information exists or becomes available with respect to this scheme.

9.2 Where we have undertaken preliminary infiltration rate tests on site on your behalf this is for indicative purposes only to enable preliminary designs to progress. Where any subsequent designs rely upon infiltration and/or these test results then you should undertake further infiltration rate tests in accordance with accepted industry standard guidelines as detailed in Building Research Establishment publication BRE Digest 365.

9.3 Except as otherwise requested by the client, Mason Clark Associates is not obliged to and disclaims any obligation to update the report for events taking place after: -

(i) The date on which this assessment was undertaken, and
(ii) The date on which the final report is delivered

9.4 Mason Clark Associates makes no representation whatsoever concerning the legal significance of its findings or the legal matters referred to in this report.

9.5 All Environment Agency mapping data used under special license and maybe time limited. Data is current as of April 2023and is subject to change.

9.6 The information presented, and conclusions drawn are based on statistical data and are for guidance purposes only. The study provides no guarantee against flooding of the study site or elsewhere, nor of the absolute accuracy of water levels, flow rates and associated probabilities.

9.7 This report has been prepared for the use of William Birch and Sons Ltd. No other third parties may rely upon or reproduce the contents of this report without the written permission of Mason Clark Associates. If any unauthorised third party comes into possession of this report, they rely on it at their own risk and the authors do not owe them any Duty of Care or Skill.

10 FURTHER REFERENCES

As part of this FRA, a further consultation with the Environment Agency was commissioned. The outcome of which was to provide further specialist information, whereby JBA and Royal HaskoningDHV were commissioned to provide a further specialist report and overtopping assessment respectively.

The JBA Report and Royal HaskoningDHV Overtopping Assessment have been used to inform this report and should be read in conjunction with this Flood Risk Assessment.

masonclarkassociates

Hull (Registered Office)
Church House
44 Newland Park
Hull HU5 2DW
[redacted]
www.masonclark.co.uk
[redacted]

Leeds
Unit E
Millshaw Business Living
Global Avenue
Leeds LS11 8PR
[redacted]
www.masonclark.co.uk

York
Partnership House
Monks Cross Drive
Monks Cross
York YO32 9GZ
[redacted]
www.masonclark.co.uk

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Sewer requisitions and diversions
Section 98 and 185 Agreements
Flood Risk Assessments
Coastal erosion flood breach analysis
Flood risk management / prevention schemes
Underground drainage design
Stormwater attenuation
SUDS
Ponds, lakes and balancing ponds

PROJECT MANAGEMENT
QUANTITY SURVEYING & CONTRACT ADVICE
CDM SERVICES

BUILDING SURVEYING SERVICES
Design, Remedial Repair / Improvement Schemes
Contract Administration
Building Surveys
Professional Opinion Reports
Condition Surveys & Schedules of Condition
Measured Surveys
Dilapidation Claims
Party Wall etc. Act Representation
Disabled Adaptations

EXPERT WITNESS SERVICES
Civil & Structural engineering disputes
Project Disputes
Health and Safety Regulations

STRUCTURAL ENGINEERING
Residential and commercial building structures
Education and healthcare facilities
Heavy industrial development
Feasibility studies for development sites
Building Regulations and Planning Applications
Access and maintenance gantries
Modular building design
Blast design
Subsidence management and resolution
Temporary works design and specification
Site and soils investigation
Sulphate attack specialists
Confined spaces assessments

CONSERVATION ENGINEERING
Engineer Accredited in Building Conservation
CARE Registered Engineer
Heritage and conservation engineering
Listed Building refurbishment
Historic Parks and Gardens
Scheduled Ancient Monuments
Monitoring and investigations
Liaison with Local Conservation Officers
Buildings at Risk and Managed Ruins

3D LASER SCANNING AND DATA CAPTURE
Latest Generation 3D Laser Scanning
Measured Building Surveys
Topographical Surveys
Monitoring Surveys
3D modelling (Revit, CAD, Inventor, Solidworks)
M & E Modelling
Volumetric / Level analysis
Scan to BIM
Scan data cloud hosting
Hi-Def HDR photographic surveys

APPENDIX A

Existing Site Plan

Notes

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2. This drawing is not to be scaled. All dimensions are to be checked on site by the contractor. Any discrepancies are to be notified to Mason Clark Associates. Obtain instructions prior to works commencing.
3. This drawing is to be read in conjunction with all the relevant contract drawings and specifications.
4. All dimensions are in millimetres and all levels are in metres AOD unless noted otherwise.
5. All work shall be carried out in accordance with Local Authority, Statutory Authority and Health & Safety Regulations.
6. Mason Clark Associates are not responsible for determining the appropriate fire period, fire boundary conditions or the associated design of fire protection or inherent fire resistance to any elements of structure, including all frames, posts, beams, joists, roof members and secondary structural elements such as lintels. Refer to the Architect or Project Manager for this information.

Rev	Details	By	Date

Unit E, Millshaw Business Living
Global Avenue, Leeds, LS11 8PR
Tel: +44 (0) 113 277 9542
www.masonclark.co.uk

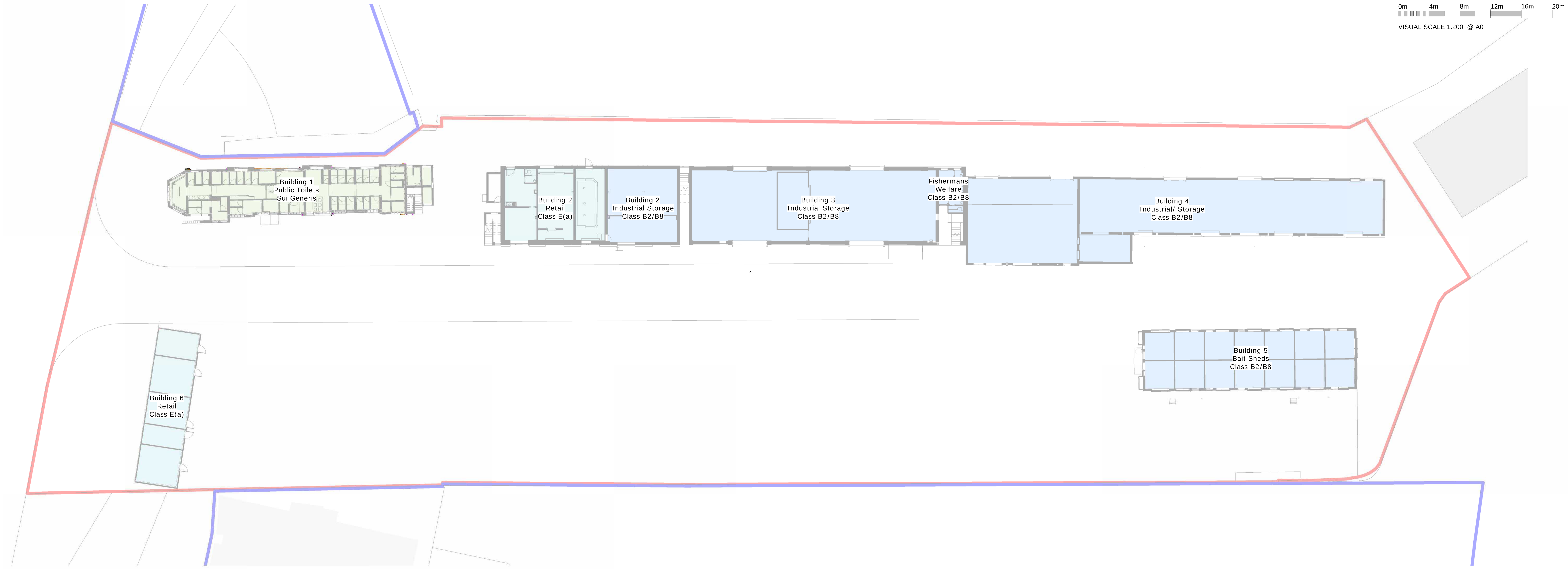
masonclarkassociates
civil and structural engineering consultants

Client.
William Birch & Sons Ltd

Project.
Scarborough West Pier Development

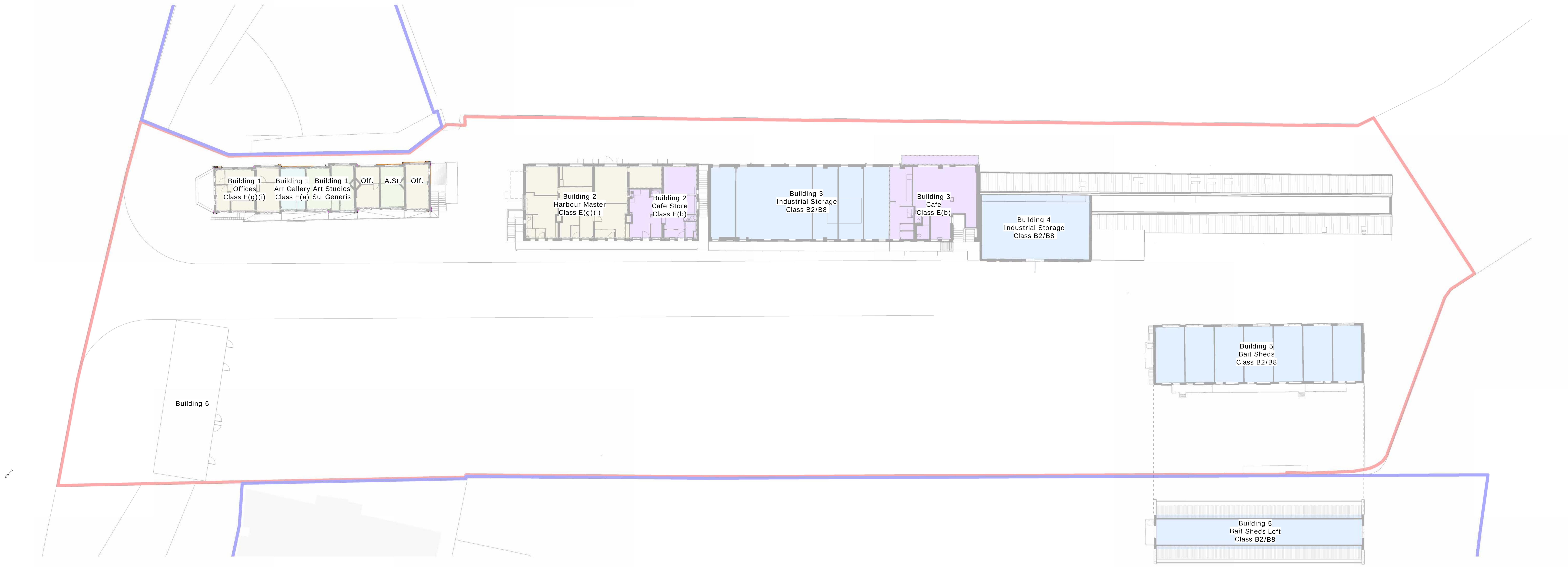
Title.
Existing Site Layout

Drawn: DW	Checked: JF	Date: 18.04.2023
Scale @ A0 : 1:250		
Drawing No : 21037-H-SK-002		Rev: P1



Existing Ground Floor Building Use Class

SCALE: 1 : 200



Existing Upper Floors Building Use Class

SCALE: 1 : 200

Existing Loft Building Class

SCALE: 1 : 200

Notes

Rev	Description	Date	By	Chk
P2	Revised Planning Issue	22/04/24	CA	CA
P1	Planning Issue	05/04/24	DS	DS

52 Princess Street
Rhodesia House
Manchester M1 6JX

Telephone+44(0)161 2375646
Website www.jeffersonsheard.com

Jefferson Sheard Architects

Project

Scarborough Harbour West Pier Redevelopment

Drawing

Building Uses Existing

Scale	Drawn	Date
1 : 200	DS	05/04/24

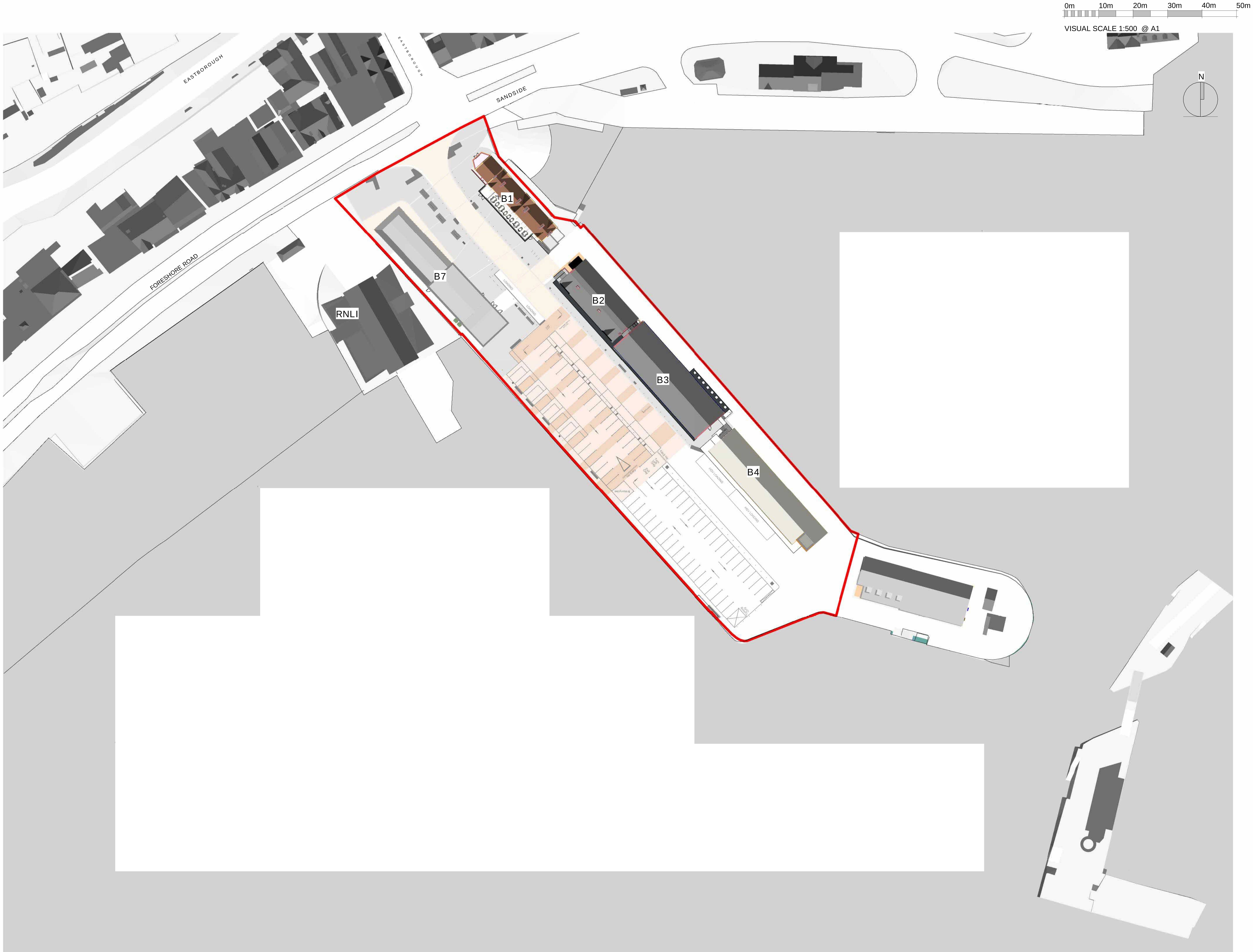
Drawing Purpose	Status
PLANNING	S2

Ref	Rev.
2135-JSA-ZZ-XX-DR-A-99020	P2

A0

APPENDIX B

Proposed Site Plan



Notes

Rev	Description	Date	By	Chk
P6	Planning Issue	30/10/23	DS	CA

52 Princess Street
Rhodesia House
Manchester M1 6JX

Telephone+44(0)161 2375646
Website www.jeffersonsheard.com

Jefferson Sheard Architects

Project

Scarborough Harbour West Pier Regeneration

Drawing

Proposed Site Plan

Scale	Drawn	Date
As indicated	SDH	04/21/23

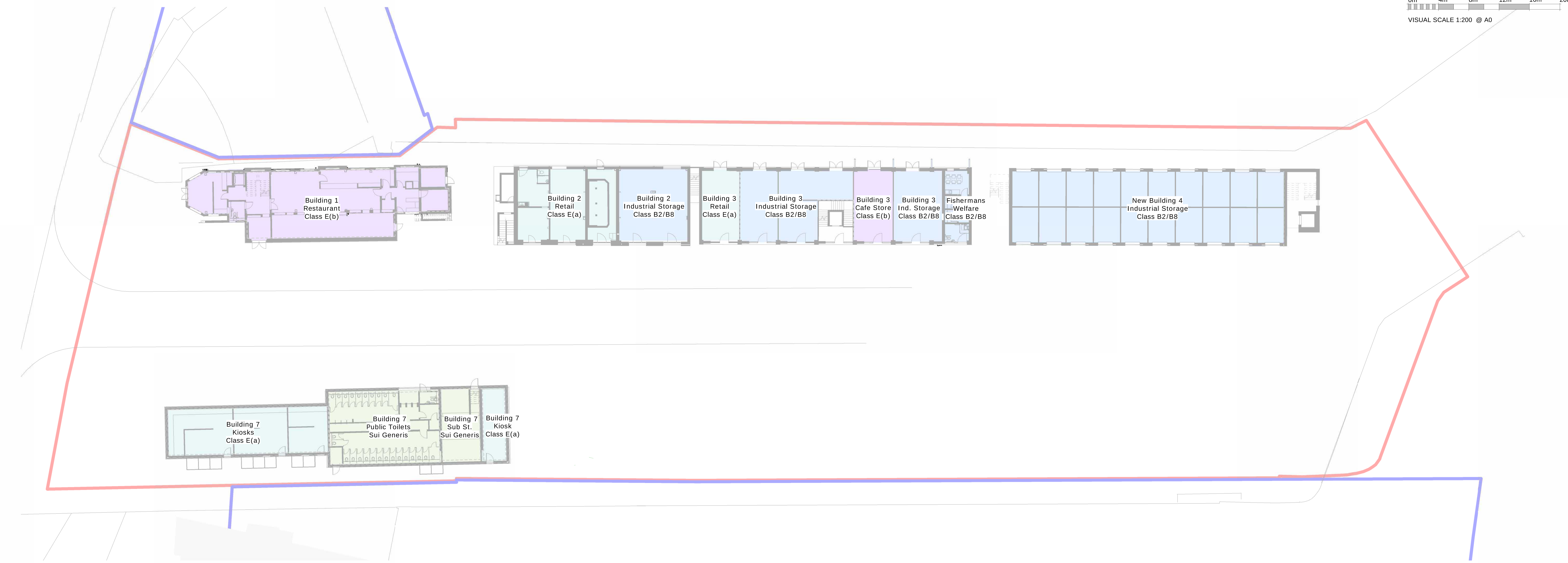
Drawing Purpose	Status
PLANNING	S2

Ref	Rev.
2135-JSA-ZZ-XX-DR-A-90003	P6

A1

0m 4m 8m 12m 16m 20m

VISUAL SCALE 1:200 @ A0

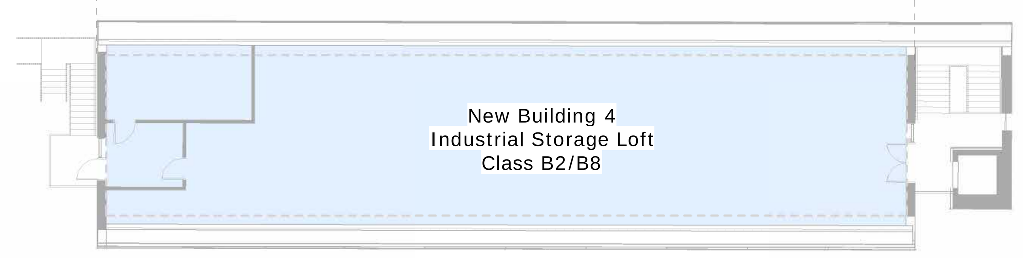


Proposed Ground Floor Building Use Class

SCALE: 1 : 200

Proposed Upper Floors Building Class

SCALE: 1 : 200



Proposed Loft Building Class

SCALE: 1 : 200

A0

Notes

Rev	Description	Date	By	Chk
P2	Revised Planning Issue	22/04/24	CA	CA
P1	Planning Issue	05/04/24	DS	DS

52 Princess Street
Rhodesia House
Manchester M1 6JX

Telephone+44(0)161 2375646
Website www.jeffersonsheard.com

Jefferson Sheard Architects

Project

Scarborough Harbour West Pier Redevelopment

Drawing

Building Uses Proposed

Scale	Drawn	Date
1 : 200	DS	05/04/24

Drawing Purpose	Status
PLANNING	S2

Ref	Rev.
2135-JSA-ZZ-XX-DR-A-99021	P2

APPENDIX C

Intrusive Ground Investigations Records

SOLMEK

12-16 Yarm Road, Stockton on Tees, TS18 3NA
Tel: 01642 607083 Email: info@solmek.com

Figure Title	
Exploratory Hole Location Plan	
Project Number	
S230227	
Project Name	
Scarborough West Pier	
Client	
William Birch and Sons	
Date	
March 2023	
DRG Number	
Figure 2	
Scale	
1:1500	@ A4 [DO NOT SCALE]

Legend Key

- Locations By Type - Empty
- Locations By Type - BH
- Locations By Type - TP
- Project Bounds - Project Bounds

Backfill / Installation	
Legend	

Backfill / Installation		
Legend		

Water Strike	Samples & In Situ Testing			Depth (m)	Level (m)	Legend
	Depth	Type	Results			
				0.25		
				0.60		
				0.80		
				1.20		

Water Strike	Samples & In Situ Testing			Depth (m)	Level (m)	Legend
	Depth	Type	Results			
				0.22		
				0.52		
				0.90		

Water Strike	Samples & In Situ Testing			Depth (m)	Level (m)	Legend
	Depth	Type	Results			
				0.22		
				0.54		
				0.75		
				0.84		

Water Strike	Samples & In Situ Testing			Depth (m)	Level (m)	Legend
	Depth	Type	Results			
				0.20		
				0.57		
				1.20		

Water Strike	Samples & In Situ Testing			Depth (m)	Level (m)	Legend
	Depth	Type	Results			
				0.05 0.10 0.30 0.40 0.63		

Water Strike	Samples & In Situ Testing			Depth (m)	Level (m)	Legend
	Depth	Type	Results			
				0.25		
				0.40		
				1.20		

APPENDIX D

Environment Agency Flood Data

Flood map for planning

Your reference	Location (easting/northing)	Created
<Unspecified>	**504785/488687**	**31 Mar 2023 13:44**

Your selected location is in flood zone 3, an area with a high probability of flooding.

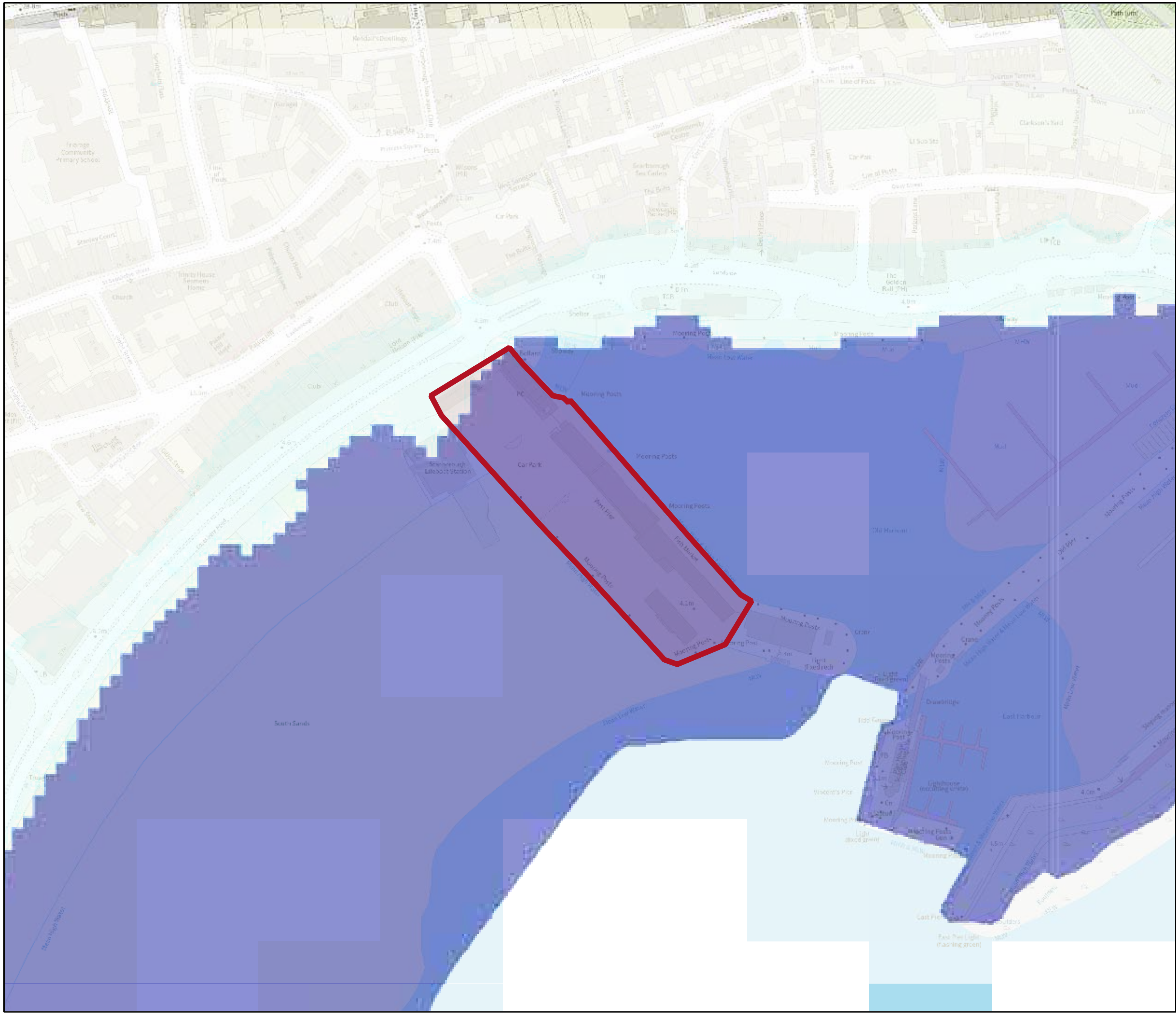
This means:

- you must complete a flood risk assessment for development in this area
- you should follow the Environment Agency's standing advice for carrying out a flood risk assessment (see www.gov.uk/guidance/flood-risk-assessment-standing-advice)

Notes

The flood map for planning shows river and sea flooding data only. It doesn’t include other sources of flooding. It is for use in development planning and flood risk assessments.

