

FLOOD RISK ASSESSMENT AND SURFACE WATER DRAINAGE STRATEGY

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Gravesham
Kent

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1 INTRODUCTION

Background

- 1.1 RMA Environmental Limited was commissioned by Northfleet Central 1 Ltd to prepare a Flood Risk Assessment (FRA) and surface water drainage strategy in support of the following development on land at Grove Road in Northfleet, Kent, DA11 9AX:

“ an outline application with all matters reserved, except for the primary means of access, for a mixed-use redevelopment involving the demolition of existing buildings and structures including site preparation/remediation works, and the development of residential units (Use Class C3), Use Class E floorspace including floorspace for retail, food and beverage, office floorspace and flexible Class E floorspace, floorspace for a new multi-use stadium with associated business and leisure facilities, floorspace for a hotel (Use Class C1), floorspace for community uses (Use Class F2) and other sui generis uses, delivery of open space and the realignment of the A226 Galley Hill Road/Stonebridge Road with hard/soft landscaping, car and cycle parking, highways works, infrastructure works, ancillary and associated works”.

- 1.2 This FRA has been prepared in accordance with the National Planning Policy Framework (NPPF), associated Planning Practice Guidance (PPG) and Environment Agency (EA) standing advice on flood risk for new development.

Site Location and Land Use

- 1.3 The site area contains predominantly a mix of commercial and industrial warehouses and yards, as well as Ebbsfleet football stadium. The site extends to an area of approximately 19 hectares (ha) and is located at National Grid Reference TQ 61539 75079 (refer to Figure 1.1).
- 1.4 The site is located within the Gravesham Borough Council authority area and is bordered by the following land uses:
- Tower Wharf is located to the north of the site;
 - the River Thames and Robins Creek are located to the north-east of the site;
 - woodland and residential dwellings are located to the south-east of the site;
 - railways lines are located to the south of the site;
 - residential dwellings are located to the south-west of the site; and
 - Northfleet Industrial Estate and Swanscombe Marshes are located to the north-west of the site.

- 1.5 Access to the site is currently via Stonebridge Road, Galley Hill Road, Thames Way and Lower Road. Further details on site topography, geology and hydrology are set out in Section 2.

Proposed Development

- 1.6 This application seeks outline planning permission with all matters reserved (except for access) for the following:
- Site clearance including removal of the existing industrial uses on-site and remediation of brownfield land as relevant;
 - Realignment of the A226 Galley Hill Road / Stonebridge Road;
 - Up to 3,500 residential units (Use Class C3);
 - A new multi-use stadium (with associated facilities) with an estimated 8,000 seats and up to 15,000 m² Gross External Area (GEA) (Sui Generis Use);
 - Up to 22,500 m² (GEA) Use Class E(a) retail floorspace;
 - Up to 9,500 m² (GEA) Use Class E(b) food and beverage floorspace;
 - Up to 18,000 m² (GEA) Use Class E(g)(i) and E(g)(ii) office floorspace;
 - Up to 5,000 m² (GEA) 'other' flexible use, comprising:
 - Up to 1,100 m² (GEA) local services (Use Class E(c));
 - Up to 1,200 m² (GEA) indoor sport, recreation and fitness (Use Class E(d));
 - Up to 1,500 m² (GEA) medical or health services (Use Class E(e));
 - Up to 1,200 m² (GEA) crèche or nursery (Use Class E(f));
 - Up to 4,000 m² (GEA) (Use Class F2) local community use;
 - Approximate 300 room hotel (Use Class C1), comprising up to 20,000 m² (GEA) floorspace;
 - Car and cycle parking; and
 - Provision of landscaping, public realm and associated works.
- 1.7 The proposed development plans are included as Appendix A.

Requirements for a Flood Risk Assessment

- 1.8 The requirements for FRAs are provided in the NPPF¹ and associated PPG². Footnote 59 in Paragraph 173 of the NPPF (December 2023) requires that a site-specific FRA should be submitted with planning applications for:
- all sites greater than 1 ha in Flood Zone 1;
 - for sites of any size within Flood Zones 2 or 3;
 - in an area within Flood Zone 1 which has critical drainage problems;
 - in an area within Flood Zone 1 which is identified in a strategic flood risk assessment as being at increased flood risk in the future; and/or
 - an area within Flood Zone 1 that may be subject to other sources of flooding, where its development would introduce a more vulnerable use.

¹ Department for Levelling Up, Housing and Communities. (2023). National Planning Policy Framework.

² Department for Levelling Up, Housing and Communities. (2022). Planning Practice Guidance. Flood Risk and Coastal Change. (Online). Available at: <https://www.gov.uk/guidance/flood-risk-and-coastal-change>.