This information relates to the selected location and is not specific to any property within it. The map is updated regularly and is correct at the time of printing.



Environment Agency

Flood map for planning

Your reference
<Unspecified>

Location (easting/northing)
504785/488687

Scale
1:2500

Created
31 Mar 2023 13:44

- Selected area
- Flood zone 3
- Flood zone 2
- Flood zone 1
- Flood defence
- Main river
- Water storage area

0 20 40 60m

Flood risk

Extent of flooding

Location

Enter a place or postcode

Extent of flooding from rivers or the sea

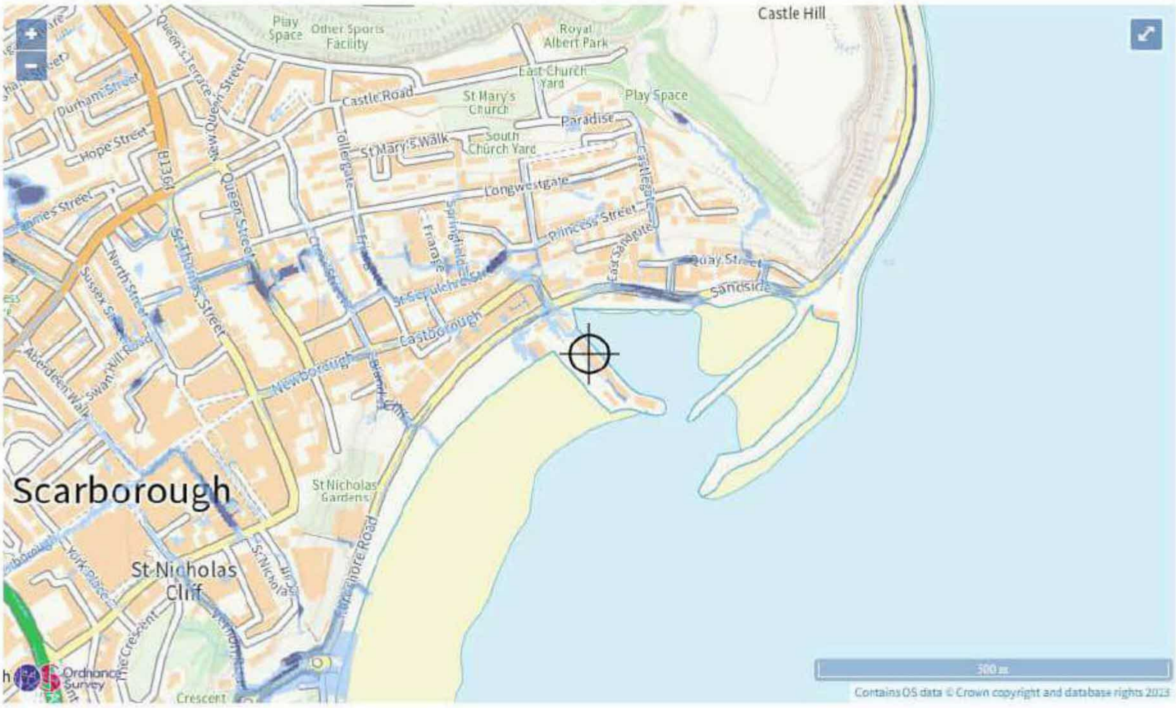
High Medium Low Very low Location you selected

Flood risk

Extent of flooding

Location

Enter a place or postcode



Extent of flooding from surface water

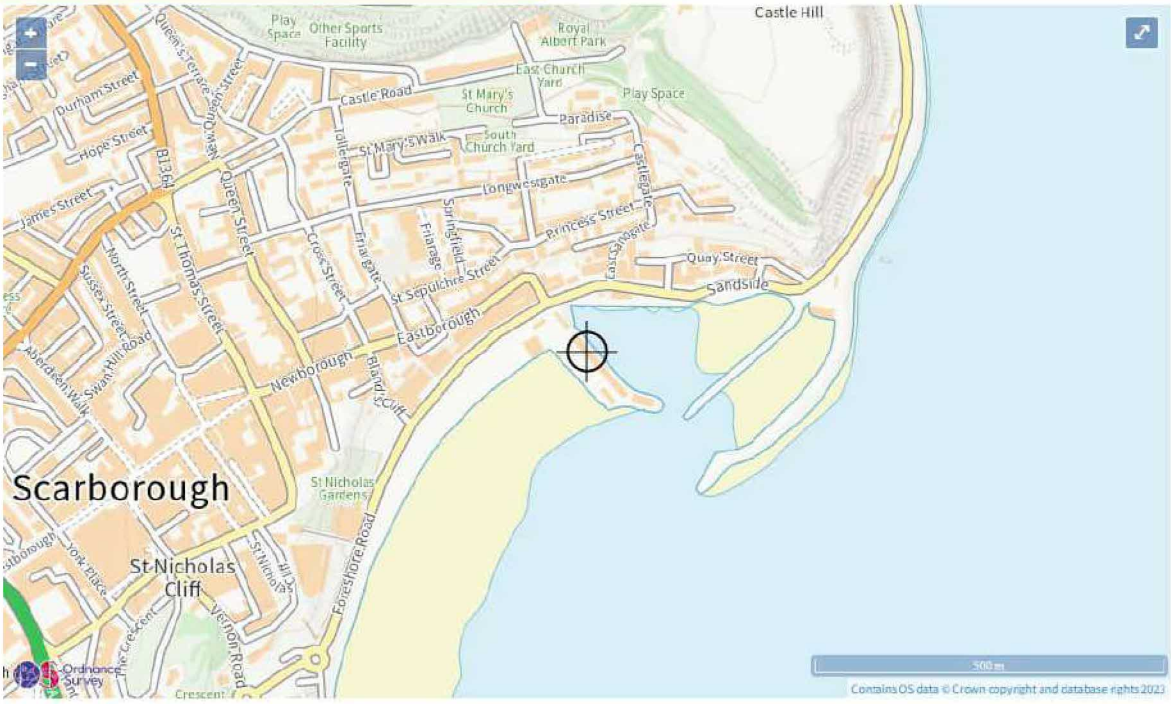
High Medium Low Very low Location you selected

Flood risk

Extent of flooding

Location

Enter a place or postcode



Maximum extent of flooding from reservoirs:

when river levels are normal | when there is also flooding from rivers | Location you selected

Flood risk assessment data

Location of site: 504791 / 488679 (shown as easting and northing coordinates)
Document created on: 24 February 2023
This information was previously known as a product 4.
Customer reference number: FCD7KMAD6B7C

Map showing the location that flood risk assessment data has been requested for.

How to use this information

You can use this information as part of a flood risk assessment for a planning application. To do this, you should include it in the appendix of your flood risk assessment.

We recommend that you work with a flood risk consultant to get your flood risk assessment.

Included in this document

In this document you'll find:

- how to find information about surface water and other sources of flooding
- definitions for the terminology used throughout
- flood map for planning (rivers and the sea)
- historic flooding
- information about strategic flood risk assessments
- information about this data
- information about flood risk activity permits
- help and advice

Not included in this document

This document does not include a Flood Defence Breach Hazard Map.

If your location has a reduced flood risk from rivers and sea because of defences, you need to request a Flood Defence Breach Hazard Map and information about the level of flood protection offered at your location from the Yorkshire Environment Agency team at [redacted]. This information will only be available if modelling has been carried out for breach scenarios.

Include a site location map in your request.

Information that's unavailable

This document **does not** contain:

- flood defences and attributes
- modelled data
- climate change modelled data

We aren't able to display flood defence locations and attributes as there are no formal flood defences in the area of interest.

There is not any modelled data available for this location. This is because detailed modelling hasn't been carried out in this area.

There is not any modelled climate change data for this location. This is because detailed modelling hasn't been carried out in this area. You will need to consider the latest flood risk assessment climate change allowances and factor in the new allowances to demonstrate the development will be safe from flooding.

Surface water and other sources of flooding

Use the long term flood risk service to find out about the risk of flooding from:

- surface water
- ordinary watercourses
- reservoirs

For information about sewer flooding, contact the relevant water company for the area.

Terminology used

Annual exceedance probability (AEP)

This refers to the probability of a flood event occurring in any year. The probability is expressed as a percentage. For example, a large flood which is calculated to have a 1% chance of occuring in any one year, is described as 1% AEP.

Metres above ordnance datum (mAOD)

All flood levels are given in metres above ordnance datum which is defined as the mean sea level at Newlyn, Cornwall.

Flood map for planning (rivers and the sea)

Your selected location is in flood zone 3.

Flood zone 3 shows the area at risk of flooding for an undefended flood event with a:

- 0.5% or greater probability of occurring in any year for flooding from the sea
- 1% or greater probability of occurring in any year for fluvial (river) flooding

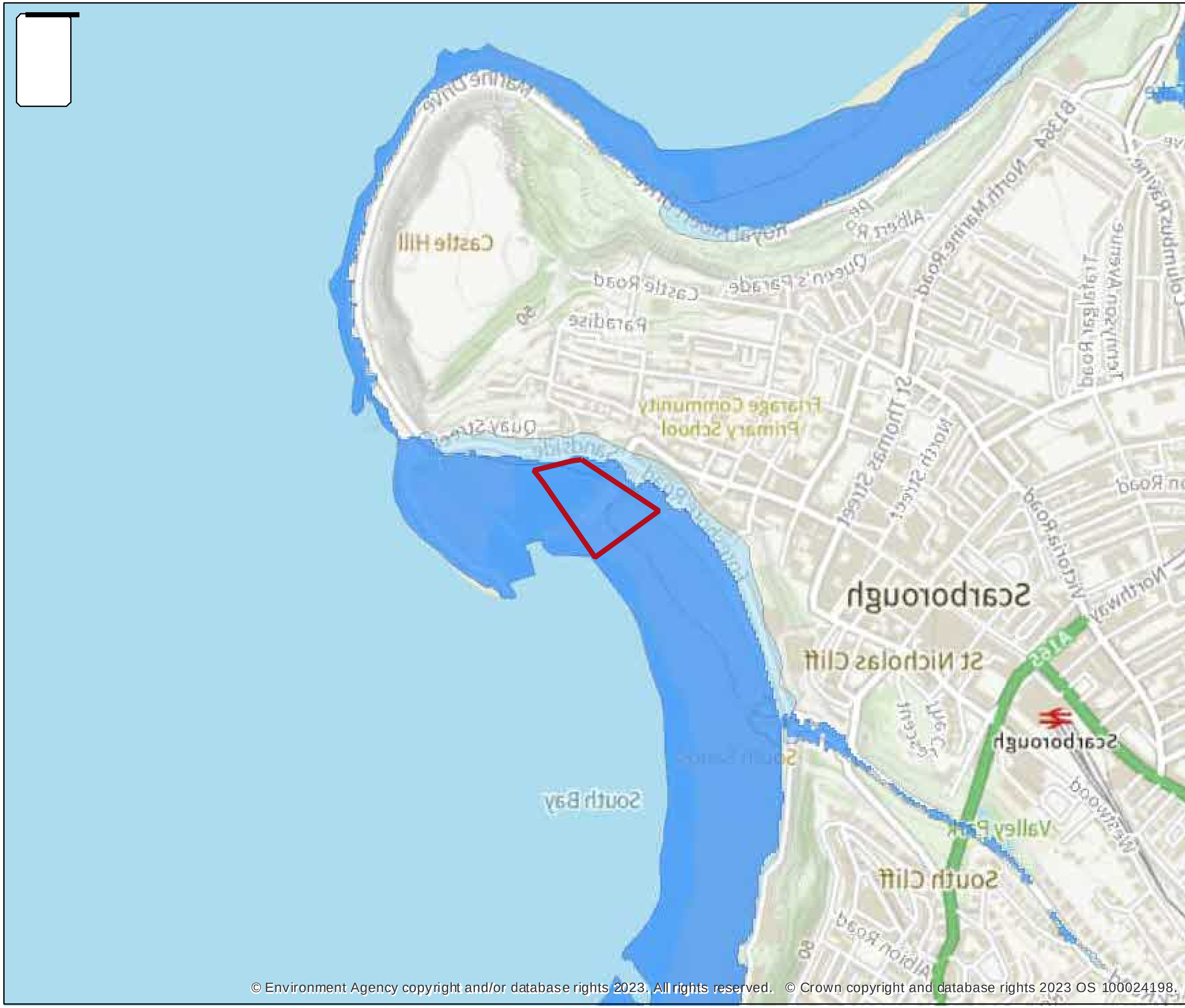
Flood zone 2 shows the area at risk of flooding for an undefended flood event with:

- between a 0.1% and 0.5% probability of occurring in any year for flooding from the sea
- between a 0.1% and 1% probability of occurring in any year for fluvial (river) flooding

It's important to remember that the flood zones on this map:

- refer to the land at risk of flooding and do not refer to individual properties
- refer to the probability of river and sea flooding, ignoring the presence of defences
- do not take into account potential impacts of climate change

This data is updated on a quarterly basis as better data becomes available.



Environment Agency

Flood map for planning

Location (easting/northing)
504791/488679

Scale
1:10,000

Created
24 Feb 2023

- Selected area
- Flood zone 3
- Flood zone 2

0 100 200 300 400 500
metres

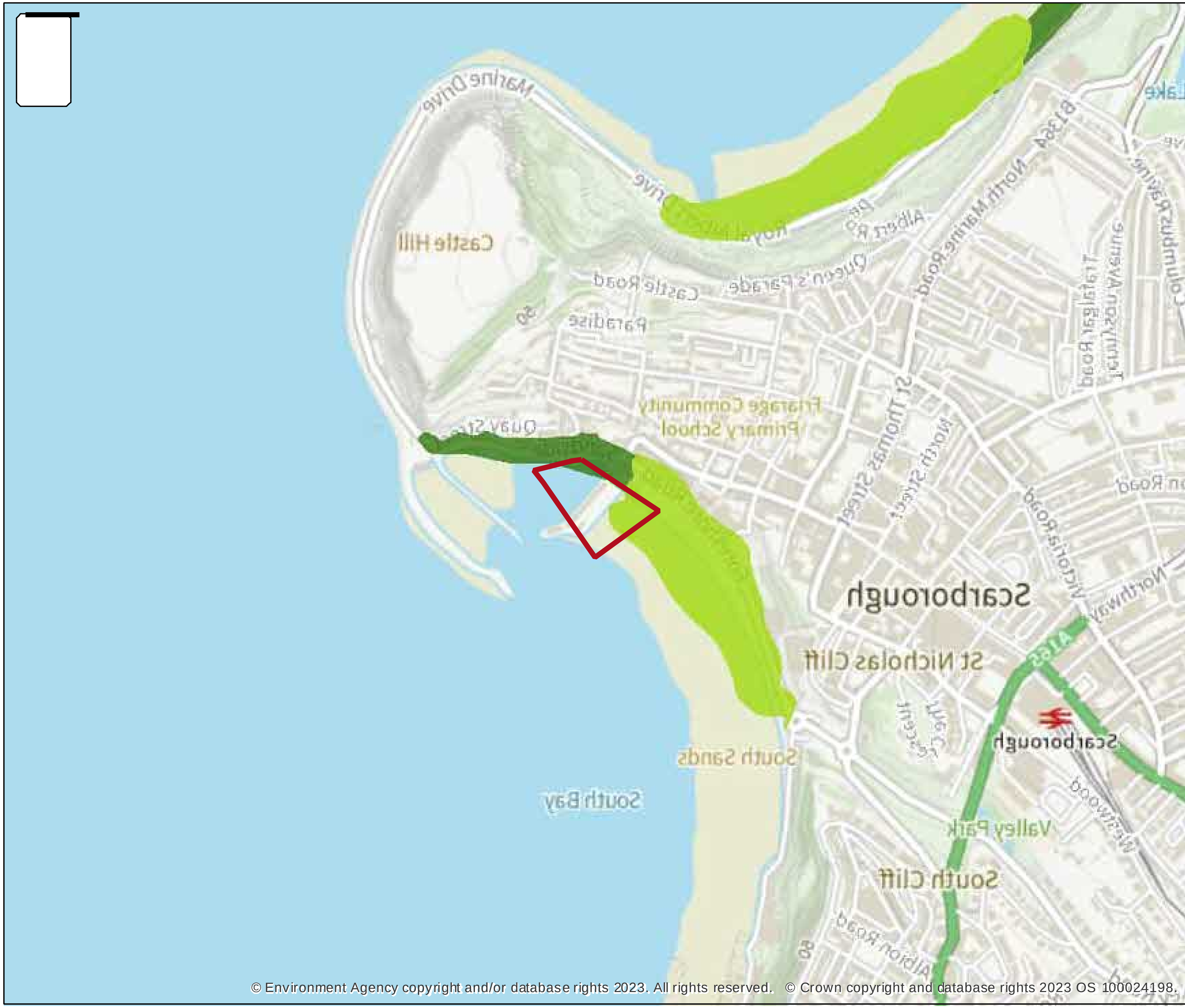
Historic flooding

This map is an indicative outline of areas that have previously flooded. Remember that:

- our records are incomplete, so the information here is based on the best available data
- it is possible not all properties within this area will have flooded
- other flooding may have occurred that we do not have records for
- flooding can come from a range of different sources - we can only supply flood risk data relating to flooding from rivers or the sea

You can also contact your Lead Local Flood Authority or Internal Drainage Board to see if they have other relevant local flood information. Please note that some areas do not have an Internal Drainage Board.

Download recorded flood outlines in GIS format



Environment Agency

Historic flood map

Location (easting/northing)
504791/488679

Scale
1:10,000

Created
24 Feb 2023

Selected area
Main river
Date of flood event
January, 2017
December, 2013

0 100 200 300 400 500
metres

Historic flood event data

Start date	End date	Source of flood	Cause of flood	Affects location
13 January 2017	15 January 2017	sea	other	Yes
5 December 2013	6 December 2013	sea	overtopping of defences	Yes

Strategic flood risk assessments

We recommend that you check the relevant local authority's strategic flood risk assessment (SFRA) as part of your work to prepare a site specific flood risk assessment.

This should give you information about:

- the potential impacts of climate change in this catchment
- areas defined as functional floodplain
- flooding from other sources, such as surface water, ground water and reservoirs

About this data

This data has been generated by strategic scale flood models and is not intended for use at the individual property scale. If you're intending to use this data as part of a flood risk assessment, please include an appropriate modelling tolerance as part of your assessment. The Environment Agency regularly updates its modelling. We recommend that you check the data provided is the most recent, before submitting your flood risk assessment.

Flood risk activity permits

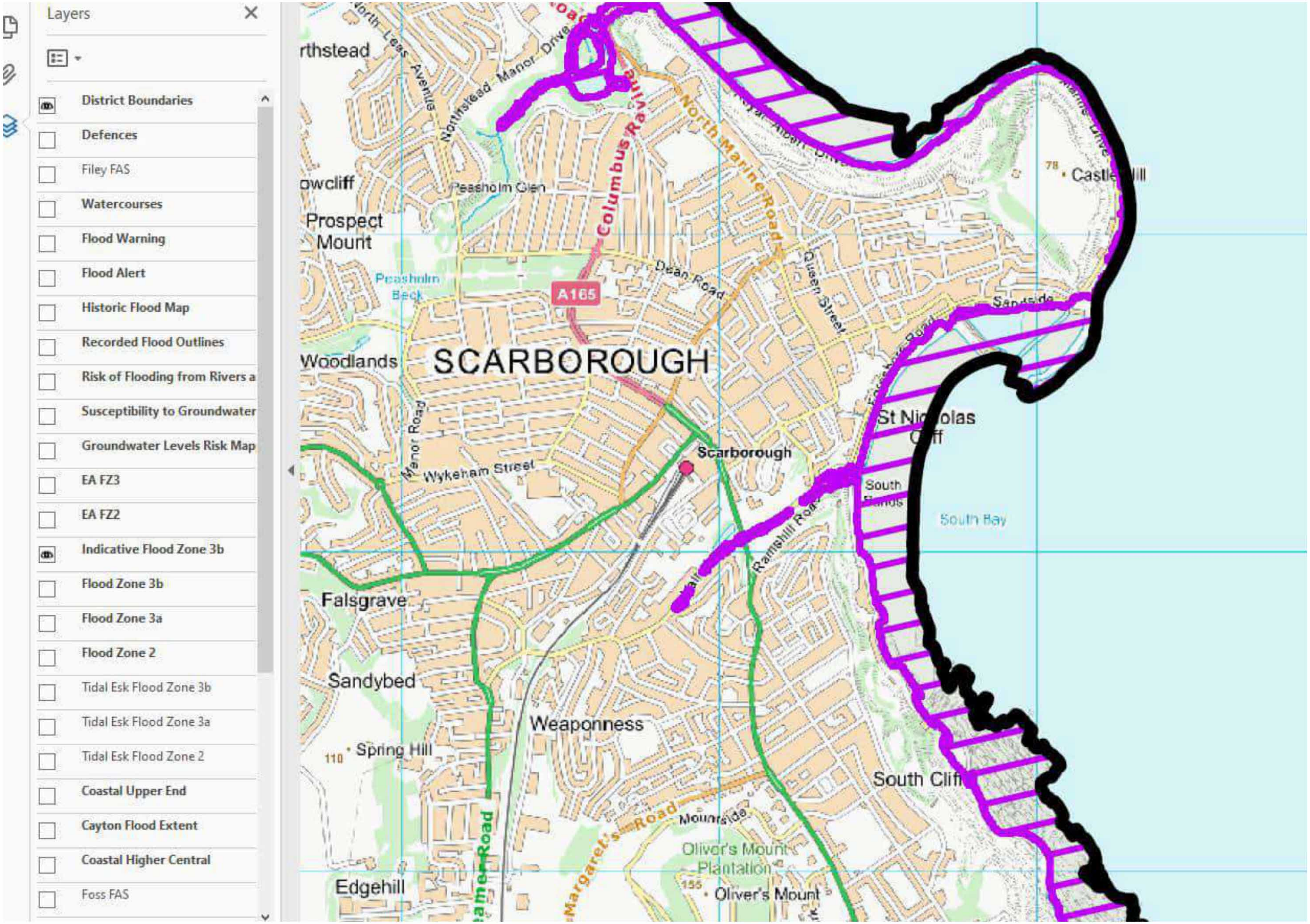
Under the Environmental Permitting (England and Wales) Regulations 2016 some developments may require an environmental permit for flood risk activities from the Environment Agency. This includes any permanent or temporary works that are in, over, under, or nearby a designated main river or flood defence structure.

Find out more about flood risk activity permits

Help and advice

Contact the Yorkshire Environment Agency team at neyorkshire@environment-agency.gov.uk for:

- more information about getting a product 5, 6, 7 or 8
- general help and advice about the site you're requesting data for


Layers
District Boundaries
Defences
Filey FAS
Watercourses
Flood Warning
Flood Alert
Historic Flood Map
Recorded Flood Outlines
Risk of Flooding from Rivers a
Susceptibility to Groundwater
Groundwater Levels Risk Map
EA FZ3
EA FZ2
Indicative Flood Zone 3b
Flood Zone 3b
Flood Zone 3a
Flood Zone 2
Tidal Esk Flood Zone 3b
Tidal Esk Flood Zone 3a
Tidal Esk Flood Zone 2
Coastal Upper End
Cayton Flood Extent
Coastal Higher Central
Foss FAS
SCARBOROUGH
Scarborough
Prospect Mount
Woodlands
Falsgrave
Sandybed
Weaponness
Spring Hill
Edgehill
Peasholm Glen
Peasholm Beck
Columbus Ravine
A165
North Marine Road
Dean Road
Queen Street
Wykeham Street
Manor Road
Ramshill Road
St Nicholas Cliff
South Sands
South Bay
South Cliff
Castle Hill
Northstead Manor Drive
North Leas Avenue
Oliver's Mount Plantation
Oliver's Mount
Mountside
Margaret's Road
Seamer Road
Sandside
110
155
78

APPENDIX E

Extract from Scarborough SFRA Map

A3

Legend

- Main River
- Watercourse at Wheatcroft Cliff
- Reported Main River Flooding
- Reported Ordinary Watercourse Flooding
- Reported Coastal Flooding
- Reported Groundwater Flooding
- Reported Groundwater and Surface Runoff Flooding
- Reported Surface Runoff Flooding
- Reported Sewer Flooding
- Reported Drainage Issues
- Woodlands Beck Estimated 1% Flood Extent
- Flood Zone 2
- Flood Zone 3

NOTES:

1) For indication only

2) The locations of reported flooding incidents are based on information from a variety of sources and the accuracy of reported locations is variable. The reported flood locations shown are only intended to indicate that a reported flood event has occurred within or close to a settlement. This figure should not be relied upon to identify the location within the settlement where a reported event has occurred.

F1	2010-01-13	FH	AM	GF
Issue	Date	By	Chkd	Appd

Metres

0 200 400 800

ARUP

Admiral House
Rose Wharf
78 East Street
Leeds
LS9 8EE

Client

Ryedale District Council, Scarborough Borough Council and North York Moors National Park Authority

Job Title

Northeast Yorkshire Strategic Flood Risk Assessment Update

Drawing Title

Existing Flood Risk Situation in Southern Scarborough

Scale at A3

1:15,000

Drawing Status

For Issue

Job No	Drawing No	Issue
209466-00	**11.2**	**F1**

13/01/2010 17:51:19

\\global\europe\Leeds\Jobs\200000\209466-00\0 Arup\0-12 Water\0-12-20 GIS\Workspaces\NEYorkshire_Maps_2010_v2.mxd

Template A3: Version 2

Mr James Fawcett
Mason Clark Associates
Millshaw Business Living (Unit B) Global Avenue
Leeds
LS11 8PR

Our ref: RA/2023/145716/01-L01
Your ref: N/A

Date: 19 May 2023

Dear James

CHARGED FOR FLOOD RISK ADVICE

SCARBOROUGH WEST PIER

We have reviewed the Scarborough West Pier, Flood Risk Assessment (FRA) and our comments are as follows.

> We note that Scarborough Council have designated the development area as Indicative Flood Zone 3b. This is not something the Environment Agency can change you will need to discuss this with the LPA and challenge the designation / demonstrate that the site is 3a and not 3b. In regard to what has been produced in the FRA we are happy that there is sufficient information to agree that the development can be assessed as being in flood zone 3.
> Section 6.5 - We suggest that you get in touch with the LPA and agree a flood warning and evacuation plan prior to submitting for planning.
> We are happy to accept that the finished floor levels are unable to be altered as long as the flood resilient and flood resistant measures are incorporated into the final designs.
> Section 6.2 Flood Resistant Construction. We are happy with the proposed measures, please have the flood resistant measures incorporated into the design drawings.

Yours sincerely

Mrs Jennifer Dickinson
Planning Advisor

[redacted]

Environment Agency
Lateral 8 City Walk, LEEDS, LS11 9AT.
Customer services line: 03708 506 506
www.gov.uk/environment-agency
End

APPENDIX F

Flood Zone 3B Extents

Version 3.0

Notes

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3. This drawing is to be read in conjunction with all the relevant contract drawings and specifications.
4. All dimensions are in millimetres and all levels are in metres AOD unless noted otherwise.
5. All work shall be carried out in accordance with Local Authority, Statutory Authority and Health & Safety Regulations.
6. Mason Clark Associates are not responsible for determining the appropriate fire period, fire boundary conditions or the associated design of fire protection or inherent fire resistance to any elements of structure, including all frames, posts, beams, joists, roof members and secondary structural elements such as lintels. Refer to the Architect or Project Manager for this information.

Rev	Details	By	Date

Unit E, Millshaw Business Living
Global Avenue, Leeds, LS11 8PR
Tel: +44 (0) 113 277 9542
www.masonclark.co.uk

masonclarkassociates
civil and structural engineering consultants

Client.
William Birch & Sons Ltd

Project.
Scarborough West Pier Development

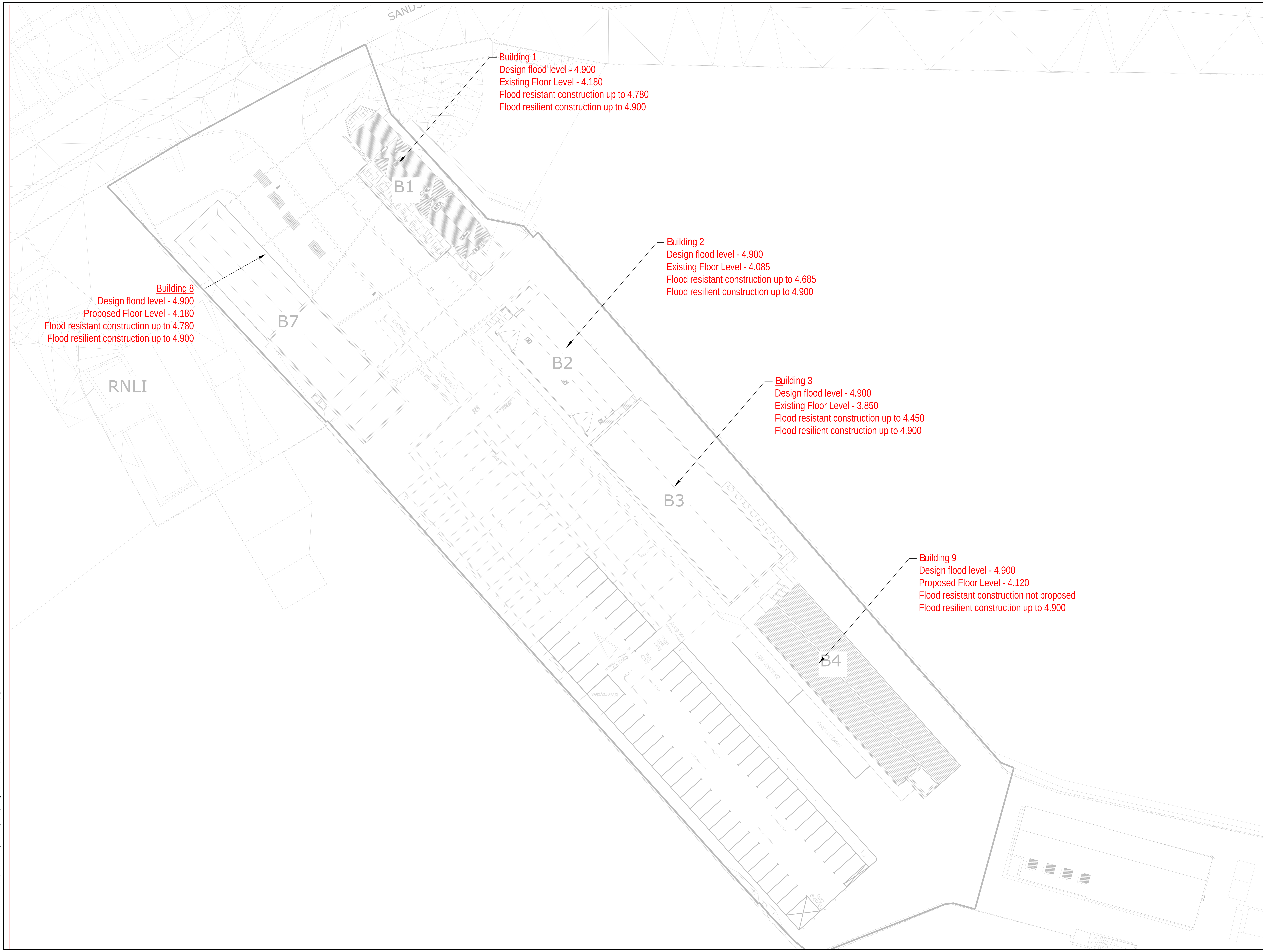
Title.
Flood Zone 3B Extents Around Site Perimeter

Drawn: DW	Checked: JF	Date: 18.04.2023
Scale @ A0 : 1:250		
Drawing No : 21037-H-SK-001		Rev: P1

W:\MCA Jobs\21000-21099\21037H - Scarborough West Pier Development\Drawings\Working Drawings\21037-H-SK-001 - FFlood Zone 3B Extents.dwg

APPENDIX G

Flood Resilient and Flood Resistant Levels



Notes

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2. This drawing is not to be scaled. All dimensions are to be checked on site by the contractor. Any discrepancies are to be notified to Mason Clark Associates. Obtain instructions prior to works commencing.
3. This drawing is to be read in conjunction with the relevant contract drawings and documents, including the NBS specification.
4. All dimensions are in millimetres and all levels are in metres AOD unless noted otherwise.
5. All work shall be carried out in accordance with Local Authority, Statutory Authority and Health & Safety Regulations.

Rev	Details	By	Date
T2	Site Plan Updated	DW	02.11.2023
T1	RIBA 4 Issue	DW	25.07.2023

masonclarkassociates
civil and structural engineering consultants
Unit E, Millshaw Business Living
Global Avenue, Leeds, LS11 8PR
Tel: +44 (0) 113 277 9542
www.masonclark.co.uk

Client.
William Birch & Sons Ltd

Project.
Scarborough West Pier Development

Title.
Flood Resilient and Flood Resistant Design Depths

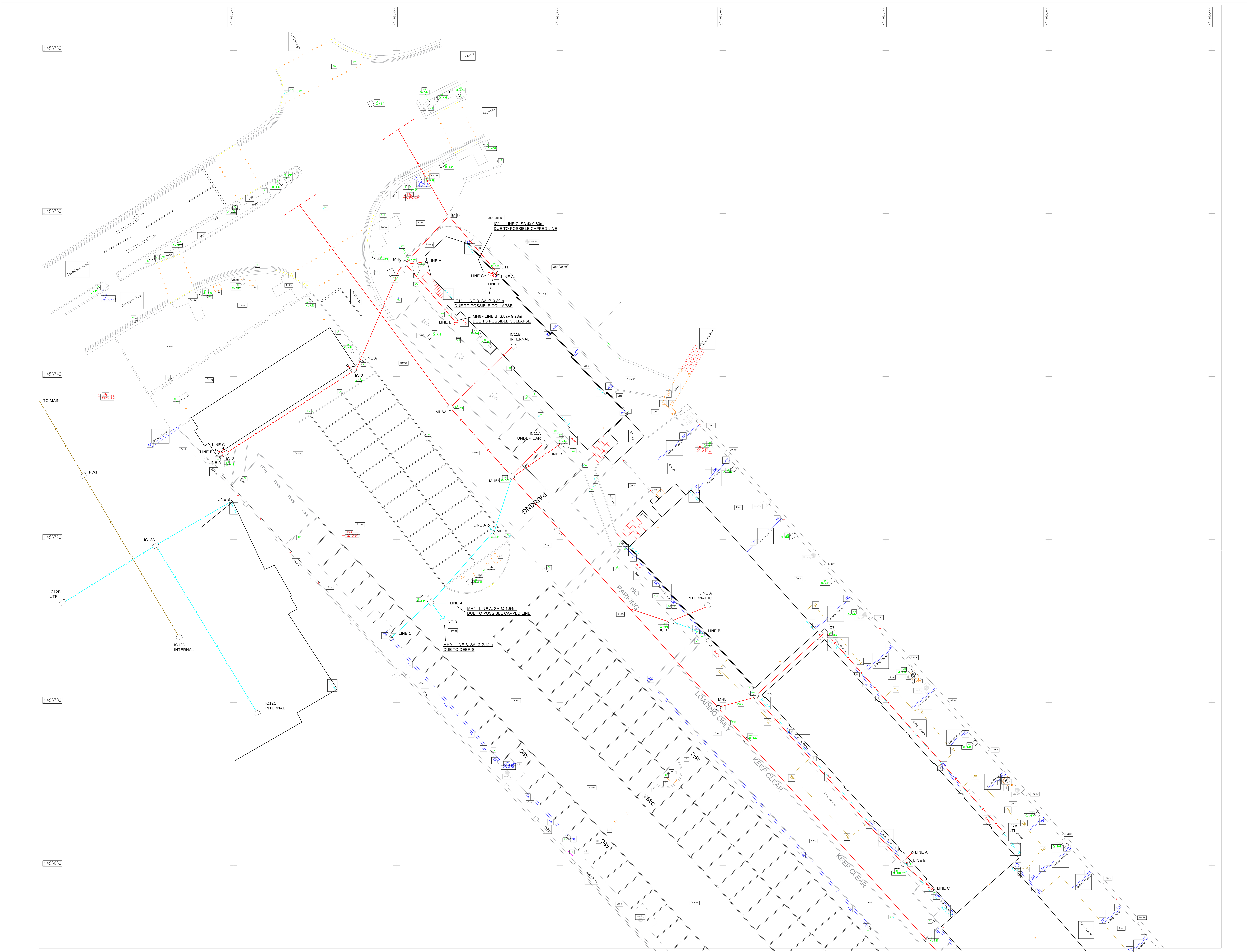
Drawn: DW | Checked: JF | Date: 18.04.2023

Scale @ A0 : 1:200

Drawing No : 21037-H-DR-102 | Rev: T2

APPENDIX H

Existing Drainage Survey



Key:

ACO (Slot Drain)	
Assumed Route	
Combined Water Line	
Foul Water Line	
Surface Water Line	
Trade Effluent Line	
Backdrop	
Capped Line	
Collapse	
Fence	
Gate	
Gully (GY)	
Manhole/IC	
Outfall	
Rodding Eye	
RWP/SVP	
Survey Abandoned	
Trap	

Abbreviations:

ACO	Slot Drain (ACO Channel)
AR	Assumed Route
B1	Branch/Branches (e.g. B1, B2, B3, etc.)
BD	Backdrop
CL	Cover Level
CP	Catch Pit
CW	Combined Water
D	Depth
DH	Drain Head
DT	Dye Tested
EOT	End Of Trace
FGY	Foul Gully
FH	Fire Hydrant
FW	Foul Water
GY	Gully
IC	Inspection Chamber
IL	Invert Level
LH	Lamphole
MH	Manhole
NRV	Non-Return Valve
OF	Outfall
PS	Pump Station
RE	Rodding Eye
RWP	Rain Water Pipe
SA	Survey Abandoned
SK	Soakaway
SVP	Soil Vent Pipe
SW	Surface Water
TFR	Taken From Records
TW	Trade Effluent Water
UTGA	Unable To Gain Access
UTL	Unable To Locate
UTR	Unable To Raise (lift)
UTS	Unable To Survey
UTT	Unable To Trace
VP	Vent Pipe
WM	Water Meter
WO	Wash Out Valve

Disclaimer:

This drawing & layout is for guidance purposes only. The accuracy and location of the drainage system cannot be guaranteed.

JET AIRE SERVICES

Head office: Northways Court, Great North Road, Aberford, Leeds, LS25 3AU
Telephone: 0113 393 5500

North East: Plot 2, Ironmasters Park, Riverside Road, Middlesbrough, TS2 1UT
Telephone: 01642 450983

Email: enquiries@jetaire.co.uk
Web: www.jetaire.co.uk

Client:
Mason Clarke Associates Ltd

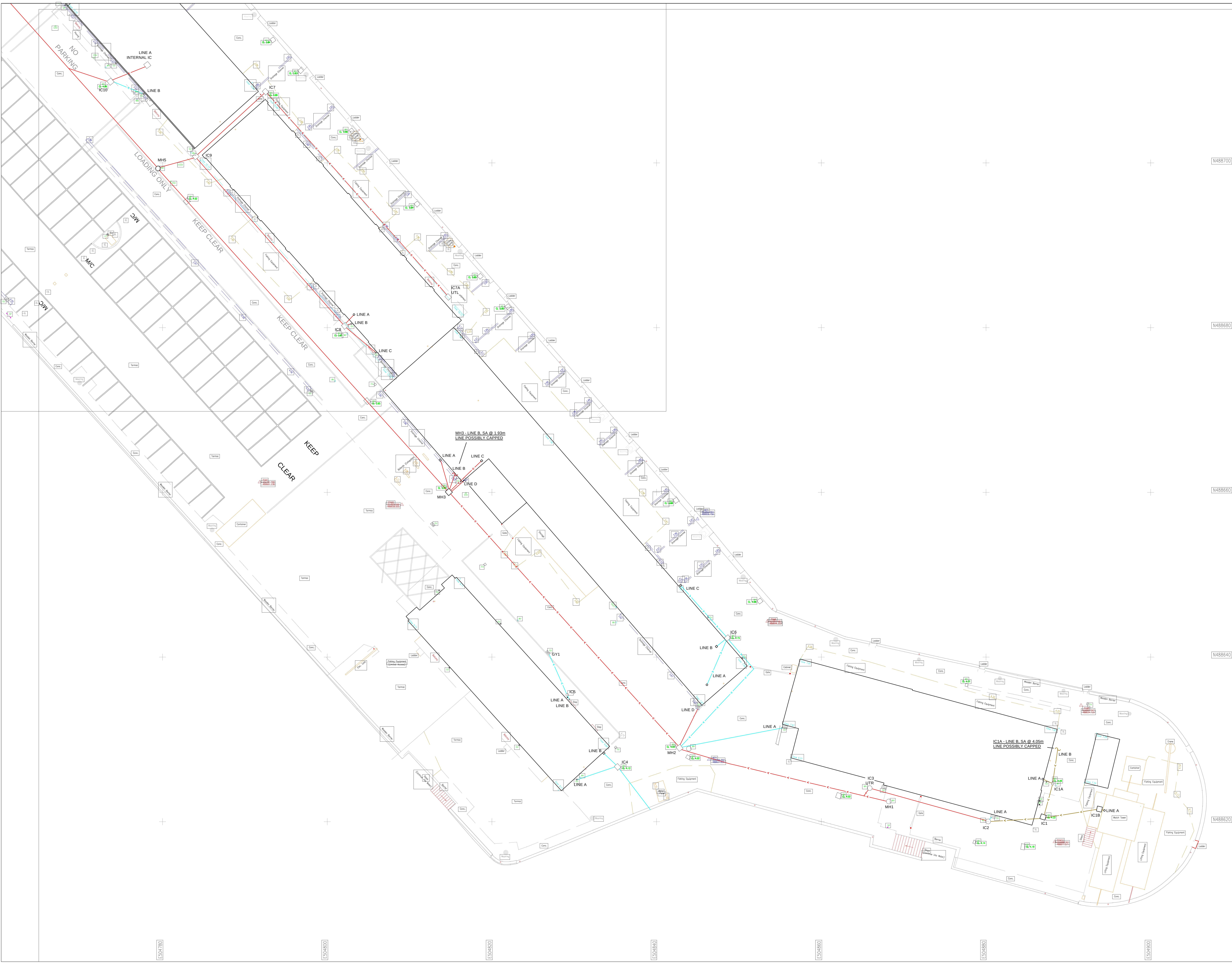
Site:
West Pier
Harbour
Scarborough
Y011 1PD

Project:
GR/16852 CCTV Investigation Survey

Surveyor:	Drawn By:	Originator:
CF	SM	MP

Survey Date: 10/09/2021

Scale:	Sheet Number:
NTS @ A1	1 Of 1



Key:

- ACO (Slot Drain)
- Assumed Route
- Combined Water Line
- Foul Water Line
- Surface Water Line
- Trade Effluent Line
- Backdrop
- Capped Line
- Collapse
- Fence
- Gate
- Gully (GY)
- Manhole/IC
- Outfall
- Rodding Eye
- RWP/SVP
- Survey Abandoned
- Trap

Abbreviations:

ACO	Slot Drain (ACO Channel)
AR	Assumed Route
B1	Branch/Branches (e.g. B1, B2, B3, etc.)
BD	Backdrop
CL	Cover Level
CP	Catch Pit
CW	Combined Water
D	Depth
DH	Drain Head
DT	Dye Tested
EOT	End Of Trace
FGY	Foul Gully
FH	Fire Hydrant
FW	Foul Water
GY	Gully
IC	Inspection Chamber
IL	Invert Level
LH	Lamphole
MH	Manhole
NRV	Non-Return Valve
OF	Outfall
PS	Pump Station
RE	Rodding Eye
RWP	Rain Water Pipe
SA	Survey Abandoned
SK	Soakaway
SVP	Soil Vent Pipe
SW	Surface Water
TFR	Taken From Records
TW	Trade Effluent Water
UTGA	Unable To Gain Access
UTL	Unable To Locate
UTR	Unable To Raise (lift)
UTS	Unable To Survey
UTT	Unable To Trace
VP	Vent Pipe
WM	Water Meter
WO	Wash Out Valve

Disclaimer:

This drawing & layout is for guidance purposes only. The accuracy and location of the drainage system cannot be guaranteed.

JET AIRE SERVICES

Head office: Northways Court, Great North Road, Aberford, Leeds, LS25 3AU
Telephone: 0113 393 5500

North East: Plot 2, Ironmasters Park, Riverside Road, Middlesbrough, TS2 1UT
Telephone: 01642 450983

Email: enquiries@jetaire.co.uk
Web: www.jetaire.co.uk

Client:
Mason Clarke
Associates Ltd

Site:
West Pier
Harbour
Scarborough
YO11 1PD

Project:
GR/16852 CCTV Investigation Survey

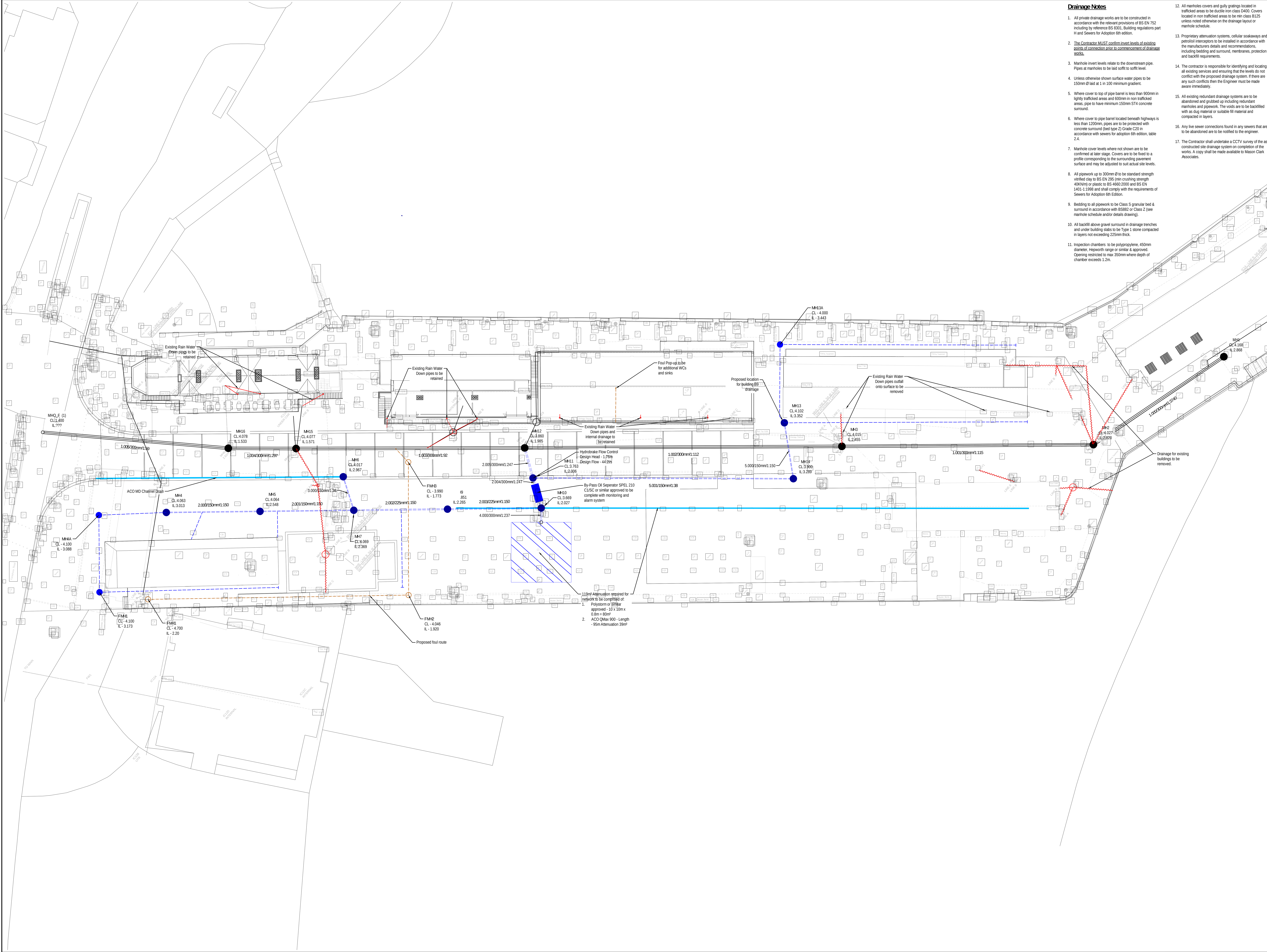
Surveyor:	Drawn By:	Originator:
CF	SM	MP

Survey Date:
10/09/2021

Scale:	Sheet Number:
NTS @ A1	1 Of 1

APPENDIX I

Surface Water Calculations and Drainage Design



Drainage Notes

1. All private drainage works are to be constructed in accordance with the relevant provisions of BS EN 752 including by reference BS 8301, Building regulations part H and Sewers for Adoption 6th edition.
2. The Contractor MUST confirm invert levels of existing points of connection prior to commencement of drainage works.
3. Manhole invert levels relate to the downstream pipe. Pipes at manholes to be laid soffit to soffit level.
4. Unless otherwise shown surface water pipes to be 150mm Ø laid at 1 in 100 minimum gradient.
5. Where cover to top of pipe barrel is less than 900mm in lightly trafficked areas and 600mm in non trafficked areas, pipe to have minimum 150mm ST4 concrete surround.
6. Where cover to pipe barrel located beneath highways is less than 1200mm, pipes are to be protected with concrete surround (bed type Z) Grade C20 in accordance with sewers for adoption 6th edition, table 2.4.
7. Manhole cover levels where not shown are to be confirmed at later stage. Covers are to be fixed to a profile corresponding to the surrounding pavement surface and may be adjusted to suit actual site levels.
8. All pipework up to 300mm Ø to be standard strength vitrified clay to BS EN 295 (min crushing strength 40KN/m) or plastic to BS 4660:2000 and BS EN 1401-1:1998 and shall comply with the requirements of Sewers for Adoption 6th Edition.
9. Bedding to all pipework to be Class S granular bed & surround in accordance with BS882 or Class Z (see manhole schedule and/or details drawing).
10. All backfill above gravel surround in drainage trenches and under building slabs to be Type 1 stone compacted in layers not exceeding 225mm thick.
11. Inspection chambers to be polypropylene, 450mm diameter, Hepworth range or similar & approved. Opening restricted to max 350mm where depth of chamber exceeds 1.2m.
12. All manholes covers and gully gratings located in trafficked areas to be ductile iron class D400. Covers located in non trafficked areas to be min class B125 unless noted otherwise on the drainage layout or manhole schedule.
13. Proprietary attenuation systems, cellular soakaways and petrol/oil interceptors to be installed in accordance with the manufacturers details and recommendations, including bedding and surround, membranes, protection and backfill requirements.
14. The contractor is responsible for identifying and locating all existing services and ensuring that the levels do not conflict with the proposed drainage system. If there are any such conflicts then the Engineer must be made aware immediately.
15. All existing redundant drainage systems are to be abandoned and grubbed up including redundant manholes and pipework. The voids are to be backfilled with as dug material or suitable fill material and compacted in layers.
16. Any live sewer connections found in any sewers that are to be abandoned are to be notified to the engineer.
17. The Contractor shall undertake a CCTV survey of the as constructed site drainage system on completion of the works. A copy shall be made available to Mason Clark Associates.