1.9 The EA's Flood Zones are defined as follows:

- Flood Zone 1 is defined as land with little or no flood risk (an annual exceedance probability [AEP] of flooding of less than 0.1%);
- Flood Zone 2 is defined as having a medium flood risk (an AEP of between 0.1% and 0.5% for tidal areas or 0.1% and 1.0% for rivers); and
- Flood Zone 3 is defined as high risk (with an AEP of greater than 0.5% for tidal areas or greater than 1.0% for rivers).

1.10 The EA's Surface Water Flood Risk extents are defined as follows:

- Very low surface water flood risk is defined where "each year, this area has a chance of flooding of less than 1 in 1000 (0.1%)."
- Low surface water flood risk is defined where "each year, the area has a chance of flooding of between 1 in 1000 (0.1%) and 1 in 100 (1%)."
- Medium surface water flood risk is defined where "each year, this area has a chance of flooding of between 1 in 100 (1%) and 1 in 30 (3.3%)."
- High surface water flood risk is defined where "each year, this area has a chance of flooding of greater than 1 in 30 (3.3%)."

1.11 FRAs should describe and assess all flood risks (from rivers, the sea, surface water, sewers, reservoirs and groundwater) to and from the development and demonstrate how they will be managed, including an evaluation of climate change effects.

Relevant Planning Policy

1.12 This FRA has been undertaken with reference to the following key policy and guidance documents:

- Gravesham Local Plan Core Strategy Local Plan (Adopted September 2014)³;
- Gravesham Water and Flood Risk Background Paper (October 2020)⁴;
- Kent County Council's Drainage and Planning Policy Statement (2019)⁵;
- Kent Design Guide Making it Happen – Appendix C2 Drainage Systems⁶; and
- Other relevant planning policy and guidance documents.

Consultation

1.13 Consultation has been undertaken with the EA throughout the design of the proposed development (refer to Appendix B). This has included initial pre-application advice with regard to flood levels, flood modelling, flood defences and Finished Floor Levels (FFLs) of the proposed buildings.

³Gravesham Borough Council. (2014). *Gravesham Borough Council Core Strategy Local Plan*.

⁴Gravesham Borough Council. (2020). *Gravesham Water And Flood Risk Background paper*.

⁵Kent County Council. (2019). *DRAFT Drainage and Planning Policy Statement – Local Flood Risk Management Strategy Guidance*.

⁶Kent County Council (2007). *The Kent Design Guide – Making It Happen Sustainability (Drainage Systems) – Appendix C2*.

- 1.14 As well as this, consultation has been undertaken with regards to daylighting the culvert that is currently present on site and updating the River Ebbsfleet flood model to include the daylighting scenario. This report has been updated to address these points where necessary.
- 1.15 Consultation has been undertaken with the Lead Local Flood Authority (LLFA) with regard to the surface water drainage strategy, surface water flooding and groundwater flooding (refer to Appendix C).
- 1.16 Asset location plans have been received from Southern Water which indicate that surface water and foul sewers are located along Stonebridge Road within the site (refer to Appendix D). Foul sewers are located along Grove Road and the unnamed road in the western part of the site and a rising main is located along Lower Road and Stonebridge Road within the site.

2 BASELINE ENVIRONMENTAL CONDITIONS

Topography

- 2.1 According to Light Detection and Ranging (LiDAR) data and the spot levels within the site, the majority of the site slopes in a southerly direction towards the south-eastern corner, although the south-east corner and the northern and western parts of the site slopes in a northerly direction (refer to Appendix E). The highest level is recorded to be at a level of approximately 4.80 metres Above Ordnance Datum (mAOD) in the northern part of the site, falling to approximately 2.52 mAOD in the south-eastern corner of the site (refer to Appendix E).

Hydrology

- 2.2 The closest 'main river'⁷ is the River Ebbfleet which flows through the south-eastern part of the site, within a culvert, in a northerly direction and enters Robins Creek approximately 25 m to the north-east of the site. This ultimately flows into the River Thames via a tidal flap resulting in the discharge from the Robins Creek being restricted by the tidal regime of the River Thames. According to the Flood Estimation Handbook (FEH) web service, this watercourse has a catchment area of 46.1 km² at the site location.
- 2.3 Ebbsfleet is an open watercourse up until 130 m south of the site where it meets Thames Way. The EA's Flood Map Improvements: Ebbsfleet Modelling Report states that the Ebbsfleet enters a 450 m long culvert with a 1.71 m diameter, referred to as the Long Culvert, beneath the A226 Thames Way and outfalls into a small section of open channel to the east of the site. The watercourse then enters a 63 m long culvert with a 0.95 m diameter, referred to as Grove Road Culvert, before discharging into Robins Creek.
- 2.4 Swanscombe Marshes (part of the Swanscombe Peninsula Site of Special Scientific Interest) are located to the north-west of the site which comprise areas of marshland and a number of local land drains.
- 2.5 The River Thames tidal defences are located outside of the application site boundary to the north and the defences along the edge of Robins Creek are located outside of the application site boundary to the east.
- 2.6 There are no other significant watercourses or water bodies within the surrounding area.