Notes

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2. This drawing is not to be scaled. All dimensions are to be checked on site by the contractor. Any discrepancies are to be notified to Mason Clark Associates. Obtain instructions prior to works commencing.
3. This drawing is to be read in conjunction with the relevant contract drawings and documents, including the NBS specification.
4. All dimensions are in millimetres and all levels are in metres AOD unless noted otherwise.
5. All work shall be carried out in accordance with Local Authority, Statutory Authority and Health & Safety Regulations.

Health & Safety Information

In addition to the hazards and risks normally associated with the type of works detailed on this drawing, please note the following abnormal risks to Health & Safety.

Refer to Mason Clark Associates project specific Design Risk Assessment (DRA).

Construction Phase	
HAZ-C1	
HAZ-C2	
Maintenance Phase	
HAZ-M1	
HAZ-M2	
Demolition Phase	
HAZ-D1	
HAZ-D2	

It is assumed that all works will be carried out by a competent contractor working where appropriate to an approved method statement

Legend

- Proposed Surface Water Pipework
- Existing Combined Pipework
- Proposed Drainage Channel
- Proposed Foul Drainage
- Existing Drainage to be retained.
- Existing Drainage to be removed
- Proposed Attenuation Tank
- Proposed Surface Water Chamber
- Existing Combined Chamber

Rev	Details	By	Date

masonclarkassociates
civil and structural engineering consultants

Unit E, Millshaw Business Living
Global Avenue, Leeds, LS11 8PR
Tel: +44 (0) 113 277 9542
www.masonclark.co.uk

Client. William Birch & Sons Ltd

Project. Scarborough West Pier Development

Title. Proposed Drainage Design

Drawn: DW	Checked: JF	Date: 23.02.2023
Scale @ A0 : 1:200		
Drawing No : 21037-H-DR-215		Rev: P1

Version 3.0

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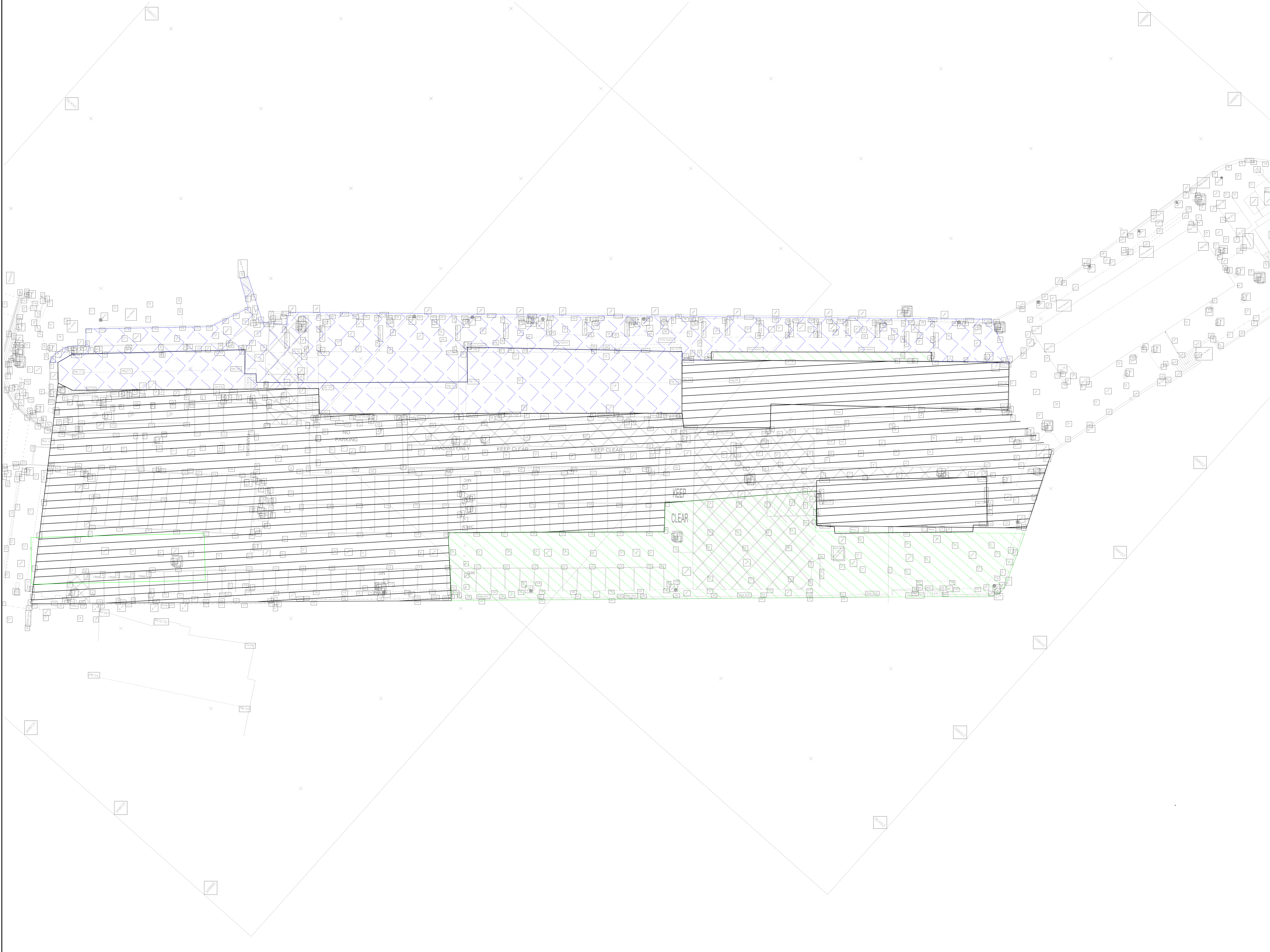

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Construction Phase	
HAZ-C1	
HAZ-C2	
Maintenance Phase	
HAZ-M1	
HAZ-M2	
Demolition Phase	
HAZ-D1	
HAZ-D2	

It is assumed that all works will be carried out by a competent contractor working where appropriate to an approved method statement

Legend

Existing Positively drained area subject to redevelopment	$4507m^2$
Undrained areas subject to redevelopment to be drained into new network	$1583m^2$
Existing buildings and hardstanding drainage to be retained	

Based on the North Yorkshire sustainable drainage systems guidance 2022 - https://www.northyorks.gov.uk/info/sustainable-drainage-systems-guidance-2022-update#Brownfield%20peak%20flow%20control
The proposed design flow shall be restricted to a 30% reduction of the existing Brownfield runoff rate or if this cannot be modelled then 140l/s per hectare.

Rain water down pipes serving the buildings to be refurbished will remain insitu

The existing buildings / hardstanding subject to redevelopment have a an area of 0.4507 ha

Applying a brownfield run-off rate of 140l/s/ha produce an existing brownfield run off rate of 63l/s.

A 30% betterment results in a proposed discharge rate of 144l/s

This shall be achieved by an hydrobrake chamber and attenuation tank.
The attenuation tank shall be $120m^3$ and has been sized for the critical storm which has been modelled as a 60 minute 1 in 100 year +40% climate change.

Rev	Details	By	Date

masonclarkassociates
civil and structural engineering consultants
Unit E, Millshaw Business Living
Global Avenue, Leeds, LS11 8PR
Tel: +44 (0) 113 277 9542
www.masonclark.co.uk

Client.
William Birch & Sons Ltd

Project.
Scarborough West Pier Development

Title.
Proposed Drainage Design Strategy

Drawn: DW	Checked: JF	Date: 23.02.2023
Scale @ A0 : 1:200		
Drawing No : 21037-H-DR-215		Rev: P1

STORM SEWER DESIGN by the Modified Rational Method

Design Criteria for Storm

Pipe Sizes STANDARD Manhole Sizes STANDARD

FSR Rainfall Model - England and Wales

Return Period (years)	5	Foul Sewage (l/s/ha)	0.000	Maximum Backdrop Height (m)	1.500
M5-60 (mm)	19.000	Volumetric Runoff Coeff.	0.750	Min Design Depth for Optimisation (m)	1.200
Ratio R	0.350	PIMP (%)	100	Min Vel for Auto Design only (m/s)	1.00
Maximum Rainfall (mm/hr)	50	Add Flow / Climate Change (%)	0	Min Slope for Optimisation (1:X)	500
Maximum Time of Concentration (mins)	30	Minimum Backdrop Height (m)	0.200		

Designed with Level Soffits

Network Design Table for Storm

« - Indicates pipe capacity < flow

PN	Length (m)	Fall (m)	Slope (1:X)	I.Area (ha)	T.E. (mins)	Base Flow (l/s)	k (mm)	HYD SECT	DIA (mm)	Section Type	Auto Design

Network Results Table

PN	Rain (mm/hr)	T.C. (mins)	US/IL (m)	Σ I.Area (ha)	Σ Base Flow (l/s)	Foul (l/s)	Add Flow (l/s)	Vel (m/s)	Cap (l/s)	Flow (l/s)

Network Design Table for Storm

PN	Length (m)	Fall (m)	Slope (1:X)	I.Area (ha)	T.E. (mins)	Base Flow (l/s)	k (mm)	HYD SECT	DIA (mm)	Section Type	Auto Design
S1.000	26.177	0.007	3739.6	0.000	5.00	0.0	0.600	o	300	Pipe/Conduit	
S1.001	41.884	0.365	114.8	0.000	0.00	0.0	0.600	o	300	Pipe/Conduit	
S1.002	52.812	0.470	112.4	0.018	0.00	0.0	0.600	o	300	Pipe/Conduit	
S2.000	15.605	0.104	150.1	0.040	5.00	0.0	0.600	o	150	Pipe/Conduit	
S2.001	15.605	0.104	150.1	0.000	0.00	0.0	0.600	o	150	Pipe/Conduit	
S3.000	5.851	0.162	36.1	0.093	5.00	0.0	0.600	o	150	Pipe/Conduit	
S2.002	15.605	0.104	150.1	0.000	0.00	0.0	0.600	o	225	Pipe/Conduit	

Network Results Table

PN	Rain (mm/hr)	T.C. (mins)	US/IL (m)	Σ I.Area (ha)	Σ Base Flow (l/s)	Foul (l/s)	Add Flow (l/s)	Vel (m/s)	Cap (l/s)	Flow (l/s)
S1.000	50.00	6.76	2.868	0.000	0.0	0.0	0.0	0.25	17.5	0.0
S1.001	50.00	7.24	2.820	0.000	0.0	0.0	0.0	1.47	103.7	0.0
S1.002	50.00	7.83	2.455	0.018	0.0	0.0	0.0	1.48	104.8	2.5
S2.000	50.00	5.32	3.013	0.040	0.0	0.0	0.0	0.82	14.5	5.4
S2.001	50.00	5.64	2.548	0.040	0.0	0.0	0.0	0.82	14.5	5.4
S3.000	50.00	5.06	2.967	0.093	0.0	0.0	0.0	1.68	29.7	12.5
S2.002	50.00	5.88	2.369	0.133	0.0	0.0	0.0	1.07	42.3	18.0

Network Design Table for Storm

PN	Length (m)	Fall (m)	Slope (1:X)	I.Area (ha)	T.E. (mins)	Base Flow (l/s)	k (mm)	HYD SECT	DIA (mm)	Section Type	Auto Design
S2.003	15.605	0.104	150.1	0.000	0.00	0.0	0.600	o	225	Pipe/Conduit	
S4.000	2.368	0.010	236.8	0.000	5.00	0.0	0.600	o	300	Pipe/Conduit	
S2.004	5.191	0.021	247.2	0.367	0.00	0.0	0.600	o	300	Pipe/Conduit	
S5.000	9.429	0.063	149.7	0.039	5.00	0.0	0.600	o	150	Pipe/Conduit	
S5.001	43.352	1.133	38.3	0.000	0.00	0.0	0.600	o	150	Pipe/Conduit	
S2.005	5.191	0.021	247.2	0.000	0.00	0.0	0.600	o	300	Pipe/Conduit	

Network Results Table

PN	Rain (mm/hr)	T.C. (mins)	US/IL (m)	Σ I.Area (ha)	Σ Base Flow (l/s)	Foul (l/s)	Add Flow (l/s)	Vel (m/s)	Cap (l/s)	Flow (l/s)
S2.003	50.00	6.12	2.265	0.133	0.0	0.0	0.0	1.07	42.3	18.0
S4.000	50.00	5.04	2.037	0.000	0.0	0.0	0.0	1.02	71.9	0.0
S2.004	50.00	6.21	2.027	0.500	0.0	0.0	0.0	1.00	70.4	67.7
S5.000	50.00	5.19	3.352	0.039	0.0	0.0	0.0	0.82	14.5	5.3
S5.001	50.00	5.63	3.289	0.039	0.0	0.0	0.0	1.63	28.8	5.3
S2.005	50.00	6.30	2.006	0.540	0.0	0.0	0.0	1.00	70.4«	73.1

Network Design Table for Storm

PN	Length (m)	Fall (m)	Slope (1:X)	I.Area (ha)	T.E. (mins)	Base Flow (l/s)	k (mm)	HYD SECT	DIA (mm)	Section Type	Auto Design
S6.000	33.011	0.564	58.5	0.000	5.00	0.0	0.600	o	100	Pipe/Conduit	
S6.001	16.062	0.275	58.5	0.000	0.00	0.0	0.600	o	100	Pipe/Conduit	
S1.003	38.066	0.414	91.9	0.000	0.00	0.0	0.600	o	300	Pipe/Conduit	
S1.004	11.275	0.038	296.7	0.000	0.00	0.0	0.600	o	300	Pipe/Conduit	
S1.005	31.022	0.530	58.5	0.000	0.00	0.0	0.600	o	300	Pipe/Conduit	

Network Results Table

PN	Rain (mm/hr)	T.C. (mins)	US/IL (m)	Σ I.Area (ha)	Σ Base Flow (l/s)	Foul (l/s)	Add Flow (l/s)	Vel (m/s)	Cap (l/s)	Flow (l/s)
S6.000	50.00	5.55	2.550	0.000	0.0	0.0	0.0	1.01	7.9	0.0
S6.001	50.00	5.81	1.986	0.000	0.0	0.0	0.0	1.01	7.9	0.0
S1.003	50.00	8.22	1.985	0.558	0.0	0.0	0.0	1.64	115.9	75.5
S1.004	50.00	8.42	1.571	0.558	0.0	0.0	0.0	0.91	64.2«	75.5
S1.005	50.00	8.67	1.533	0.558	0.0	0.0	0.0	2.06	145.5	75.5

Online Controls for Storm

Hydro-Brake® Optimum Manhole: S9, DS/PN: S2.005, Volume (m³): 3.0

Unit Reference	MD-SHE-0270-4420-1760-4420	Sump Available	Yes
Design Head (m)	1.760	Diameter (mm)	270
Design Flow (l/s)	44.2	Invert Level (m)	2.006
Flush-Flo™	Calculated	Minimum Outlet Pipe Diameter (mm)	300
Objective	Minimise upstream storage	Suggested Manhole Diameter (mm)	2100
Application	Surface		

Control Points	Head (m)	Flow (l/s)	Control Points	Head (m)	Flow (l/s)
Design Point (Calculated)	1.760	44.2	Kick-Flo®	1.189	36.6
Flush-Flo™	0.541	44.2	Mean Flow over Head Range	-	37.9

The hydrological calculations have been based on the Head/Discharge relationship for the Hydro-Brake® Optimum as specified. Should another type of control device other than a Hydro-Brake Optimum® be utilised then these storage routing calculations will be invalidated

Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)
0.100	8.6	0.600	44.1	1.600	42.2	2.600	53.3	5.000	73.2	7.500	89.2
0.200	27.7	0.800	43.1	1.800	44.7	3.000	57.2	5.500	76.7	8.000	92.0
0.300	41.7	1.000	41.3	2.000	47.0	3.500	61.6	6.000	80.0	8.500	94.8
0.400	43.5	1.200	36.8	2.200	49.2	4.000	65.7	6.500	83.2	9.000	97.5
0.500	44.1	1.400	39.6	2.400	51.3	4.500	69.6	7.000	86.2	9.500	100.1

Storage Structures for Storm

Tank or Pond Manhole: S7, DS/PN: S4.000

Invert Level (m) 2.037

Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.000	120.0	1.000	120.0	1.001	0.0

1 year Return Period Summary of Critical Results by Maximum Level (Rank 1) for Storm

Simulation Criteria

Areal Reduction Factor 1.000 Manhole Headloss Coeff (Global) 0.500 MADD Factor * 10m³/ha Storage 2.000
Hot Start (mins) 0 Foul Sewage per hectare (l/s) 0.000 Inlet Coeffiecient 0.800
Hot Start Level (mm) 0 Additional Flow - % of Total Flow 0.000 Flow per Person per Day (l/per/day) 0.000

Number of Input Hydrographs 0 Number of Offline Controls 0 Number of Time/Area Diagrams 0
Number of Online Controls 1 Number of Storage Structures 1 Number of Real Time Controls 0

Synthetic Rainfall Details

Rainfall Model FSR M5-60 (mm) 19.000 Cv (Summer) 0.750
Region England and Wales Ratio R 0.350 Cv (Winter) 0.840

Margin for Flood Risk Warning (mm) 0.0 DVD Status OFF
Analysis Timestep 2.5 Second Increment (Extended) Inertia Status OFF
DTS Status ON

Profile(s) Summer and Winter
Duration(s) (mins) 15, 30, 60, 120, 180, 240, 360, 480, 600, 720, 960, 1440, 2160, 2880, 4320, 5760, 7200, 8640, 10080
Return Period(s) (years) 1, 30, 100
Climate Change (%) 0, 0, 40

PN	US/MH Name	Storm	Return Period	Climate Change	First (X) Surcharge	First (Y) Flood	First (Z) Overflow	Overflow Act.	Water Level (m)	Surcharged Depth (m)	Flooded Volume (m³)	Flow / Cap.	Overflow (l/s)	Half Drain Time (mins)	Pipe Flow (l/s)
S1.000	S1	15 Summer	1	+0%					2.868	-0.300	0.000	0.00			0.0

1 year Return Period Summary of Critical Results by Maximum Level (Rank 1) for Storm

PN	US/MH Name	Status	Level Exceeded
S1.000	S1	OK	

1 year Return Period Summary of Critical Results by Maximum Level (Rank 1) for Storm

PN	US/MH Name	Storm	Return Period	Climate Change	First (X) Surcharge	First (Y) Flood	First (Z) Overflow	Overflow Act.	Water Level (m)	Surcharged Depth (m)	Flooded Volume (m³)	Flow / Cap.	Overflow (l/s)	Half Drain Time (mins)
S1.001	S2	15 Summer	1	+0%					2.820	-0.300	0.000	0.00		
S1.002	S3	15 Winter	1	+0%					2.483	-0.272	0.000	0.02		
S2.000	S4	15 Winter	1	+0%	100/15 Summer				3.077	-0.086	0.000	0.37		
S2.001	S5	15 Winter	1	+0%	30/15 Summer				2.612	-0.086	0.000	0.38		
S3.000	S5	15 Winter	1	+0%	30/15 Summer	100/15 Winter			3.040	-0.077	0.000	0.47		
S2.002	S6	15 Winter	1	+0%	30/15 Summer				2.474	-0.120	0.000	0.44		
S2.003	S8	15 Winter	1	+0%	30/15 Summer				2.369	-0.121	0.000	0.44		
S4.000	S7	60 Winter	1	+0%	30/15 Summer				2.198	-0.139	0.000	0.12		
S2.004	S8	15 Winter	1	+0%	30/15 Summer				2.271	-0.056	0.000	0.40		
S5.000	S13	15 Winter	1	+0%	100/15 Summer				3.417	-0.085	0.000	0.38		
S5.001	S13	15 Winter	1	+0%	100/15 Summer				3.332	-0.107	0.000	0.18		
S2.005	S9	15 Winter	1	+0%	30/15 Summer				2.263	-0.043	0.000	0.50		
S6.000	S10	15 Summer	1	+0%					2.550	-0.100	0.000	0.00		
S6.001	S11	15 Winter	1	+0%	30/15 Summer				2.081	-0.004	0.000	0.02		
S1.003	S12	15 Winter	1	+0%					2.084	-0.201	0.000	0.24		
S1.004	S13	15 Winter	1	+0%					1.719	-0.152	0.000	0.49		
S1.005	S14	15 Winter	1	+0%					1.621	-0.212	0.000	0.19		

PN	US/MH Name	Pipe Flow (l/s)	Status	Level Exceeded
S1.001	S2	0.0	OK	
S1.002	S3	1.9	OK	

1 year Return Period Summary of Critical Results by Maximum Level (Rank 1) for Storm

PN	US/MH Name	Pipe Flow (l/s)	Status	Level Exceeded
S2.000	S4	5.0	OK	
S2.001	S5	5.0	OK	
S3.000	S5	11.6	OK	
S2.002	S6	16.6	OK	
S2.003	S8	16.4	OK	
S4.000	S7	7.2	OK*	
S2.004	S8	18.8	OK	
S5.000	S13	4.9	OK	
S5.001	S13	4.9	OK	
S2.005	S9	23.6	OK	
S6.000	S10	0.0	OK	
S6.001	S11	0.2	OK	
S1.003	S12	25.2	OK	
S1.004	S13	25.3	OK	
S1.005	S14	25.0	OK	

30 year Return Period Summary of Critical Results by Maximum Level (Rank 1) for Storm

Simulation Criteria

Areal Reduction Factor 1.000 Manhole Headloss Coeff (Global) 0.500 MADD Factor * 10m³/ha Storage 2.000
Hot Start (mins) 0 Foul Sewage per hectare (l/s) 0.000 Inlet Coeffiecient 0.800
Hot Start Level (mm) 0 Additional Flow - % of Total Flow 0.000 Flow per Person per Day (l/per/day) 0.000

Number of Input Hydrographs 0 Number of Offline Controls 0 Number of Time/Area Diagrams 0
Number of Online Controls 1 Number of Storage Structures 1 Number of Real Time Controls 0

Synthetic Rainfall Details

Rainfall Model FSR M5-60 (mm) 19.000 Cv (Summer) 0.750
Region England and Wales Ratio R 0.350 Cv (Winter) 0.840

Margin for Flood Risk Warning (mm) 0.0 DVD Status OFF
Analysis Timestep 2.5 Second Increment (Extended) Inertia Status OFF
DTS Status ON

Profile(s) Summer and Winter
Duration(s) (mins) 15, 30, 60, 120, 180, 240, 360, 480, 600, 720, 960, 1440, 2160, 2880, 4320, 5760, 7200, 8640, 10080
Return Period(s) (years) 1, 30, 100
Climate Change (%) 0, 0, 40

PN	US/MH Name	Storm	Return Period	Climate Change	First (X) Surcharge	First (Y) Flood	First (Z) Overflow	Overflow Act.	Water Level (m)	Surcharged Depth (m)	Flooded Volume (m³)	Flow / Cap.	Overflow (l/s)	Half Drain Time (mins)	Pipe Flow (l/s)
S1.000	S1	15 Summer	30	+0%					2.868	-0.300	0.000	0.00			0.0

30 year Return Period Summary of Critical Results by Maximum Level (Rank 1) for Storm

PN	US/MH Name	Status	Level Exceeded
S1.000	S1	OK	

30 year Return Period Summary of Critical Results by Maximum Level (Rank 1) for Storm

PN	US/MH Name	Storm	Return Period	Climate Change	First (X) Surcharge	First (Y) Flood	First (Z) Overflow	Overflow Act.	Water Level (m)	Surcharged Depth (m)	Flooded Volume (m³)	Flow / Cap.	Overflow (l/s)	Half Drain Time (mins)
S1.001	S2	15 Summer	30	+0%					2.820	-0.300	0.000	0.00		
S1.002	S3	15 Winter	30	+0%					2.503	-0.252	0.000	0.06		
S2.000	S4	15 Winter	30	+0%	100/15 Summer				3.127	-0.036	0.000	0.91		
S2.001	S5	15 Winter	30	+0%	30/15 Summer				2.835	0.137	0.000	0.93		
S3.000	S5	15 Winter	30	+0%	30/15 Summer	100/15 Winter			3.161	0.044	0.000	1.13		
S2.002	S6	15 Winter	30	+0%	30/15 Summer				2.750	0.156	0.000	1.08		
S2.003	S8	15 Winter	30	+0%	30/15 Summer				2.647	0.157	0.000	1.11		
S4.000	S7	60 Winter	30	+0%	30/15 Summer				2.465	0.128	0.000	0.38		
S2.004	S8	15 Winter	30	+0%	30/15 Summer				2.556	0.229	0.000	0.74		
S5.000	S13	15 Winter	30	+0%	100/15 Summer				3.469	-0.033	0.000	0.94		
S5.001	S13	15 Winter	30	+0%	100/15 Summer				3.358	-0.081	0.000	0.43		
S2.005	S9	15 Winter	30	+0%	30/15 Summer				2.543	0.237	0.000	0.92		
S6.000	S10	15 Summer	30	+0%					2.550	-0.100	0.000	0.00		
S6.001	S11	15 Winter	30	+0%	30/15 Summer				2.126	0.041	0.000	0.02		
S1.003	S12	15 Winter	30	+0%					2.127	-0.158	0.000	0.46		
S1.004	S13	15 Winter	30	+0%					1.803	-0.068	0.000	0.95		
S1.005	S14	15 Winter	30	+0%					1.659	-0.174	0.000	0.37		

PN	US/MH Name	Pipe Flow (l/s)	Status	Level Exceeded
S1.001	S2	0.0	OK	
S1.002	S3	5.9	OK	

30 year Return Period Summary of Critical Results by Maximum Level (Rank 1) for Storm

PN	US/MH Name	Pipe Flow (l/s)	Status	Level Exceeded
S2.000	S4	12.2	OK	
S2.001	S5	12.5	SURCHARGED	
S3.000	S5	28.0	SURCHARGED	
S2.002	S6	40.4	SURCHARGED	
S2.003	S8	41.4	SURCHARGED	
S4.000	S7	23.1	SURCHARGED*	
S2.004	S8	35.1	SURCHARGED	
S5.000	S13	12.0	OK	
S5.001	S13	12.1	OK	
S2.005	S9	43.2	SURCHARGED	
S6.000	S10	0.0	OK	
S6.001	S11	0.2	SURCHARGED	
S1.003	S12	49.0	OK	
S1.004	S13	48.7	OK	
S1.005	S14	48.8	OK	

100 year Return Period Summary of Critical Results by Maximum Level (Rank 1) for Storm

Simulation Criteria

Areal Reduction Factor 1.000 Manhole Headloss Coeff (Global) 0.500 MADD Factor * 10m³/ha Storage 2.000
Hot Start (mins) 0 Foul Sewage per hectare (l/s) 0.000 Inlet Coeffiecient 0.800
Hot Start Level (mm) 0 Additional Flow - % of Total Flow 0.000 Flow per Person per Day (l/per/day) 0.000

Number of Input Hydrographs 0 Number of Offline Controls 0 Number of Time/Area Diagrams 0
Number of Online Controls 1 Number of Storage Structures 1 Number of Real Time Controls 0

Synthetic Rainfall Details

Rainfall Model FSR M5-60 (mm) 19.000 Cv (Summer) 0.750
Region England and Wales Ratio R 0.350 Cv (Winter) 0.840

Margin for Flood Risk Warning (mm) 0.0 DVD Status OFF
Analysis Timestep 2.5 Second Increment (Extended) Inertia Status OFF
DTS Status ON

Profile(s) Summer and Winter
Duration(s) (mins) 15, 30, 60, 120, 180, 240, 360, 480, 600, 720, 960, 1440, 2160, 2880, 4320, 5760, 7200, 8640, 10080
Return Period(s) (years) 1, 30, 100
Climate Change (%) 0, 0, 40

PN	US/MH Name	Storm	Return Period	Climate Change	First (X) Surcharge	First (Y) Flood	First (Z) Overflow	Overflow Act.	Water Level (m)	Surcharged Depth (m)	Flooded Volume (m³)	Flow / Cap.	Overflow (l/s)	Half Drain Time (mins)	Pipe Flow (l/s)
S1.000	S1	15 Summer	100	+40%					2.868	-0.300	0.000	0.00			0.0

100 year Return Period Summary of Critical Results by Maximum Level (Rank 1) for Storm

PN	US/MH Name	Status	Level Exceeded
S1.000	S1	OK	

100 year Return Period Summary of Critical Results by Maximum Level (Rank 1) for Storm

PN	US/MH Name	Storm	Return Period	Climate Change	First (X) Surcharge	First (Y) Flood	First (Z) Overflow	Overflow Act.	Water Level (m)	Surcharged Depth (m)	Flooded Volume (m³)	Flow / Cap.	Overflow (l/s)	Half Drain Time (mins)
S1.001	S2	15 Summer	100	+40%					2.820	-0.300	0.000	0.00		
S1.002	S3	15 Winter	100	+40%					2.521	-0.234	0.000	0.11		
S2.000	S4	15 Winter	100	+40%	100/15 Summer				3.859	0.696	0.000	1.21		
S2.001	S5	15 Winter	100	+40%	30/15 Summer				3.690	0.992	0.000	1.34		
S3.000	S5	15 Winter	100	+40%	30/15 Summer	100/15 Winter			4.016	0.899	0.007	1.69		
S2.002	S6	15 Winter	100	+40%	30/15 Summer				3.547	0.953	0.000	1.58		
S2.003	S8	15 Winter	100	+40%	30/15 Summer				3.344	0.854	0.000	1.60		
S4.000	S7	60 Winter	100	+40%	30/15 Summer				3.038	0.701	0.000	0.70		
S2.004	S8	60 Winter	100	+40%	30/15 Summer				3.176	0.849	0.000	0.94		
S5.000	S13	15 Winter	100	+40%	100/15 Summer				3.733	0.231	0.000	1.53		
S5.001	S13	15 Winter	100	+40%	100/15 Summer				3.597	0.158	0.000	0.70		
S2.005	S9	60 Winter	100	+40%	30/15 Summer				3.160	0.854	0.000	0.94		
S6.000	S10	15 Summer	100	+40%					2.550	-0.100	0.000	0.00		
S6.001	S11	15 Winter	100	+40%	30/15 Summer				2.135	0.050	0.000	0.01		
S1.003	S12	15 Summer	100	+40%					2.136	-0.149	0.000	0.50		
S1.004	S13	15 Winter	100	+40%					1.871	0.000	0.000	1.01		
S1.005	S14	15 Summer	100	+40%					1.664	-0.169	0.000	0.39		

PN	US/MH Name	Pipe Flow (l/s)	Status	Level Exceeded
S1.001	S2	0.0	OK	
S1.002	S3	10.7	OK	

100 year Return Period Summary of Critical Results by Maximum Level (Rank 1) for Storm

PN	US/MH Name	Pipe Flow (l/s)	Status	Level Exceeded
S2.000	S4	16.2	SURCHARGED	
S2.001	S5	17.9	SURCHARGED	
S3.000	S5	41.7	FLOOD	
S2.002	S6	58.9	SURCHARGED	
S2.003	S8	59.9	SURCHARGED	
S4.000	S7	43.1	SURCHARGED*	
S2.004	S8	44.5	SURCHARGED	
S5.000	S13	19.6	SURCHARGED	
S5.001	S13	19.7	SURCHARGED	
S2.005	S9	44.1	SURCHARGED	
S6.000	S10	0.0	OK	
S6.001	S11	0.1	SURCHARGED	
S1.003	S12	54.1	OK	
S1.004	S13	51.7	OK	
S1.005	S14	51.8	OK	

APPENDIX J

Foul Calculations

Job No.	Calc Sheet	Rev	Date	Calcs by
21037-H	6-1	R0	27/04/2023	DW

Project	Scarborough West Pier
Element	Foul Drainge Discharge

masonclarkassociates
civil and stuctural engineering consultants

Ref	Calculations	Output

Number Number Units

Foul Discharge has been calculated as per BSEN 12056-2 gravity drainge systems inside buildings

Using Table 3 Typical Frequency Factors the buildings have been given the following frequency factors

Building 1 is a restaurant therefore k= 0.7
Building 2 has shops and workspaces therefore k= 0.5
Building 3 has shops, café, and workspaces therefore k= 0.7
Building 7 is a toilet open to the public therefore k=1.0
Building 4 has shops and workspaces therefore k=0.5

The average k value is 0.64 which has been used to establish the impact on the foul system.

Job No.	Calc Sheet	Rev	Date	Calcs by
21037-H	6-11	R0	27/04/2023	DW

masonclarkassociates
civil and stuctural engineering consultants

Project	Scarborough West Pier
Element	Foul Drainage Allowance

Ref	Calculations				Output
	Flow Rate Equation	$Q_w \, _w = K \sqrt{\quad D}$			
Building 1	Appliance	Number	Discharge Unit	Σ Discharge Unit	
	WC with 7.5l cistern	5	2	10	
k = 0.7	Wash Basin	6	0.5	3	
	Kitchen Sink	3	0.8	2.4	
	Single urinal	2	0.8	1.6	
			Total	17	
				Flow Rate	2.8861739
Building 2	Appliance	Number	Discharge Unit	Σ Discharge Unit	
	WC with 7.5l cistern	2	2	4	
k = 0.5	Wash Basin	2	0.5	1	
	Kitchen Sink	4	0.8	3.2	
			Total	8.2	
				Flow Rate	1.4317821
Building 3	Appliance	Number	Discharge Unit	Σ Discharge Unit	
	WC with 7.5l cistern	7	2	14	
k = 0.7	Wash Basin	8	0.5	4	
	Kitchen Sink	3	0.8	2.4	
			Total	20.4	
				Flow Rate	3.1616451
Building 7	Appliance	Number	Discharge Unit	Σ Discharge Unit	
	WC with 7.5l cistern	26	2	52	
k = 1	Wash Basin	18	0.5	9	
	Kitchen Sink	8	0.8	6.4	
	Single urinal	4	0.8	3.2	
			Total	70.6	
				Flow Rate	8.4023806
Building 4	Appliance	Number	Discharge Unit	Σ Discharge Unit	
	WC with 7.5l cistern	0	2	0	
k = 0.5	Wash Basin	0	0.5	0	
	Kitchen Sink	3	0.8	2.4	
			Total	2.4	
				Flow Rate	0.7745967

Total Impact on existing Combined Sewer

k = 0.68 Flow Rate = 7.41 l/s

APPENDIX K

Sequential Test

Proposed regeneration of Scarborough West Pier – Flood Risk Sequential Test

Introduction

Paragraph 162 of the National Planning Policy Framework (NPPF) states that the aim of the sequential test is *"to steer new development to areas with the lowest risk of flooding from any source. Development should not be allocated or permitted if there are reasonably available sites appropriate for the proposed development in areas with a lower risk of flooding"*.

As set out in the Flood Risk Assessment, the site is located in Flood Zone 3a so has a high probability of flooding i.e. land having a 1% or greater annual probability of river flooding or land having a 0.5% or greater annual probability of sea flooding. Therefore, the sequential test needs to be undertaken to compare reasonably available sites within low (Flood Zone 1) and medium risk areas (Flood Zone 2).

Paragraph 024 (Reference ID: 7-024020220825) of Planning Practice Guidance states that for individual planning applications subject to the Sequential Test, the area to apply the test will be defined by local circumstances relating to the catchment area for the type of development proposed. Furthermore "Reasonably available sites are those in a suitable location for the type of development with a reasonable prospect that the site is available to be developed at the point in time envisaged for the development. These could include a series of smaller sites and/or part of a larger site if these would be capable of accommodating the proposed development. Such lower-risk sites do not need to be owned by the applicant to be considered reasonably available."

Methodology

A meeting was held with the Daniel Metcalf (Area Planning Manager – Scarborough and Whitby) and Matthew Lickes (Senior Planning Policy Officer) from North Yorkshire Council (NYC) on Wednesday 5th July to discuss the scope of the sequential test. The test focussed on the proposed car park (Sui Generis) and the new floor space associated with those uses identified as less vulnerable in Annex 3 (Flood risk vulnerability classification) of the NPPF. This includes:

- The four retail units in Building 7 (Use Class E (a)); and
- The restaurant in Building 1 (Use Class E (b)).

Both of those uses could reasonably be provided in the Town Centre as defined in the Scarborough Borough Local Plan (adopted 2017) and therefore, the land between the Site and the western extent of the Town Centre was used as the area of search. For the car park it was acknowledged that this served the users of the Pier, wider Harbour and South Beach and to the area of search was restricted to within a 5 minutes' walk of the Site.

The identification of potential sites and premises involved the following three tasks:

- Review of the information held by NYC on vacant ground floor units in the Town Centre. This is compiled on a quarterly basis;
- Site visit to identify vacant units within the area of search that are being actively marketed and can therefore be identified as 'reasonably available'; and
- Use of aerial imagery e.g. Google Earth, to identify potential vacant sites to accommodate a car park. This was restricted to previously developed land within 5 minutes' walk of West Pier, the wider harbour and South Beach.

The size of the uses under consideration is as follows:

Building 1	Restaurant	469 square metres (m²)
Building 7	Kiosk 1 (retail)	51m²
	Kiosk 2 (retail)	43m²
	Kiosk 3 (retail)	32m²
	Kiosk 5 (retail)	27m²
Car park	1,273m²	

Results

No suitable alternative sites were identified for the car park within the area of search.

For the retail uses associated with the proposed, potential alternative sites were identified as follows:

Use	Location	Available Floorspace (m²)	Flood zone	Comments
Kiosk 1	Newborough, YO11 1NA	52m²	1	- Ground floor unit - Located in Town Centre - Existing lawful Use Class E - Advertised via : https://www.cphproperty.co.uk/commercial-lettings/property/1740-newborough-town-scarborough
Kiosk 3	53 Dean Road YO12 7SN	41m²	1	- Advertised via Ellis Hay - Ground floor unit - Edge of Town Centre - Lawful Use Class E

Kiosks combined as part of a new build	Windmill site, Foreshore Road	159m²	2	- Owned by NYC and vacant for a number of years - Planning application submitted to provide shower and lockers for beach users and to accommodate the hire of water sports equipment – decision pending

For the restaurant there are vacant premises in the area of search, but these are much larger. For example, there is a vacant unit on Chapman's Yard which is currently being marketed for 1,325m² of Use Class E but this is considered to be unsuitable as the proposed restaurant is 469m². No other premises are deemed suitable.

Conclusion

The sequential test has revealed that for some of the proposed uses there are suitable reasonably available sites in areas that have a lower risk of flooding. Therefore, in the context of the NPPF and Planning Practice Guidance it can be concluded the sequential test has been failed and that consideration therefore needs to be given to the wider the benefits of the proposed development as part of the planning balance exercise. There is nothing within the Development Plan or those documents that constitute a material consideration such as the NPPF, which states that a planning application should automatically be refused if the sequential test has been failed. Therefore, it is for the applicant to put forward the case for the Proposed Development and to explain its wider benefits. This is addressed in Sections 5 and 6 of the Planning Statement, which forms part of the planning application package.

APPENDIX L

Scarborough West Pier Table

North Yorkshire Council
Detailed Site Summary Table

Site details

Address	Scarborough West Pier, YO11 1PD
Area	~7,500m^2
Current land use	Brownfield
Proposed land use	Commercial

Sources of flood risk

Location of the site within the catchment	West Pier is located at the northern end of Scarborough South Bay and acts as a coastal breakwater for Scarborough Harbour. The site is located on the North East coast of England, south of the Tees and north of the Humber. It is situated under the Castle Headland in the sheltered South Bay. The site is primarily at risk from coastal flood sources as well as surface water risks.
Topography	The West Pier topography typically ranges between 3.80m to 4.30mAODN.
Existing drainage features	Unknown. Evidence of surface water drainage pipes (Figure 1-1) in locations where a raised lip is from ground level back to sea. While in other areas there is no raised lip, such as West pier Car Park, where the slope of the topography allows for drainage straight back seaward.  Figure 1-1: Drainage pipes
Coastal	1. Environment Agency Flood Map for Planning The proposed development site is almost entirely located in Flood Zone 3 on the Environment Agency Flood Map for Planning (Figure 1-2). There are no formal flood defences acknowledged. Flood Zone 3 means the site is classified as having a high probability of flooding. This means in any year land has a 0.5% or more chance of flooding from the sea.

Figure 1-2: Environment Agency Flood Map for Planning – Flood Zones

2. Extreme water level flood risk

To investigate flood risk to the site from extreme water levels, a projection model was undertaken using the latest coastal extreme water levels, sea level rise guidance, and site specific topograpahy. The following datasets were used:

- Extreme sea levels from the Coastal Flood Boundary Dataset (CFBD) using chainage point _3752
- Sea Level Rise estimates using the United Kingdom Climate Projections 2018 (UKCP18) guidance using Representation Concentration Pathway (RCP) 8.5 and the Higher Central (70th percentile) emmissions scenario.
- Environment Agency Digitial Terrain Model 1m LIDAR dataset

The analysis was undertaken using a 3.3%, 0.5% and 0.1% Annual Exceedance Probability (AEP) event. The CFBD extreme sea levels were uplifted from a 2017 base year to present day (2024 epoch) and a 75-year future climate change (2099 epoch) scenario. A 75-year design life was considered as the proposed development is considered to be commercial and not residential. The National Planning Policy Framework (NPPF) states that the lifetime of a non-residential development depends on the characteristics of that development but a period of at least 75-years is likely to form a starting point for assessment. The UKCP18 RCP 8.5 Higher Central uplifts are detailed in Table 1-1 and the uplifted water levels detailed in Table 1-2.

Table 1-1: UKCP18 Sea level rise uplift values

Year	Uplift (m)
2017 to 2024	0.04
2017 to 2099	0.73

Table 1-2: Uplifted extreme water levels

Annual Exceedance Probability Event (%)	2017 epoch (mAOD)	2024 epoch (mAOD)	2099 epoch (mAOD)
3.3	3.87	3.91	4.61
0.5	4.17	4.21	4.90
0.1	4.44	4.48	5.17

Figures of the projection modelling are provided seperately to this document. The mapped results for the 0.5% AEP event for the 2024 epoch (which relates to Flood Zone 3) and 2099 (75-year design life) epoch are displayed on Figure 1-3 and 1-4 respectively. The results show that during a 0.5% AEP present day extreme water level event a large portion of the site would be inundated (~80% of site area). Flood depths are typically less than 0.15m across the site although there are some areas where flood depths reach nearly 0.50m. Figure 1-3 shows that the entire site would be inundated during a 0.5% AEP event under climate change conditions in the 2099 epoch. Flood depths are significant, with most of the site inundated to depths greater than 0.50m and in some areas flood depths reach over 1.00m.

The 3.3% AEP event in 2024 (broadly equivalent to Flood Zone 3b, classed as functional flood plain) is shown on Figure 1-5. The site is largely flood free and raised above the functional Flood Zone 3b, with some small flood depths shown at the lowest ground elevations across the site on the eastern side. Flood depths are small, almost all being less than 0.10m, and this is likely to be conservative in extent due to the filtering of the DTM to remove existing buildings which has extended the lowest levels towards the centre of West Pier. It is likely that with a more realistic ground model any flood risk posed by the 3.3% AEP extreme water level would be just lapping over the eastern edge of West Pier in a few places.

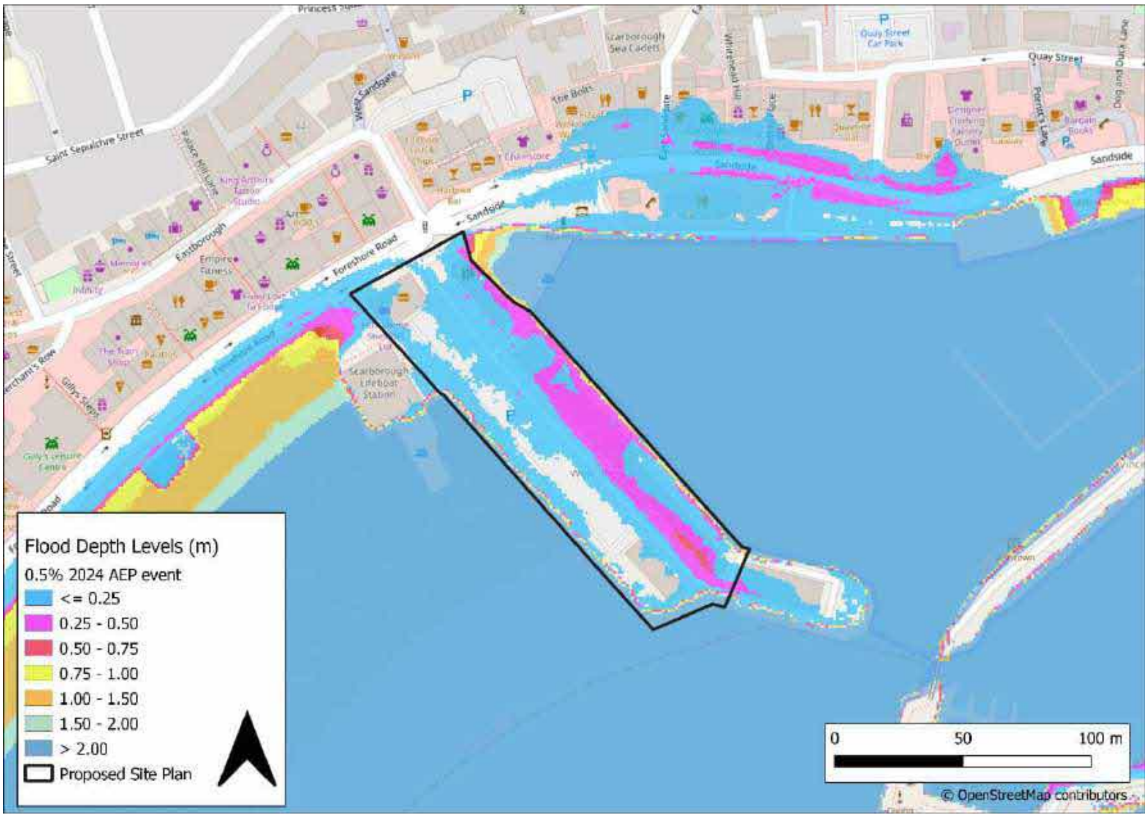


Figure 1-3: 0.5% AEP event 2024 epoch – Flood depths

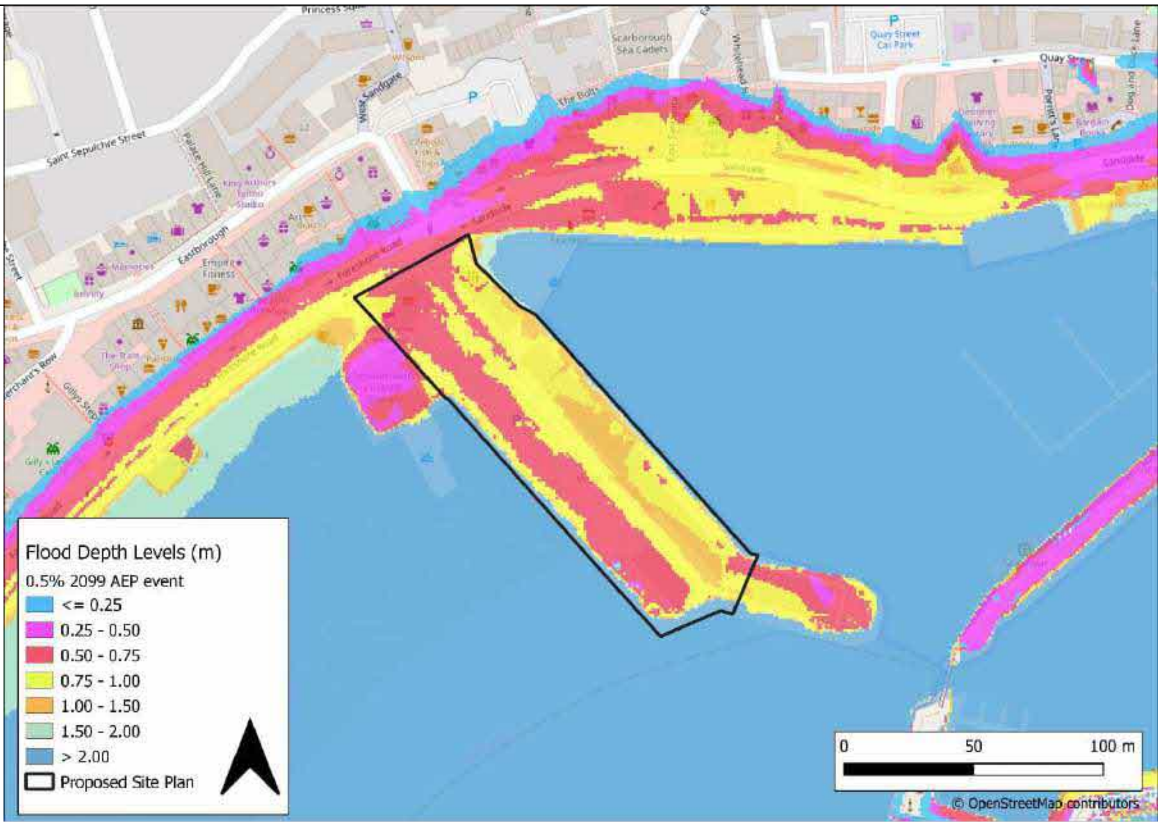


Figure 1-4: 0.5% AEP event 2099 epoch – Flood depths

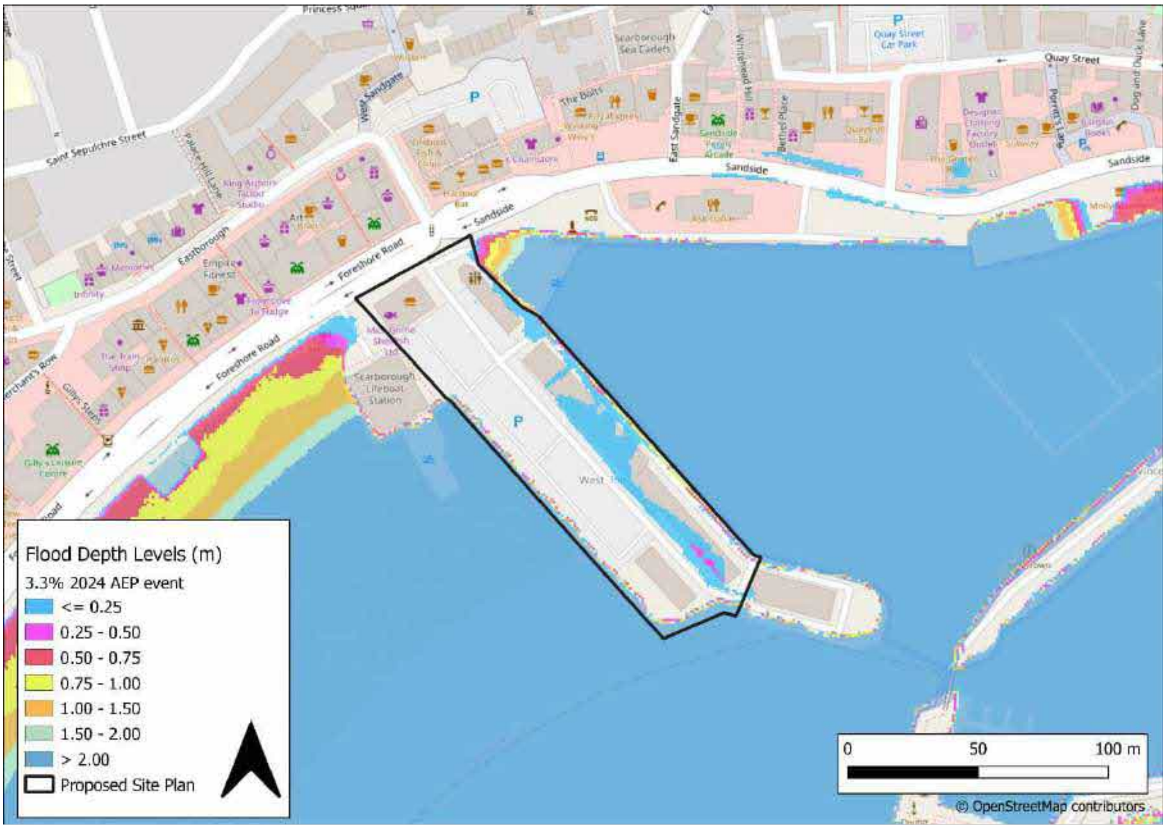


Figure 1-5: 3.3% AEP event 2024 epoch – Flood depths

3. Wave action flood risk considerations

While extreme water levels are one of the main drivers of flood inundation in coastal areas, a significant proportion of flooding, especially along the open coast, can be attributed to the overtopping of defences from wave action (Figure 1-6). West Pier is sheltered by Castle Hill and the eastern breakwater arms of Scarborough Harbour, although it remains exposed to southerly and south easterly winds. Therefore the threat of wave action from the North Sea, in combination with extreme water levels, is an important flood risk factor and has been known to impact Scarborough seafront regularly during large storm events.