⁷ Main river is defined by the EA as any watercourse that contributes significantly to the hydrology of a catchment.

Geology and Hydrogeology

- 2.7 According to the British Geological Survey (BGS) online viewer⁸, the majority of the site is underlain by the superficial deposits of Alluvium comprising clay, silt, sand and gravel. Areas along the eastern and western boundaries are underlain by the superficial deposits of Head comprising clay, silt, sand and gravel. A few areas along the eastern boundary and north-western corner are not underlain by any superficial geology.
- 2.8 According to Defra's online Magic Map⁹, the EA classify the Alluvium and Head deposits as undifferentiated Secondary Aquifer; these are defined as areas where *"it has not been possible to attribute either category A or B to a rock type. In most cases, this means that the layer in question has previously been designated as both minor and non-aquifer in different locations due to the variable characteristics of the rock type."*
- 2.9 According to the BGS Geology of Britain Viewer, the site is entirely underlain by the bedrock geology of the Lewes Nodular Chalk Formation, Seaford Chalk Formation and Newhaven Chalk Formation comprising chalk.
- 2.10 The Lewes Nodular Chalk Formation, Seaford Chalk Formation and Newhaven Chalk Formation is classified by the EA as a Principal Aquifer; these are defined as *"layers of rock or drift deposits that have high intergranular and/or fracture permeability - meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale. In most cases, principal aquifers are aquifers previously designated as major aquifer"*.
- 2.11 From reviewing the BGS 1:50,000 map series England and Wales Sheet 271 for Dartford, it shows that the site is located in an area of previously worked ground. The BGS map also shows that Kempton Park Gravels are located beneath the Alluvium deposits underlying the site.
- 2.12 The EA classify the Kempton Park Gravels as Secondary A Aquifer; these are defined as *"permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers."*
- 2.13 From reviewing BGS mapping, there is an available borehole record located in the centre of the site (TQ67SW791), which was drilled to a depth of 21.34 m and had the following geological sequence:
- Drift deposits (4.28 m thick); and
 - Chalk and flints (at least 17.06 m thick).

⁸ British Geological Survey. (2019). Geology of Britain 3D (Beta version)

⁹ DEFRA. Magic Map. <https://magic.defra.gov.uk/MagicMap.aspx>

- 2.14 The Groundsure Reports within the Phase 1 Land Contamination Assessment Report (included within ES Volume 3, Appendix Ground Conditions: Annex 2) confirms that the site is underlain by artificial deposits of made ground and worked ground specifically in the northern extent of the site. The Groundsure report confirms that there is a mix of artificial ground permeability on site with a maximum permeability of 'very high'.
- 2.15 The majority of the site is located within the Zone II (Outer Protection Zone) groundwater Source Protection Zone and a limited area in the western boundary is located within the Zone 3 (Total Catchment) groundwater Source Protection Zone.
- 2.16 Zone II (Outer Protection Zone) groundwater Source Protection Zone is defined as *'by the 400-day travel time from a point below the water table. Additionally, this zone has a minimum radius of 250 or 500 metres, depending on the size of the abstraction. The travel time is derived from consideration of the minimum time required to provide delay, dilution and attenuation of slowly degrading pollutants'*.
- 2.17 Zone 3 (Total Catchment) groundwater Source Protection Zone is defined as *'the area around a source within which all groundwater recharge is presumed to be discharged at the source. In confined aquifers, the source catchment may be displaced some distance from the source. For heavily exploited aquifers, the final Source Catchment Protection Zone can be defined as the whole aquifer recharge area where the ratio of groundwater abstraction to aquifer recharge (average recharge multiplied by outcrop area) is less than 0.75'*.