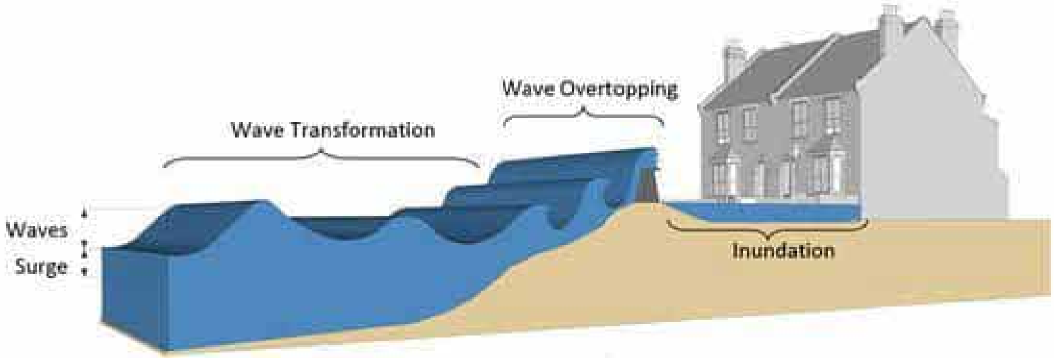


Figure 1-6: Components of sea level variation that combine to cause coastal flooding

Evidence of both extreme water levels and wave action have historically impacted Scarborough, although no specific mention of West Pier being inundated is mentioned. During the December 5th 2013 coastal storm (left image on Figure 1-7) extreme water levels were exacerbated by wave action leading to the inundation of Foreshore Road along the seafront, where commercial properties were impacted. Simlar recent wave and water level impacts were seen along Foreshore Road during storm events on March 1st 2018 and January 13th 2017. During an event on March 9th 2009 wave overtopping was seen impacting Royal Albert Drive on North Bay with large waves passing over the defence.

Figure 1-7: Scarborough seafront inundation 05/12/2013, (Left) and overtopping at Royal Albert Drive, 09/03/2009 (Right)

3.1 Modelled wave and overtopping flood risk

Wave transformation and overtopping modelling was undertaken as part of the Environment Agency Yorkshire Flood Forecasting Update 2017. Four One-Dimentional (1D) SWAN wave models (Figure 1-8 blue transects – West Pier transect labelled as Scarborough 5) transformed deep water outputs from model JP23 to the defensive toes of EurOtop overtopping models in Scarboroughs South Bay. Table 1-3 shows the results of a 0.5% and 3.3% AEP present day event at West Pier. The 0.5% AEP event shows a signifcant wave height and peak period of 0.88m and 8.14s respectively and a resultant peak wave overtopping rate of 150 litres per second per metre of defence. These values are close to the modelled calibration event for the December 5th 2013 event undertaken as part of the Yorkshire modelling, which identified an overtopping rate of 220 litres per second per metre of defence at West Pier. The 3.3% AEP present day event (Flood Zone 3b) shows a peak overtopping rate of 58 litres per second per metre of defence. These rates exceed the EurOtop limits for overtopping for people and vehicles at the seafront which is 1 litre per second per metre of defence for wave heights of up to 2m, and between 10 and 20 litres per second per metre of defence for wave heights up to 1m.

When considering the State of The Nation 10,000-year synthetic coastal storm event dataset at West Pier, the 10,000-year event overtopping rate reaches 1,760 litres per second per metre of defence. While significant wave heights can reach 2.17m with a period of 8.13s.

The work undertaken for forecasting purposes as part of the Yorkshire Flood Forecasting Update 2017 project highlights a risk of wave overtopping at West Pier. Resultant flood risk was not mapped as part of the Yorkshire project, but it is evident that there is a risk to public safety as wave action impacts the pier itself and leads to wave overtopping and overwashing the pier.
It is recommended that a site specific wave overtopping Flood Risk Assessment is undertaken to better inform wave and overtopping risk to the site and to further consider outline mitigation options.

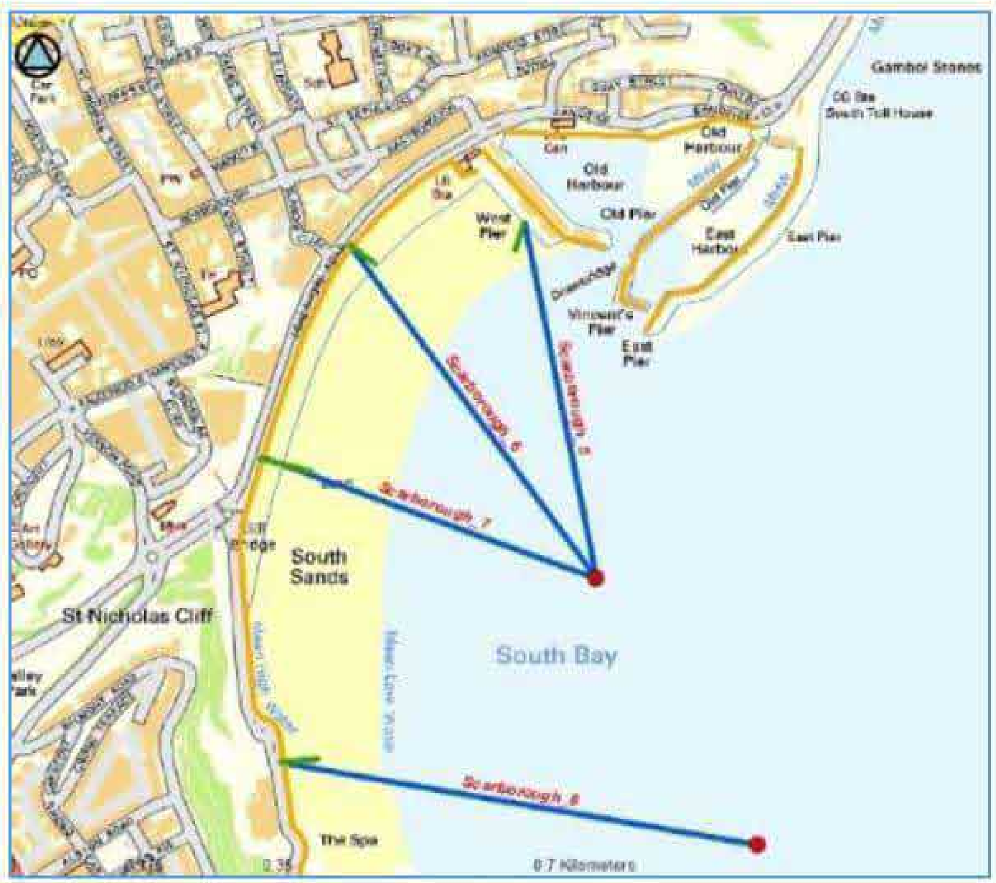


Figure 1-8: SWAN 1D transects simulated as part of the Yorkshire Flood Forecasting Update 2017

Table 1-3: Nearshore wave conditions and overtopping rate at West pier for key AEPs

AEP (%)	Significant Wave Height (m)	Peak Wave Period (s)	Wave Direction (Deg)	Overtopping rate (l/s/m)
0.5	0.88	8.14	128	150
3.3	1.28	8.17	139	58

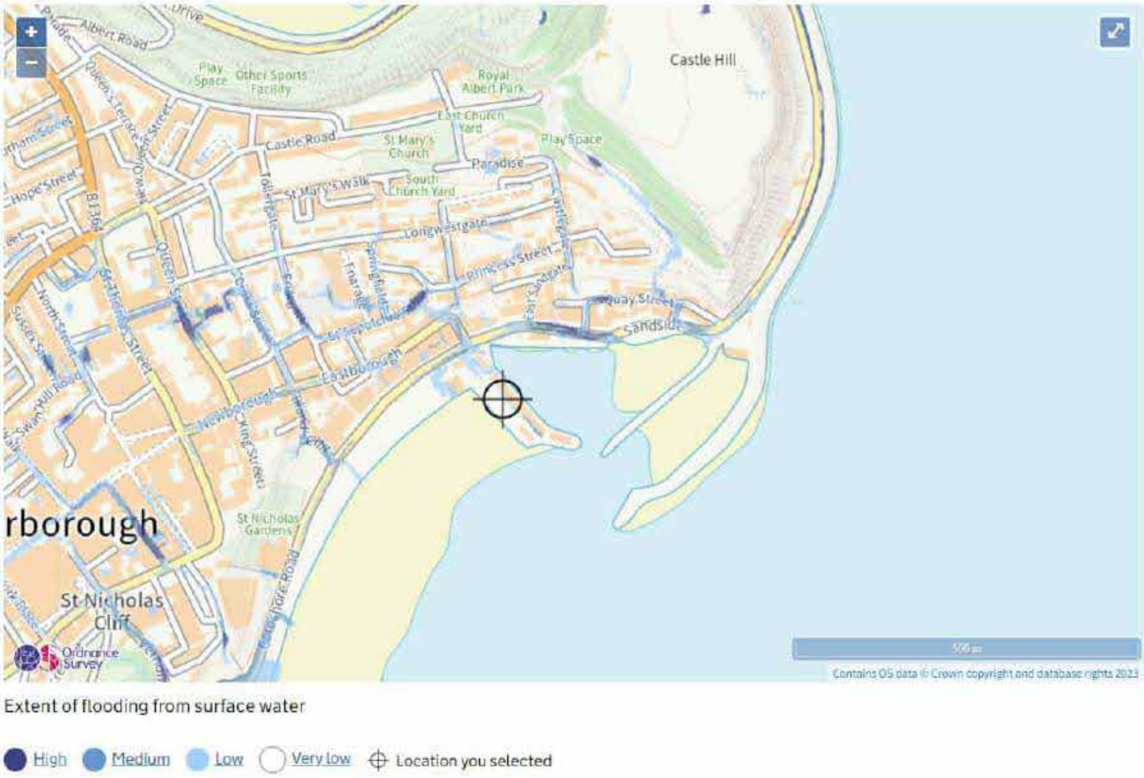
4. Considerations for development at West pier

Considerations for development at West Pier are detailed in Table 1-4.

Table 1-4: Considerations for development at West Pier

Consideration	Discussion
Flood Zone Classification	The site lies within coastal Flood Zone 3 (in any year land has a 0.5% or more chance of flooding from the sea). The site is largely elevated above the 3.3% AEP present day extreme sea level, meaning the site could be classed as being out of

		Flood Zone 3b (defined as the functional floodplain) when considering only extreme sea levels. However there remains both a flood risk and public safety risk from wave overtopping during a 3.3% AEP present day event. There may need to be wave overtopping mitigations measures that need to be considered especially with respect to public safety.
	Finished Floor Levels	It is recommended that for commercial and retail development the Finished Floor Levels are set above 4.90mAOD. This is the 0.5% AEP event extreme sea levels in the 2099 epoch (75-year development design life). Current ground levels at West pier range between 3.80m to 4.30mAODN and therefore ground raising is recommended. Flood modelling would be required to determine if any such ground raising would worsen flood risk elsewhere.
	Access and Egress	The primary access and egress route is via West Pier Road that runs the length of the development site. This road joins Foreshore and Sandside Roads. During a 0.5% AEP event in the 2099 epoch, flood depths on West pier road peak between 0.60 and 0.95m, while flood depths on Foreshore and Sandside are in the region of 0.50 and 0.60m, this would restrict emergency access and egress. It is recommended that emergency vehicles avoid the seafront as much as possible during a large coastal storm event, making use of roads to the north such as Eastborough which are elevated above the coastal frontage. Consideration could be given to safe egress to first floors of any proposed development. It is recommended that any development signs up to the Environment Agency Flood Warning System, and an Emergency Evacuation Plan is put in place.
	Development type	It is understood that the proposed development is largely to consist of commercial and retail units. The design of these should consider being water compatible or how they can be made flood resilient using Property Flood Resilience measures for example.

	Wave overtopping	It is recommended that a site specific wave overtopping assessment is undertaken. This assessment should consider in more detail the risk from wave action at the site and reference the EurOtop 2018 tolerable limits for overtopping guidance. There may be a need to consider potential flood mitigation options.
Surface water	The site is shown to have a Low surface water flood risk as shown on Figure 2-1 from the Environment Agency Flood Map for Planning.  ***Figure 2-1: Environment Agency Flood Map for Planning – Surface Water***	
Reservoir	The site is not at risk from reservoir flooding.	

APPENDIX M

Flood Warning and Evacuation Plan

Procedure

1. Background

1.1. Scarborough Harbours West Pier is susceptible to overtopping and tidal flooding when certain environmental conditions are in play. These include a wind and sea direction from a sector ranging between ESE and SSE where height of tide exceeds 7.2m CD or where wind driven swell on top of HoT exceeds this level.

1.2. During these conditions, overtopping may be experienced on Rowley's Corner (the SE tip of West Pier) and along the SW face of the pier.

1.3. Given the unlevel surface of the pier, flood water will naturally travel across the pier towards the Fish Market which is the lowest point of the pier.

1.4. The drainage channel which runs most of the length of the pier is designed for rainwater removal and will quickly become inundated by flood water.

1.5. This procedure outlines measures which should be considered in the event of tidal inundation or overtopping onto the pier. Dynamic risk assessment must be conducted by onscene commanders to assess if the individual measure is appropriate to the prevailing conditions and circumstances.

2. Measures

2.1. Overtopping

2.1.1. The following measures should be considered during an overtopping event:

☐ Activate enhanced PPE for team inc. Lifejackets

☐ Relocation of fishing equipment

☐ Ensure Fish Market doors are CLOSED

☐ Ensure Fish Market chiller door is fully closed

☐ Notification of public facing tenants where staff/customers are on site

☐ Closure of Pier to vehicular traffic

☐ Closure of Pier to pedestrian traffic

☐ Evacuation of persons from the West Pier

2.2. Tidal Inundation

2.2.1. The following measures should be considered during a tidal inundation event:

☐ Activate enhanced PPE for team inc. Lifejackets and flood poles

☐ Ensure Fish Market doors are OPEN

☐ Ensure Fish Market chiller door is fully closed

☐ Notification of all tenants where staff/customers are on site

☐ Closure of Pier to vehicular traffic

☐ Closure of Pier to pedestrian traffic

☐ Evacuation of persons from the West Pier

☐ Alert vessel owners if moorings are likely to be impacted

2.3. Flood Water from Landward

2.3.1. The following measures should be considered during a flood water event from landward:

☐ Activate enhanced PPE for team inc. Lifejackets and flood poles

☐ Ensure Fish Market doors are CLOSED

☐ Ensure Fish Market chiller door is fully closed

☐ Notification of customer facing tenants where staff/customers are on site

☐ Closure of Pier to vehicular traffic

☐ Closure of Pier to pedestrian traffic

☐ Evacuation of non-harbour users from the West Pier

2.4. Strong Winds

2.4.1. The following measures should be considered during strong winds:

☐ Activate enhanced PPE for team inc. Hard Hats

☐ Notification of customer facing tenants where staff/customers are on site

☐ Closure of Pier to vehicular traffic

☐ Closure of Pier to pedestrian traffic

☐ Evacuation of persons from the West Pier

3. Closure and Evacuation of West Pier

3.1. Where it is deemed appropriate to protect life and property, the Pier should be closed to both people and vehicles with consideration also given to relocating vessels.

3.2. To affect the closure, the following procedure should be followed and then supplemented by the evacuation procedure at section 3.3. If sufficient resources allow, it may be possible to operate the closure and evacuation procedures simultaneously.

☐ Deploy barriers to the entrance of West Pier with one team member leaving the outbound lane of the road clear

☐ Tape off accesses behind the first building on the Pier and between the crab kiosks and Lifeboat station

☐ If appropriate, update LPS Watchkeeper to cease berthing on the Fish Quay

☐ Inform Resilience and Emergencies Team Duty Officer

[redacted]

☐ Inform Head of Harbours & Assistant Director

3.3. Once the site is secured to prevent a further increase of people and vehicles, evacuation should commence immediately:

☐ Assess whether it is safe for people already on the pier to approach parked vehicles and to be near buildings if a risk of falling objects (roof tiles etc) exists.

☐ Inform businesses on the pier that due to the risks associated with the weather conditions, the pier is required to close. Ask them to inform their patrons and guide them towards the entrance of the pier or to parked vehicles if it was deemed safe to do so.

☐ Avoid walking pedestrians through flood water, particularly avoiding the central drain if covered by water. NB: Dislocated drain covers may exist and unseen if submerged by flood water.

☐ If evacuation is not possible, other than through flood water, NYFRS should be contacted for assistance. Consider that it may be safer to keep people inside buildings if they are on an upper level.

☐ Deploy a team member to intercept persons in the car park and generally around the pier. Advise them that for safety reasons the pier is now closed and the must leave immediately. Where possible, guide them away from flood water and avoid the central drain, as above.

☐ Conduct headcount of individuals who must remain on the pier for operational reasons including vessel owners/crew standing by their vessel, harbour staff and emergency service workers.

☐ Update Resilience and Emergencies Team Duty Officer

[redacted]

☐ Update Head of Harbours & Assistant Director

Associated Risk Assessments

CHA W/S/31 – West Pier Scarborough Harbour Operations
CHA W/S/41 – Flooding of Harbour Property
CHA W/S/91 - Safety of Navigation inc. Navigation lights & provision of Local Port Services
CHA W/S/101 - Lifejackets

Associated References

SMS Annex 4 - Incident Response / Notification Matrix
SMS Annex 17 – Port Emergency Plan

Change Record

Ver. #	Changes made	Editor	Date
1	First version	Chris Burrows, HM	19/10/2023

APPENDIX N

Scarborough West Pier Wave Overtopping Assessment

Note / Memo

HaskoningDHV UK Ltd.
Water & Maritime

To:	Gary Collinson
From:	Thomas Green
Date:	29 January 2024
Copy:	
Our reference:	PC5767-RHD-XX-ZZ-TN-Z-0001
Classification:	Confidential
Checked by	Keming Hu and Nick Cooper

Subject: **Scarborough West Pier Wave Overtopping Assessment**

1 Introduction

Royal HaskoningDHV has been commissioned to undertake a wave overtopping assessment to support the understanding of flood risk associated with wave overtopping at Scarborough West Pier.
It is understood that the outcomes of this assessment will be supplementary to the Flood Risk Assessment, Scarborough West Pier (2023) undertaken by Mason Clark Associates on behalf of William Birch and Sons Ltd (Report Reference 21037-H-RP-001-R0) and the outcomes used to update the proposed flood mitigation measures as considered necessary by the promoting parties.

2 Assessment Scope

The scope of the wave overtopping assessment can be summarised by the following activities:

- Review the existing information available for the site (including a review of the Flood Risk Assessment, Scarborough West Pier (2023) and the draft Scarborough Coastal Defence Strategy Refresh Wave Overtopping Report (2022) by Royal HaskoningDHV (the Strategy Refresh);
- Gather data to derive hydraulic conditions, including:
  - Assessment of extreme tidal levels;
  - Evaluation of extreme wave heights for the area;
  - Analysis of joint probability of extreme water levels and wave heights; and
  - Assessment of climate change and sea level rise.
- Derive a ‘nearshore’ wave climate at Scarborough West Pier.
- Undertake a wave overtopping assessment.
- Calculate potential flood depth on Scarborough Pier due to wave overtopping.

2.1 Scarborough Coastal Defence Strategy Refresh Wave Overtopping Report Summary

As part of the Strategy Refresh project being delivered by Royal HaskoningDHV, a wave overtopping assessment was undertaken to better understand the risks from wave overtopping and sea flooding within the strategy area of Scarborough’s North Bay, Castle Headland and South Bay. The assessment included:

- An offshore extreme wave and wind analysis;
- Obtaining extreme sea level data from the Environment Agency's Coastal Flood Boundaries project;
- Calculating sea level rise data from the United Kingdom Climate Impact Projections 2018 (UKCP18) project;
- Calculating the predicted sea level rise for Scarborough;
- Undertaking a joint probability assessment of extreme water levels and wave heights.
- Wave transformation modelling to derive a nearshore wave climate. This included:
    - Setting up a SWAN model, based on the Environment Agency State of the Nation (SoN) SWAN Model.
    - Calibration and verification of the model.
    - Undertaking simulations of present day and future wave transformations from offshore to inshore; and
    - Identifying the wave direction that results in the 'worst-case' wave climate for each area.
- Wave overtopping assessment.

To maintain consistency with the outcomes of the Strategy Refresh, the approach to deriving nearshore hydraulic conditions for the wave overtopping assessment remain the same. A summary of the approach undertaken is provided below.

2.2 Derivation of Hydraulic Conditions

2.2.1 Offshore Wave and Wind Analysis

As part of the Strategy Refresh Royal HaskoningDHV undertook an offshore extreme wave analysis based on 40 years of hindcast data from WaveWatch III wave model produced by the Met Office. This dataset provides a time series of offshore conditions, including wave height, wave period, wave direction and wind speed. The data was obtained for the offshore grid point P2031, chosen as this point is used as the wave input by the Environment Agency's State of the Nation (SoN) SWAN model and this model formed the basis for wave transformation modelling as part of the Strategy Refresh project. The results of the offshore wave analysis undertaken as part of the Strategy Refresh project have been utilised for this study to ensure consistency in approach. Figure 2-1 shows the geographical location of Grid Point P2031 in relation to the SoN SWAN model and Scarborough.

Figure 2-1: UK Met Office wave hindcast point P2031 (red point) in relation to Scarborough and SoN SWAN model (purple line)

Figure 2-2 presents the wave rose showing the significant wave heights for wave hindcast grid point P2031. It shows that the predominant wave direction at this location is coming from north and northeast with waves coming from south-east being also slightly higher than remaining sectors.

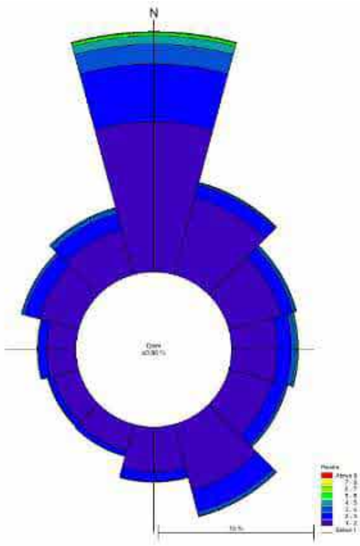


Figure 2-2: Wave Rose showing significant wave height for P2031

A probability and statistical extreme value analysis, following the well-known Generalised Extreme Value (GEV) distribution method, was undertaken for wave hindcast point P2031 to derive extreme wave heights (Hs) for the following return period (RP) events: 1, 10, 20, 50, 75, 100, 200 and 1,000 years; and 12 direction sectors between 0-360° at 30° intervals. Resulting values for these return periods are shown in Table 2-1. It should be noted that only direction sectors with waves coming from North (0°) to South (180°) are presented in Table 2-1 because these directions are the only wave directions which could possibly have an impact upon the Scarborough Strategy frontage due to its shore orientation.

Table 2-1: Extreme Offshore Wave Conditions for P2031.

RP	Waves coming from (degrees)							
	North (0°)		North-North East (30°)		East-North East (60°)		East (90°)	
	Hs (m)	Tp (s)	Hs (m)	Tp (s)	Hs (m)	Tp (s)	Hs (m)	Tp (s)
1	6.25	12.13	4.13	9.76	3.75	9.42	4.08	9.70
10	7.46	12.52	5.64	11.28	5.26	10.98	5.48	11.21
20	7.72	12.73	6.09	11.97	5.61	11.25	5.76	11.39
50	8.00	12.96	6.67	12.15	6.02	11.90	6.08	11.96
75	8.11	13.05	6.93	12.38	6.19	12.07	6.20	12.08
100	8.18	13.11	7.11	12.22	6.31	12.19	6.29	12.17
200	8.33	13.23	7.56	12.60	6.57	12.05	6.46	12.33
1,000	8.61	13.45	8.58	13.42	7.09	12.20	6.79	12.25

Table 2-1: Continued.

RP	Waves coming from (degrees)					
	East-South East (120°)		South-South East (150°)		South (180°)	
	Hs (m)	Tp (s)	Hs (m)	Tp (s)	Hs (m)	Tp (s)
1	3.90	9.61	3.89	9.60	3.12	8.67
10	4.78	10.51	4.82	10.55	3.84	9.53
20	4.99	10.74	5.08	10.79	4.04	9.66
50	5.24	10.96	5.41	11.14	4.28	9.94
75	5.34	11.06	5.55	11.18	4.38	10.05
100	5.41	11.14	5.66	11.30	4.45	10.13
200	5.56	11.19	5.90	11.53	4.62	10.33
1,000	5.86	11.49	6.43	12.30	4.98	10.69

2.2.2 Offshore Wind Analysis

Wind is an important forcing factor required for wave transformation modelling as it ensures a realistic wave generation and propagation from offshore to nearshore within the wave transformation model.

As part of the Strategy Refresh Project Wind data from the UK Met Office wave hindcast data grid point P2031 was used for the offshore wind analysis. A 'typical' wind speed to wave height relationship was calculated for the direction sectors North (0°) to South (180°) which are most relevant to this study as they would likely have the greatest impact on the study frontage. Figure 2-3 shows this relationship between wind speed and waves from these offshore directions for wave hindcast data point P2031, with significant wave heights shown along the X-axis and wind speed shown along the Y-axis. This relationship has then been used to calculate the wind speeds that were applied in the model.

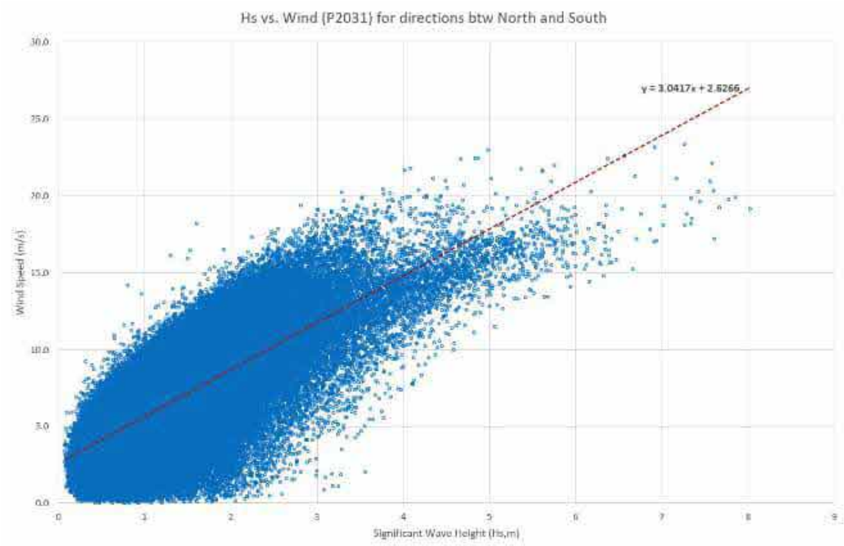


Figure 2-3: Relationship between offshore wind speed and significant wave height for direction sectors North to South at P2031 (extract from Scarborough Coastal Defence Strategy Refresh Wave Overtopping Report (2022) by Royal HaskoningDHV)

2.2.3 Baseline Still Water Levels

Astronomical tidal levels can be affected by positive surge conditions to create extreme water levels. The most recently published source of information on extreme water levels in the present day is from the Environment Agency's Coastal Design Sea Levels - Coastal Flood Boundary Extreme Sea Levels (2018) project. Figure 2-4 shows the Coastal Flood Boundary grid points and point 3752 has been used for this study (maintaining consistency with the Strategy Refresh) and the extreme water level values from this source for various return period events are presented in Table 2-2. Note: the baseline still water levels also match those used in the Flood Risk Assessment, Scarborough Water Pier (2023).

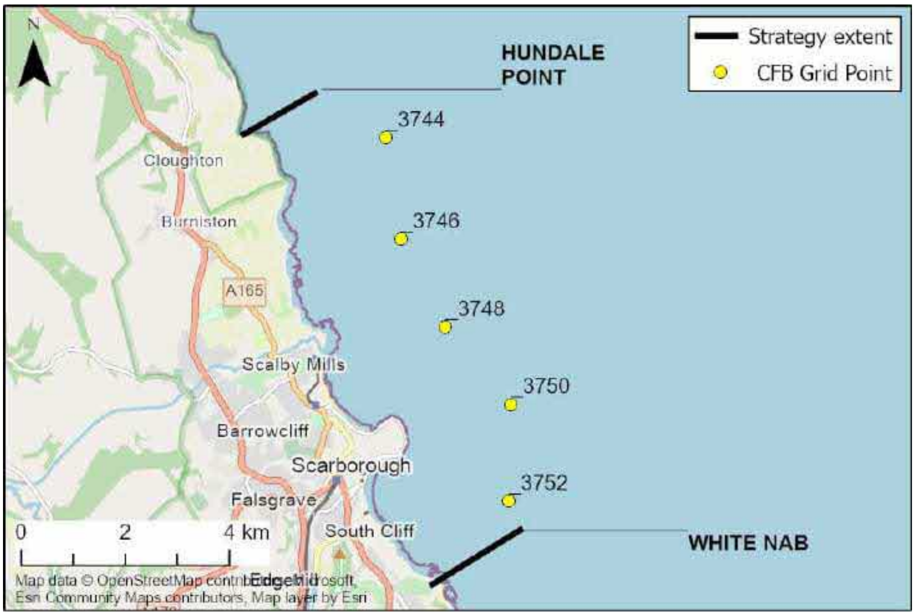


Figure 2-4: Environment Agency's Coastal Flood Boundaries (CFB) model grid points located along the study frontage (extract from Scarborough Coastal Defence Strategy Refresh Wave Overtopping Report (2022) by Royal HaskoningDHV)

Table 2-2: *Environment Agency's CFB point 3752 extreme water levels at Scarborough (base date of 2017)*

Return Period (years)	1	10	20	50	75	100	200	1000
Extreme Water Level (mOD)	3.39	3.71	3.81	3.95	4.01	4.05	4.17	4.44

2.2.4 Climate change and sea level rise

The baseline (base date of 2017) extreme water levels may be affected through the course of the next 40 years (and beyond) by the effects of global climate change and, in particular, sea level rise. As such, water levels need to be adjusted to account for sea level rise from the base date of 2017 to 2025 for the 'present day' scenario and then into the future for year 2065. For this, the design climate allowance has been based on the 70th percentile (higher central) value of UKCP18 Representative Concentration pathway (RCP) 8.5. Planning for more severe climate impacts should be based on the 95th percentile (upper end) value of RCP8.5. However, to align with the Flood Risk Assessment, Scarborough West Pier (2023), the higher percentile has not been considered. Resulting values for Scarborough are presented in Table 2-3.

Table 2-3: Present Day (2025) and future (2065) extreme sea levels at Scarborough

Return period event (1 in X yrs)	Extreme sea level			
	Base Date (2017) (m OD)	Present Day (2025) (mODN)	2065 (m OD) Design	2065 (m OD) Severe
1	3.39	3.43	3.73	3.66
10	3.71	3.75	4.05	3.98
20	3.81	3.85	4.15	4.08
50	3.95	3.99	4.29	4.22
100	4.05	4.09	4.39	4.32
200	4.17	4.21	4.51	4.44
1,000	4.44	4.48	4.78	4.71

2.2.5 Joint Probability Analysis

The purpose of a joint probability analysis is to understand the relationship between high water levels and large wave events. Coastal flood risk usually arises due to a combination of high-water levels and large waves. The probability of occurrence of such events can be represented through the use of 'return periods' of event occurrence. A joint probability analysis (JPA) has therefore been undertaken of extreme water levels and wave heights, applying the desk-based Defra / EA Joint Probability Analysis: Dependence Mapping and Best Practice (2005). This methodology remains consistent with the Strategy Refresh.

A joint probability analysis was undertaken for the Strategy Refresh for a selection of suitable return periods. Only those wave directions that could possibly have an impact on the Scarborough frontage, namely waves coming from North (0°), North-North East (30°), East-North East (60°), East (90°), East-South East (120°), South-South East (150°) and South (180°), were been selected for the joint probability analysis (JPA). The results of the JPA are shown in Table 2-4 and Table 2-5 for a 1 in 1 year and 1 in 200 year return period events respectively, where Hs is significant wave height and Tp is peak wave period.

Table 2-4: Results of JPA for 1 in 1 year RP event

Water Level (mOD)	North (0°)		North-North East (30°)		East-North East (60°)		East (90°)		East-South East (120°)		South-South East (150°)		South (180°)	
	Hs (m)	Tp (sec)	Hs (m)	Tp (sec)	Hs (m)	Tp (sec)	Hs (m)	Tp (sec)	Hs (m)	Tp (sec)	Hs (m)	Tp (sec)	Hs (m)	Tp (sec)
2.61	6.25	12.13	4.13	9.76	3.75	9.42	4.08	9.70	3.90	9.61	3.89	9.60	3.12	8.67
2.93	6.10	11.98	3.97	9.69	3.56	9.18	3.89	9.60	3.79	9.48	3.79	9.47	3.04	8.55
3.01	5.66	11.29	3.50	9.10	3.02	8.53	3.36	9.00	3.49	9.17	3.50	9.18	2.81	8.47
3.13	5.22	10.94	3.03	8.54	2.48	8.47	2.83	8.51	3.19	8.77	3.21	8.79	2.58	8.12
3.34	4.20	9.84	1.94	8.13	1.23	7.15	1.60	7.40	2.49	8.49	2.54	8.57	2.05	7.70
3.43	3.76	9.43	1.47	7.79	0.69	6.22	1.08	6.67	2.19	7.96	2.25	8.06	1.72	7.66

Waves coming from (degrees)

Table 2-5: Results of JPA for 1 in 200 year RP event

Water Level (mOD)	North (0°)		North-North East (30°)		East-North East (60°)		East (90°)		East-South East (120°)		South-South East (150°)		South (180°)	
	Hs (m)	Tp (sec)	Hs (m)	Tp (sec)	Hs (m)	Tp (sec)	Hs (m)	Tp (sec)	Hs (m)	Tp (sec)	Hs (m)	Tp (sec)	Hs (m)	Tp (sec)
3.01	8.33	13.23	7.56	12.60	6.57	12.05	6.46	12.33	5.56	11.19	5.90	11.53	4.62	10.33
3.13	8.26	13.17	7.34	12.42	6.45	12.32	6.38	12.25	5.49	11.22	5.79	11.42	4.54	10.24
3.34	7.83	12.82	6.32	12.20	5.77	11.41	5.89	11.52	5.09	10.80	5.21	10.93	4.13	9.77
3.43	7.60	12.63	5.87	11.51	5.44	11.17	5.63	11.26	4.89	10.63	4.96	10.70	3.94	9.66
3.65	6.85	12.31	4.83	10.56	4.48	10.17	4.78	10.51	4.33	9.99	4.32	9.99	3.46	9.13
3.75	6.46	12.33	4.37	10.04	4.00	9.61	4.32	9.98	4.05	9.66	4.04	9.65	3.24	8.83
3.85	6.04	11.92	3.91	9.61	3.49	9.17	3.83	9.52	3.76	9.43	3.75	9.42	3.01	8.51
3.99	5.46	11.19	3.28	8.89	2.78	8.43	3.13	8.68	3.36	8.99	3.37	9.01	2.71	8.32
4.05	5.20	10.92	3.01	8.51	2.46	8.44	2.82	8.48	3.18	8.75	3.20	8.78	2.57	8.11
4.09	5.02	10.73	2.82	8.48	2.24	8.05	2.60	8.15	3.06	8.58	3.08	8.61	2.56	8.09
4.21	4.58	10.29	2.35	8.23	1.70	7.63	2.07	7.73	2.76	8.39	2.79	8.45	2.25	8.06

Waves coming from (degrees)

2.2.6 Climate Change Allowances

Wave heights at the coast may change because of increased water depths (associated with sea level rise) or changes to the frequency, duration and severity of storms. The Environment Agency guidance for flood and coastal risk projects recommends the allowances listed in Table 2-6. The allowances should be used in any coastal modelling of climate change and have been applied to the SWAN wave transformation model for this study.

Table 2-6: Offshore wind speed and extreme wave height allowances

Parameter	2000 to 2055	2056 to 2125
	Allowance	Allowance
Offshore wind speed	5%	10%
Extreme wave height	5%	10%

3 Wave Transformation Modelling

A wave transformation model was developed as part of the Strategy Refresh to enable the extreme offshore water level and wave height combinations derived during the offshore wave analysis and the joint probability analysis (described above) to be transformed from the 'offshore' to the 'nearshore' locations. The wave conditions derived from the model at the 'nearshore' locations are then used in the wave overtopping assessment.

3.1 Model Description

In order to undertake the wave transformation from the 'offshore' to the 'nearshore' areas, the SWAN (Simulation Waves Nearshore) wave transformation model was used. SWAN is a third-generation wave model, which was developed by the Delft University of Technology. It is a two-dimensional spectral wave model for coastal wave transformation and wave hindcasting from wind. It takes account of the shallow water effects such as wave refraction, shoaling, bed friction, wave breaking and more complicated wave-to-wave interaction. SWAN also considers wave diffraction, which makes it one of the most advanced coastal wave models that is commercially available.

The SWAN model that has been developed by the Environment Agency as part of the SoN project was utilised in the Strategy Refresh and re-used for this study. The model, named JP23, has a boundary that aligns with the UK Met Office hindcast data point P2031 and is already calibrated using measured wave buoy data. The SoN model JP23 extent is shown in Figure 3-1.

Figure 3-1: SoN SWAN model JP23 (purple line) with two nested models (red line) for Scarborough

3.2 Model Setup

Although the SoN SWAN JP23 model is 'ready to use', the grid resolution is quite coarse at 200m x 200m and not sufficient to accurately simulate wave behaviour in the nearshore region, nor represent the complex coastline and bathymetry in Scarborough North Bay and Scarborough South Bay and around Scarborough Headland that influence wave behaviour.

Therefore, as part of the Strategy Refresh two 'nested' wave models encompassing the nearshore areas around Scarborough's North Bay, Castle Headland and South Bay were set up with a higher grid resolution of 5m x 5m in order to more accurately capture the nearshore features and better simulate the nearshore wave conditions.

The bathymetry of the 'nested' wave models was updated and thus improved by using the latest available LiDAR and bathymetry data (described in Section 4.2). Figure 3-2 shows the bathymetry of the two 'nested' SWAN wave models.

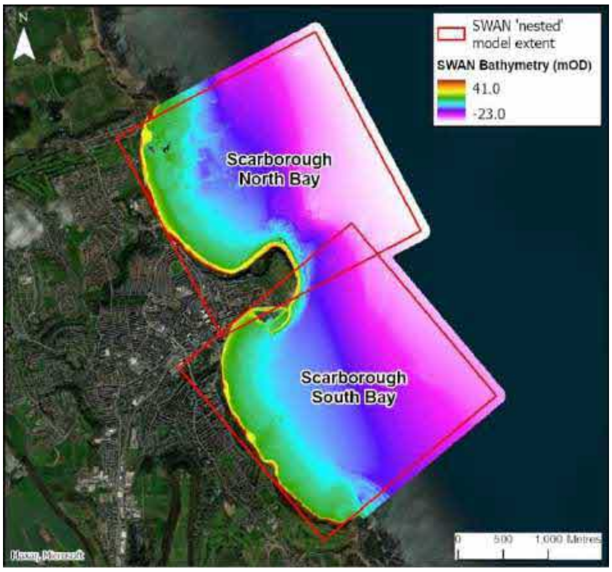


Figure 3-2: Bathymetry of 'nested' SWAN wave models

3.3 Model Verification

The SoN JP23 model has its offshore boundary close to the UK Met Office hindcast data point P2031 that was used for the Joint Probability Analysis (see Section 4.6) and the JPA results have been used as the input offshore wave conditions for the SoN JP23 model. The offshore wave conditions were then transformed using the SoN JP23 model to the two 'nested' Scarborough models.

The SoN SWAN model is already calibrated, however a model verification exercise was undertaken for the Strategy Refresh to ensure that the model achieves reasonable agreement when compared with known storm events. Six storm events measured at the Tyne/Tees wave buoy between 2016 and 2020 were chosen as input wave conditions and the results are summarised in Table 3-1. No further verification was undertaken for this assessment.

Table 3-1: Comparison between measured and modelled data at Scarborough wave buoy

Storm Event		Measured Waves at Scarborough Wave Buoy			Modelled Waves at Scarborough Wave Buoy			Difference in Hs (m)
Storm	**Date**	**Hs (m)**	**Tp (s)**	**Dir (°N)**	**Hs (m)**	**Tp (s)**	**Dir (°N)**	
Storm 1	14/01/2016 14:00	**4.3**	9.1	350	**4.7**	9.9	4	**0.4**
Storm 2	16/01/2016 03:00	**4.1**	11.1	13	**3.8**	10.8	18	**-0.3**
Storm 3	04/01/2017 14:00	**4.8**	13.3	18	**4.8**	14.4	20	**0**
Storm 4	08/12/2017 21:00	**4.7**	12.5	6	**4.7**	10.8	15	**0**
Storm 5	01/03/2018 12:00	**6.2**	11.1	75	**5.8**	10.8	73	**-0.4**
Storm 6	29/08/2020 15:00	**3.9**	9.1	3	**3.8**	9	20	**-0.1**

3.4 Test Runs

The Strategy Refresh focussed on operational wave conditions (1 in 1 year storm event) and extreme storm conditions (1 in 200 year return period event). For each of these return periods, a series of test runs were undertaken to inform the ‘worst case’ wave approach direction for wave overtopping, considering waves coming from 0° (North), 30°, 60°, 90° (East), 120°, 150° and 180° (South) based on the highest and lowest water level and corresponding joint probability wave height. For South Bay, nearshore wave heights were extracted at various ‘nearshore’ locations, Figure 3-3. The focus of the Strategy Refresh was the main outer harbour arm and Scarborough beach. The test results concluded that the ‘worst case’ wave approach direction identified was from due North (0°) where waves from the North diffract around the headland into South Bay. Table 3-2 and
Table **3-3** present the results of the test runs for a 2025 1 in 1 year return period event.

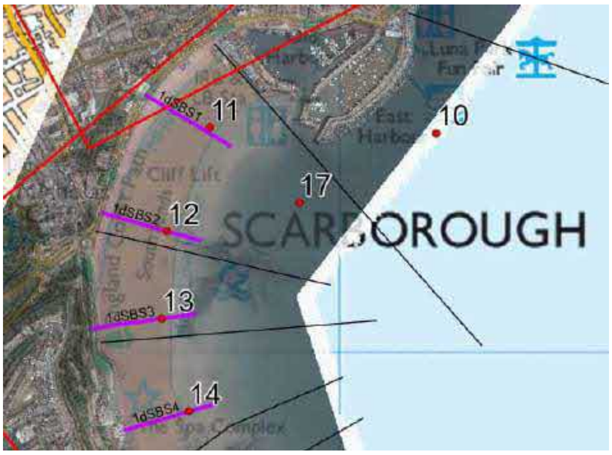


Figure 3-3: Nearshore output points used in the test runs

Table 3-2: 2025 1 in 1 year return period event – nearshore wave height and direction – low water level of +2.61mOD

Nearshore Point	Sig Wave Height (Hs, m)							Direction (deg)						
	0°	30°	60°	90°	120°	150°	180°	0°	30°	60°	90°	120°	150°	180°
P9	5.7	3.8	3.5	3.7	3.0	2.3	1.1	62.7	72.3	85.8	94.6	100.9	106.2	114.1
P10	4.4	3.4	3.3	3.6	2.9	2.1	1.0	37.3	47.5	57.2	61.5	65.1	70.0	90.2
P17	2.4	2.3	2.8	3.3	2.9	2.1	1.0	30.9	41.2	59.7	77.7	91.5	103.4	119.8
P11	0.6	0.7	1.1	1.5	1.6	1.5	0.8	48.0	54.6	64.4	71.9	77.0	83.8	95.6
P12	1.6	1.7	2.0	2.1	2.1	1.9	0.9	42.8	48.8	57.1	64.1	69.7	76.9	91.7
P13	2.0	2.0	2.0	2.1	2.1	1.9	0.9	36.1	41.3	49.0	57.8	66.5	73.6	87.4
P14	2.3	2.2	2.3	2.3	2.2	1.9	0.9	32.1	35.5	42.6	51.4	57.6	61.6	75.0
P15	2.3	2.3	2.3	2.3	2.1	1.9	0.8	38.1	42.4	54.8	67.7	77.3	84.0	95.1
P16	2.8	2.6	2.6	2.6	2.5	1.9	0.8	28.1	38.5	55.1	71.8	87.0	100.6	116.1

Table 3-3: 2025 1 in 1 year return period event – nearshore wave height and direction – high water level of +3.43mOD

Nearshore Point	Sig Wave Height (Hs, m)							Direction (deg)						
	0°	30°	60°	90°	120°	150°	180°	0°	30°	60°	90°	120°	150°	180°
P9	2.9	1.4	0.7	1.0	1.7	1.3	0.6	26.9	38.5	60.1	82.9	96.5	108.5	122.3
P10	2.3	1.2	0.7	1.0	1.6	1.2	0.6	39.9	48.3	63.6	80.8	92.5	104.1	118.4
P17	1.3	0.8	0.6	0.9	1.5	1.2	0.5	58.9	65.5	75.5	85.1	92.5	102.4	115.1
P11	0.3	0.2	0.2	0.5	1.0	0.9	0.5	85.4	107.2	110.8	113.8	115.7	118.5	123.2
P12	0.8	0.6	0.5	0.8	1.5	1.1	0.5	76.2	82.6	88.5	93.4	96.3	101.8	112.1
P13	1.4	0.9	0.5	0.9	1.6	1.2	0.5	65.6	69.5	77.2	83.9	88.5	95.6	107.0
P14	1.7	1.0	0.6	0.9	1.5	1.1	0.5	56.1	61.8	70.8	79.6	85.8	94.3	106.4
P15	2.4	1.3	0.7	0.9	1.5	1.1	0.4	36.1	44.7	56.6	67.3	73.5	83.9	100.6
P16	2.6	1.3	0.7	0.9	1.5	1.0	0.4	40.5	47.7	60.1	72.9	80.2	88.7	102.8

The wave approach direction for 'nearshore' output point 11 and 17 (being closest to West Pier) average from an East direction which means waves are either travelling away from, or parallel with, West Pier. Additional test runs were undertaken, based on the lowest water level corresponding joint probability wave height, to determine the 'worst case' wave approach direction for West Pier itself, using two new 'nearshore' output points (NP1 and NP2) situated closer to West Pier. Figure 3-4 presents the location of the new 'nearshore' output points and Table 3-4 presents the results in the same format as above. The table shows that waves coming from 0° (North) through to 120° (South) continue to run parallel with, or away from, West Pier due to the influence of the headland and outer harbour arm and would therefore not represent a realistic wave overtopping event at West Pier. However, waves coming from 150° and 180° (South) approach the end of West Pier more perpendicular (NP1) before running more parallel along the Pier (NP2). As such, NP1 indicates that the end of west pier is likely to experience wave overtopping and represents a more realistic direction and output point to use in the wave overtopping assessment.

Figure 3-4: New Nearshore Output Points

Table 3-4: 2025 1 in 1 year return period event – nearshore wave height and direction – low water level of +2.61mOD

	Sig Wave Height (Hs, m)							Direction (deg)						
	0°	30°	60°	90°	120°	150°	180°	0°	30°	60°	90°	120°	150°	180°
NP1	0.4	0.4	0.6	0.9	1.0	0.9	0.5	107	118	123	126	129	134	141
NP2	0.3	0.3	0.4	0.6	0.7	0.7	0.4	137	136	136	138	140	144	151

3.5 Wave Model Runs

The SWAN model was run for a 1 in 1 year and 1 in 200 year return period event in year 2025 and 2065 for a range of joint probability water level and wave height combinations to derive a 'nearshore' wave climate that can be used to assess the wave overtopping assessment. A summary of the 'offshore' to 'nearshore' wave climate at New Point 1 is presented in Table 3-5 to Table 3-12. Note, the joint probability assessment undertaken during the Strategy Refresh was expanded upon to provide a greater range of water level and wave height combinations for this study. To limit the number of wave model runs a range of joint probability combinations were selected.

Table 3-5: 2025 1 in 1 year return period event – 150 degrees

Joint Probability Combination	Offshore Conditions				Nearshore Conditions	
	Water Level (mOD)	Hs (m)	Tp (sec)	Wind Speed	Hs (m)	Direction (degrees)
1	2.61	3.89	9.60	14.46	0.87	135
2	2.93	3.79	9.47	14.15	-	-
3	3.01	3.50	9.18	13.27	0.79	134
4	3.13	3.21	8.79	12.39	0.73	134
5	3.34	2.54	8.57	10.35	-	-
6	3.43	2.25	8.06	9.47	0.50	133

Key: '-' means this combination was not modelled

Table 3-6: 2065 1 in 1 year return period event – 150 degrees

Joint Probability Combination	Offshore Conditions				Nearshore Conditions	
	Water Level (mOD)	Hs (m)	Tp (sec)	Wind Speed	Hs (m)	Direction (degrees)
1	2.90	4.28	9.94	15.90	0.97	134
2	3.22	4.17	9.81	15.56	-	-
3	3.31	3.85	9.54	14.60	0.90	134
4	3.43	3.53	9.14	13.63	0.82	134
5	3.64	2.79	8.45	11.39	-	-
6	3.73	2.48	8.45	10.42	0.60	134

Key: '-' means this combination was not modelled

Table 3-7: 2025 1 in 200 year return period event – 150 degrees

Joint Probability Combination	Offshore Conditions				Nearshore Conditions	
	Water Level (mOD)	Hs (m)	Tp (sec)	Wind Speed	Hs (m)	Direction (degrees)
1	3.01	5.90	11.53	20.57	1.14	129
2	3.13	5.79	11.42	20.22	-	-
3	3.34	5.21	10.93	18.47	-	-
4	3.43	4.96	10.70	17.70	1.12	134
5	3.65	4.32	9.99	15.77	-	-
6	3.75	4.04	9.65	14.91	0.94	134
7	3.85	3.75	9.42	14.04	-	-
8	3.99	3.37	9.01	12.87	0.79	134
9	4.05	3.20	8.78	12.36	-	-
10	4.09	3.08	8.61	12.00	-	-
11	4.21	2.79	8.45	11.12	0.66	134

Key: '-' means this combination was not modelled

Table 3-8: 2065 1 in 200 year return period event – 150 degrees

Joint Probability Combination	Offshore Conditions				Nearshore Conditions	
	Water Level (mOD)	Hs (m)	Tp (sec)	Wind Speed	Hs (m)	Direction (degrees)
1	3.31	6.49	12.36	22.63	1.4	132
2	3.43	6.36	12.24	22.25	-	-
3	3.64	5.73	11.37	20.32	-	-
4	3.73	5.45	11.18	19.47	1.27	133
5	3.95	4.75	10.48	17.35	-	-
6	4.05	4.44	10.12	16.40	1.06	134
7	4.15	4.13	9.76	15.44	-	-
8	4.29	3.71	9.37	14.16	0.89	134
9	4.35	3.52	9.13	13.60	-	-
10	4.39	3.39	9.03	13.20	-	-
11	4.51	3.07	8.60	12.23	0.74	134

Key: '-' means this combination was not modelled

Table 3-9: 2025 1 in 1 year return period event – 180 degrees

Joint Probability Combination	Offshore Conditions				Nearshore Conditions	
	Water Level (mOD)	Hs (m)	Tp (sec)	Wind Speed	Hs (m)	Direction (degrees)
1	2.61	3.12	8.67	12.12	0.53	142
2	2.93	3.04	8.55	11.87	-	-
3	3.01	2.81	8.47	11.17	0.48	141
4	3.13	2.58	8.12	10.48	0.44	141
5	3.34	2.05	7.70	8.87	-	-
6	3.43	1.82	7.89	8.17	0.32	140

Key: '-' means this combination was not modelled

Table 3-10: 2065 1 in 1 year return period event – 180 degrees

Joint Probability Combination	Offshore Conditions				Nearshore Conditions	
	Water Level (mOD)	Hs (m)	Tp (sec)	Wind Speed	Hs (m)	Direction (degrees)
1	2.90	3.43	9.09	13.33	0.59	142
2	3.22	3.34	8.97	13.06	-	-
3	3.31	3.09	8.63	12.29	0.54	141
4	3.43	2.84	8.52	11.53	0.52	141
5	3.64	2.26	8.07	9.75	-	-
6	3.73	2.01	7.61	8.99	0.32	140

Key: '-' means this combination was not modelled

Table 3-11: 2025 1 in 200 year return period event – 180 degrees

Joint Probability Combination	Offshore Conditions				Nearshore Conditions	
	Water Level (mOD)	Hs (m)	Tp (sec)	Wind Speed	Hs (m)	Direction (degrees)
1	3.01	4.62	10.33	16.68	0.79	142
2	3.13	4.54	10.24	16.43	-	-
3	3.34	4.13	9.77	15.20	-	-
4	3.43	3.94	9.66	14.62	0.67	141
5	3.65	3.46	9.13	13.15	-	-
6	3.75	3.24	8.83	12.47	0.57	141
7	3.85	3.01	8.51	11.78	-	-
8	3.99	2.71	8.32	10.86	0.47	141
9	4.05	2.57	8.11	10.46	-	-
10	4.09	2.48	8.46	10.17	-	-
11	4.21	2.25	8.06	9.47	0.4	140

Key: '-' means this combination was not modelled

Table 3-12: 2065 1 in 200 year return period event – 180 degrees

Joint Probability Combination	Offshore Conditions				Nearshore Conditions	
	Water Level (mOD)	Hs (m)	Tp (sec)	Wind Speed	Hs (m)	Direction (degrees)
1	3.31	5.08	10.79	18.35	0.89	142
2	3.43	4.99	10.74	18.08	-	-
3	3.64	4.55	10.25	16.72	-	-
4	3.73	4.34	10.01	16.09	0.77	141
5	3.95	3.81	9.49	14.47	-	-
6	4.05	3.56	9.18	13.72	0.64	141
7	4.15	3.31	8.93	12.96	-	-
8	4.29	2.98	8.72	11.95	0.54	140
9	4.35	2.83	8.51	11.50	-	-
10	4.39	2.73	8.35	11.18	-	-
11	4.51	2.48	8.46	10.42	0.45	140

Key: '-' means this combination was not modelled

4 Wave Overtopping Assessment

4.1 Approach

The wave overtopping was calculated using the EurOtop Manual on Wave Overtopping of Sea Defences and Related Structures (2018) methodology as outlined in Chapter 7 'Vertical and Steep Walls'. The wave overtopping calculations require a series of input conditions, refer to Figure 4-1, comprising of significant wave height (Hs), wave period (Tm-1,0), wall crest level (mOD), still water level (mOD), wall toe level (mOD) and foreshore slope (1:m).

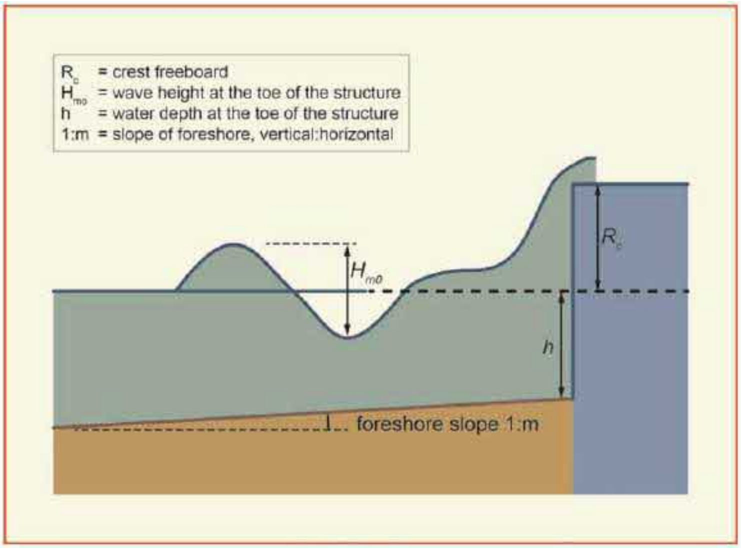


Figure 4-1: Plain vertical wall definition sketch for the key geometric parameters (extract from Figure 7.6 of the EurOtop Manual, 2018).

Figure 4-2 highlights the location of the cross-sectional profile used for the wave overtopping assessment and Figure 4-3 provides a schematic. Ground levels for the Pier were taken from the topographic survey provided within the Flood Risk Assessment, Scarborough Water Pier (2023) and toe levels of the Pier taken from the bathymetry and cross checked against the recorded water depth from the model result files. The location of the cross-sectional profile was based on the section of West Pier most likely to experience wave overtopping based on the 'nearshore' wave direction discussed in the previous section of this report. Wave overtopping has not been calculated for the longer length of Pier due to waves travelling parallel to, or away from, the pier.

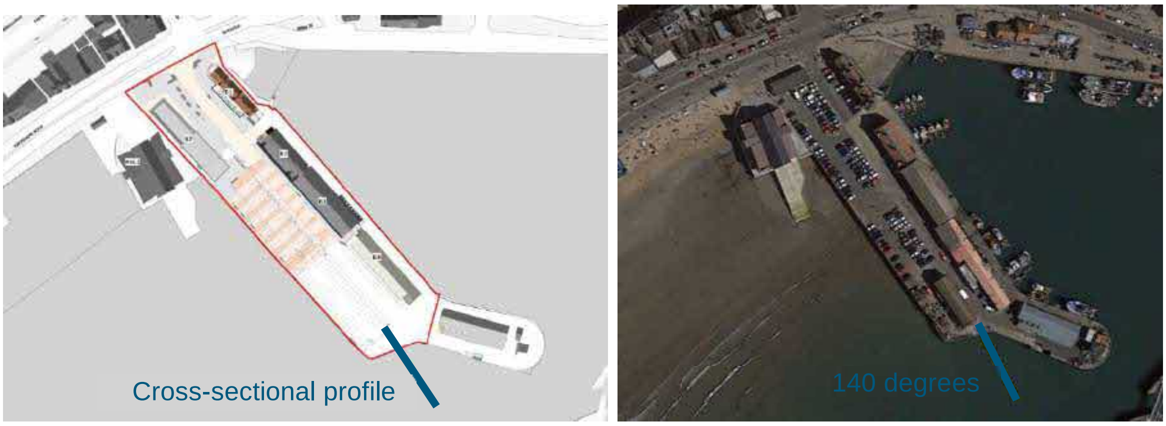


Figure 4-2: Location of the cross-section profile used for the wave overtopping assessment

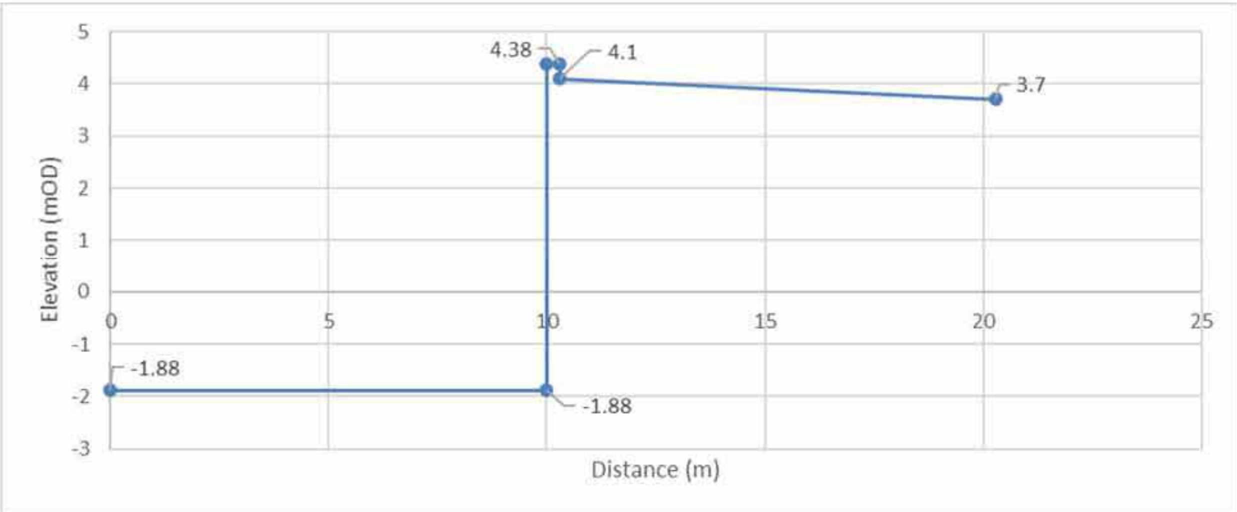


Figure 4-3: Cross-section profile schematic

4.2 Wave Overtopping Guidance

The EurOtop II Manual has been used to analyse the overtopping results. The EurOtop II Manual considers wave overtopping under four categories as defined in Section 3.1 of the Manual. These are:

- Damage to defence structure(s), either short-term or long-term, with the possibility of breaching and flooding.
- Direct hazard of injury or death to people immediately behind the defence, whether they are pedestrian, cyclists or travelling in a vehicle.
- Damage to property, operation and / or infrastructure in the area defined.
- Low depth flooding (inconvenient but not dangerous).

Due to the type and nature of the pier, the direct hazard of injury or death to people immediately behind the defence category has been used in the analysis as presented in Table 4-1.

Table 4-1: Tolerable overtopping for people and vehicles (extract from Table 3.3 of the EurOtop II Manual)

Hazard type and reason	Mean discharge q (l/s per m)	Max volume V_{max} (l per m)
People at structures with possible violent overtopping, mostly vertical structures	No access for any predicted overtopping	No access for any predicted overtopping
People at seawall / dike crest. Clear view of the sea.		
H_{m0} = 3 m	0.3	600
H_{m0} = 2 m	1	600
H_{m0} = 1 m	10-20	600
H_{m0} < 0.5 m	No limit	No limit
Cars on seawall / dike crest, or railway close behind crest		
H_{m0} = 3 m	<5	2000
H_{m0} = 2 m	10-20	2000
H_{m0} = 1 m	<75	2000
Highways and roads, fast traffic	Close before debris in spray becomes dangerous	Close before debris in spray becomes dangerous

For the purpose of this assessment, when considering danger to people, attention is given to the mean discharge limit of 1 litre/second/metre (l/s/m), although it is shown from the nearshore wave conditions modelled that the nearshore wave heights in front of the Pier are below the 2m threshold and therefore, potentially overtopping rates between 1 l/s/m and 10 l/s/m could be tolerable.

Section 3.3.5 of the EurOtop II Manual also considers wave overtopping in the context of danger to vehicles as summarised in the extract in Figure 4-4 below.

> Use of vehicles may also be dangerous under wave overtopping, particularly if flood depths can 'float' the vehicle away. If it is too dangerous for a dike watch to be on foot during storm conditions, it may be safer to drive along the crest in a vehicle, perhaps four-wheel drive. If overtopping volume or velocities that hit the vehicle become too large, it may slide. Such an event i estimated at wave overtopping volumes of around 1000 to 2000 l per m, perhaps given by wave heights around 3 m and a mean discharge of 5 l/s per m. For a wave height around 2 m this becomes a tolerable mean discharge of 10 to 20 l/s per m; and for a wave height around 1 m this is about 75 l/s per m, provided that flood depths are less than 0.3m.

Figure 4-4: Extract from Section 3.3.5 of the EurOtop II Manual

On the basis of the above and considering the likely presence of vehicles on the Pier, attention is also given to the mean discharge limit for nearshore wave heights of approximately 2m (given the previous assumptions) and therefore it is noted that overtopping rates of between 10 ls/m and 20 l/s/m could be tolerable for this scenario.

Given the above, whilst an overtopping rate of approximately 1l/s/m would be preferable, it may be appropriate to consider whether overtopping rates up to approximately 10 l/s/m would be acceptable for consideration as part of the future resilient design. However, this should also be considered within the context of the depth and velocity of the flood water once on the structure as:

"Cars will stop and / or float in water as shallow as 0.5m, whilst some emergency vehicles may survive in water of 1m. A fire engine remains controllable in depths of 0.5m up to a flow velocity of 5 m / s, due to high-level air intakes / exhausts." (Flood Risk Assessment Guidance for New Development Phase 2 R&D Technical Report FD2320/TR2, Defra / Environment Agency 2005)

4.3 Overtopping Calculations

Table 4-2 and Table 4-3 present the calculated overtopping rates (l/s/m) and cubic meters (m^3/s/m) for the 2025 and 2065 1 in 1 year and 1 in 200 year return period event, respectively. To aid comparison of the wave overtopping rates compared to the tolerable overtopping limits to people, Table 4-1, the tables below have been colour coded. Green indicates overtopping limits meets the 1l/s/m safety threshold to people and red indicates the 1l/s/m threshold is exceeded.

The results indicate that the wave approach direction of 150^{o} results in the higher predicted wave overtopping. The predicated wave overtopping limits for a 1 in 1 year return period event in year 2025 is within safety limits for both people and vehicles. However, the people safety limit in year 2065 is exceed for a wave approach direction of 150 degrees. For a 1 in 200 year return period event the vast majority of simulations exceed the safety limit for people and vehicles in both 2025 and 2065.

Table 4-2: Calculated wave overtopping rates for a 1 in 1 year return period event

Year	Joint Probability Combination	Wave approach direction (degrees)	Water Level (mOD)	Wave Height (Hs)	Wave Period (Tm)	Freeboard (m)	Overtopping Rates (l/s/m)	Overtopping Rates (m^3/s/m)
2025	1	150	2.61	0.87	3.47	1.77	0.06	0.00006
	3		3.01	0.79	3.34	1.37	0.21	0.00021
	4		3.13	0.73	3.22	1.25	0.20	0.00020
	6		3.43	0.50	2.96	0.95	0.05	0.005
2065	1		2.90	0.97	3.65	1.48	0.73	0.00073
	3		3.31	0.90	3.52	1.07	2.80	0.0028
	4		3.43	0.82	3.41	0.95	2.77	0.00277
	6		3.73	0.60	2.96	0.65	2.35	0.00235
2025	1	180	2.61	0.53	2.32	1.77	0.00	0.00
	3		3.01	0.48	2.25	1.37	0.00	0.00
	4		3.13	0.44	2.15	1.25	0.00	0.00
	6		3.43	0.32	1.92	0.95	0.00	0.00
2065	1		2.90	0.59	2.43	1.48	0.00	0.00
	3		3.31	0.54	2.35	1.07	0.04	0.00004
	4		3.43	0.52	2.31	0.95	0.06	0.00004
	6		3.73	0.32	1.92	0.65	0.00	0.00

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Table 4-3: Calculated wave overtopping rates for a 1 in 200 year return period event

Year	Joint Probability Combination	Wave approach direction (degrees)	Water Level (mOD)	Wave Height (Hs)	Wave Period (Tm)	Freeboard (m)	Overtopping Rates (l/s/m)	Overtopping Rates ($m^3/s/m$)
2025	1	150	3.01	1.14	5.34	1.37	3.79	0.00379
	4		3.43	1.12	3.95	0.95	16.32	0.01632
	6		3.75	0.94	3.61	0.63	22.07	0.02207
	8		3.99	0.79	3.35	0.39	30.73	0.03073
	11		4.21	0.66	3.12	0.17	46.89	0.04689
2065	1		3.31	1.4	4.52	1.07	19.94	0.01994
	4		3.73	1.27	4.15	0.65	59.09	0.05909
	6		4.05	1.06	8.53	0.33	82.53	0.08253
	8		4.29	0.89	3.53	0.09	105.91	0.10591
	11		4.51	0.74	3.25	-0.13	Pier over-washed by still water level	
2025	1	180	3.01	0.79	2.77	1.37	0.21	0.00021
	4		3.43	0.67	2.58	0.95	0.68	0.00068
	6		3.75	0.57	2.42	0.63	1.99	0.00199
	8		3.99	0.47	2.25	0.39	4.38	0.00438
	11		4.21	0.4	2.10	0.17	13.72	0.01372
2065	1		3.31	0.89	2.90	1.07	2.61	0.00261
	4		3.73	0.77	2.75	0.65	8.70	0.00870
	6		4.05	0.64	2.53	0.33	20.88	0.02088
	8		4.29	0.54	2.38	0.09	43.46	0.04346
	11		4.51	0.45	2.21	-0.13	Pier over-washed by still water level	

4.4 Wave Overtopping Validation

It is well known that validating wave overtopping modelling is challenging, especially when modelling future extreme events. To help provide confidence in the wave overtopping calculations undertaken, wave overtopping for the 1 in 200 year return period event in year 2025 and 2065 for wave approach direction of 150º was also calculated using an on-line tool, Bayonet GPE, developed by HR Wallingford. Bayonet GPE utilises empirical (metamodeling) techniques from the EurOtop II Manual that have been fitted to physical modelling data to generate predictions of overtopping rates. The overtopping calculations require a series of input conditions as the EurOtop method described above does. Table 4-4 provides the wave overtopping predictions for both tools and shows good agreement between the two methods.

Table 4-4: EurOtop Vs Bayonet GPE wave overtopping predictions

Year	Joint Probability Combination	EurOtop	Bayonet GPE
		Overtopping Rates (l/s/m)	Overtopping Rates (l/s/m)
2025	1	3.79	3.58
	4	16.32	14.50
	6	22.07	23.90
	8	30.73	32.90
	11	46.89	31.00
2065	1	19.94	24.40
	4	59.09	56.70
	6	82.53	92.20
	8	105.91	100.00
	11	Pier over-washed by still water level	

5 Flood Depth Assessment

The topographic levels on West Pier are generally flat, between +3.8mOD to +4.38mOD, with no substantial changes in fall. There is a short coping wall (with seepage holes) around the edge of most of the Pier which is generally around 300mm above ground level. During a storm event the coping wall is likely to locally restrict water from flowing back to the sea and may therefore cause some short-term localised flooding / retention. When the water depth exceeds the 300mm coping wall it will drain back to the sea, however the coping wall itself is likely to cause an increase in the water head which will temporarily increase the depth of flooding as water 'backs up'. For this reason, two methods have been applied to calculate the flood depth due to wave overtopping as follows:

- Method 1: The overtopping rate ($m^3/s/m$) multiplied by the length of West Pier considered likely to be at risk from wave overtopping (assumed to be 20m, Figure 5-1) multiplied by 1 hour (based on an assumed constant overtopping rate 30 minutes either side of high tide). The overtopping volumes were then 'spread' over an area of West Pier likely to be inundated and flood water contained / influenced by the perimeter wall (see Figure 5-1) to determine the corresponding flood depths.

Figure 5-1: Method 1 Schematic

- Method 2: applies the rectangular ‘broad-crested’ weir formula as represented by the Figure 5-2. Wave overtopping ‘In Flow’ remains over a 25m length and the potential ‘Out Flow’ length is represented by the length the perimeter wall runs along.

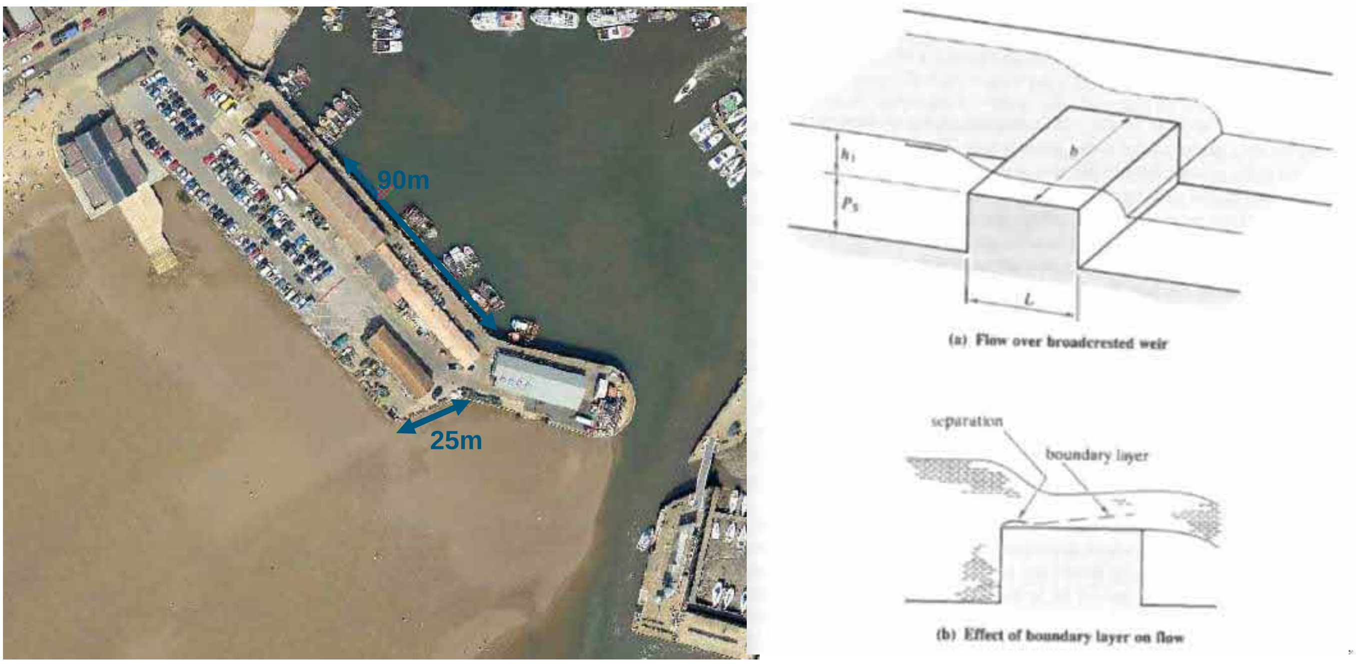

Figure 5-2: Method 2 Schematic

Table 5-1 and Table 5-2 provide a summary of the calculated flood depths using both methods. Method 1 is applicable when predicted flood depths are less than 300mm (i.e. lower than the height of the perimeter wall). If the predicted flood depth using method 1 exceeds 300mm then method 2 has been applied to represent a more realistic flood depth. In this occurrence, the predicted flood depth using Method 1 has been 'greyed out' in the tables below.

Table 5-1: Calculated Flood Depth for a 1 in 1 year return period events

Year	Direction	Joint Probability Combination	Overtopping Rates (l/s/m)	Overtopping Rates (m^3/s/m)	Flood Volume (m^3)	Flood Depth (mm) Method 1	Flood Depth (mm) Method 2
2025	150	1	0.06	0.00006	5	1	N/A
		3	0.21	0.00021	19	4	N/A
		4	0.20	0.00020	18	4	N/A
		6	0.05	0.005	5	1	N/A
2065		1	0.73	0.00073	66	15	N/A
		3	2.80	0.0028	252	57	N/A
		4	2.77	0.00277	249	57	N/A
		6	2.35	0.00235	212	48	N/A
2025	180	1	0.00	0.00	0	0	N/A
		3	0.00	0.00	0	0	N/A
		4	0.00	0.00	0	0	N/A
		6	0.00	0.00	0	0	N/A
2065		1	0.00	0.00	0	0	N/A
		3	0.04	0.00004	4	1	N/A
		4	0.06	0.00004	5	1	N/A
		6	0.00	0.00	0	0	N/A

Table 5-2: Calculated Flood Depth for a 1 in 200 year return period events

Year	Direction	Joint Probability Combination	Overtopping Rates (l/s/m)	Overtopping Rates ($m^3/s/m$)	Flood Volume (m^3)	Flood Depth (mm) Method 1	Flood Depth (mm) Method 2
2025	150	1	3.79	0.00379	341	78	N/A
		4	16.32	0.01632	1,469	334	323
		6	22.07	0.02207	1,986	451	329
		8	30.73	0.03073	2,766	629	335
		11	46.89	0.04689	4,220	959	347
2065		1	19.94	0.01994	1,795	408	327
		4	59.09	0.05909	5,318	1,209	354
		6	82.53	0.08253	7,428	1,688	367
		8	105.91	0.10591	9,532	2,166	379
		11	x	x	x	x	x
2025	180	1	0.21	0.00021	19	4	N/A
		4	0.68	0.00068	61	14	N/A
		6	1.99	0.00199	179	41	N/A
		8	4.38	0.00438	394	90	N/A
		11	13.72	0.01372	1,235	281	N/A
2065		1	2.61	0.00261	235	53	N/A
		4	8.70	0.00870	783	178	N/A
		6	20.88	0.02088	1,879	427	327
		8	43.46	0.04346	3,911	889	344
		11	x	x	x	x	x

Key: ‘x’ – represents extreme still water level exceeding the level of the Pier.

The results indicate that the flood depth associated with wave overtopping during a 1 in 1 year return period event is relatively limited with a maximum predicted depth of 57mm. However, during a 1 in 200 year return period event flood depths for an event in 2025 are predicted to reach 347mm and in 2065 are predicted to exceed the level of the Pier.

As noted above, the topographic levels on West Pier are generally flat, between +3.8mOD to +4.38mOD, with no substantial changes in fall. The 2065 1 in 200 year return period event extreme water level is +4.51mOD which exceeds all levels of West Pier. As a result of this extreme water level event, the West Pier could become inundated by 130mm (at highest points on the Pier) to 710mm (at lowest points on the Pier).

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Hull (Registered Office) Church House 44 Newland Park Hull HU5 2DW [redacted] www.masonclark.co.uk [redacted]	Leeds Unit E Millshaw Business Living Global Avenue Leeds LS11 8PR [redacted] www.masonclark.co.uk	York Partnership House Monks Cross Drive Monks Cross York YO32 9GZ [redacted] www.masonclark.co.uk

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