3 EXTERNAL FLOOD RISK

Flooding Mechanisms

- 3.1 The EA's flood map for planning¹⁰ (refer to Figure 3.1) indicates that the majority of the site lies within Flood Zone 3 (high risk) and there are small areas of Flood Zone 2 (medium risk) throughout the site. However, the site is shown to lie within an area benefitting from flood defences along the River Thames which is discussed further below.
- 3.2 The EA's surface water flood risk map¹¹ identifies that the majority of the site has a very low risk from surface water flooding with areas of low, medium and high flood risk of surface water flooding throughout the site (refer to Figure 3.2).
- 3.3 A review of Kent County Council's Local Flood Risk Management Strategy¹² concludes that groundwater flooding in the area is known to occur in areas underlain by major aquifers and is localised with floodplain sands and gravels. This is discussed further below.
- 3.4 The Thameside Stage 1 Surface Water Management Plan¹³ (SWMP; JBA Consulting, 2013) includes a record of a hydraulic overload of the foul system on Thames Way in 1994 where flooding affected a cellar, garage and building. No further details are given on the location of these records or if upgrades were conducted since 1994. Subject to consultation with Southern Water, mitigation against sewer flooding could be achieved through the provision of non-return valves which prevent water entering the property from drains and sewers. Non-return valves can be installed with gravity sewers or drains, within the property's private sewer system. Further information is provided in the CIRIA publication 'Low cost options for prevention of flooding from sewers'. Therefore, with the proposed mitigation measures within the site, the risk from sewer flooding is deemed to be low.
- 3.5 A review of the Local Flood Risk Management Strategy, SWMP and EA flood maps, has identified that there are no other significant sources of flooding at the site, i.e. from reservoirs.

Historic Flooding

- 3.6 The Thameside Stage 1 Surface Water Management Plan (SWMP; JBA Consulting, 2013) has been reviewed to establish any records of flooding at or in close proximity to the application site. This identifies that a record of flooding within the site during a breach of the Thames defences. Stonebridge Road within the site is recorded to have flooded in 2009 due to surface water to a depth of 1 ft and in 2010 due to a burst water main.

¹⁰ Environment Agency. (2019). Flood Map for Planning [Online]. [Accessed March 2024]. Available from: <https://flood-map-for-planning.service.gov.uk/>

¹¹ Environment Agency. (2019). Long term flood risk assessment for locations in England [Online]. [Accessed March 2024]. Available from: <https://flood-warning-information.service.gov.uk/long-term-flood-risk>

¹² Kent County Council. Kent Local Flood Risk Management Strategy. 2017

¹³ Kent County Council, JBA Consulting. Thameside Surface Water Management Plan

- 3.7 Consultation undertaken with the LLFA has identified a number of flood records along Thames Way, Stonebridge Road, Eagle Way, Grove Road and Lower Road due to heavy rainfall and blocked drains/gullies causing surface water flooding (refer to Appendix C).
- 3.8 The EA's historic flood map indicates that a record of historic flooding in February 1953 affected the site due to the tidal defences being overtopped (refer to Figure 3.3). However, since this flood event occurred, the River Thames defences have been upgraded reducing the risk of tidal flooding.

River Thames Flood Levels and Defences

- 3.9 The detailed flood level and flood defence data provided by the EA is included as Appendix F. The data presented has been extracted from the Thames Estuary 2100 Study produced by HR Wallingford (2008). In-channel flood levels for the closest modelled nodes to the site have been provided and these represent the highest levels permitted by the Thames Barrier. The closest modelled node to the proposed development is Node 3.23. Table 3.1 below contains the extreme water levels and defence levels that are applicable to the site.

Table 3.1 – Thames Estuary 2100 Extreme Water Levels for Node 3.23

	THAMES ESTUARY 2100 WATER LEVELS	
	PRESENT DAY	2100
Extreme Water Level (mAOD)	5.85	6.52
Defence Level (mAOD)	6.75	8.00

- 3.10 The site lies at an elevation between 2.52 mAOD and 4.80 mAOD and, therefore, is 3.33 m below the present-day extreme flood level and 4.00 m below the 2100 extreme flood level based on the extreme water levels downstream of the Thames Barrier.
- 3.11 However, the flood defence crest heights downstream of the Thames Barrier are significantly higher than the extreme water levels and, therefore, the site is provided protection for all scenarios.
- 3.12 The River Thames defences provide a standard of protection up to the 0.1% annual exceedance probability (AEP) combined tidal and fluvial event. This remains true up to the year 2070, after which the standard of protection will decrease with time. However, the Thames Estuary 2100 project¹⁴ has studied options to manage flood risk in the Thames Estuary up to the year 2100, with the aim of implementing flood protection measures for the future.

¹⁴ TE2100, available on the Gov.uk website: <https://www.gov.uk/government/publications/thames-estuary-2100-te2100>

- 3.13 The River Thames defences were originally designed with an allowance for sea level rise due to climate change to the year 2030. However, these defences were constructed with a predicted sea level rise of 8 mm/yr, whereas the actual rate of sea level rise has been measured at approximately 3 mm/yr. Therefore, the River Thames flood defences are providing a greater flood defence capability than expected and will not need any major changes until 2070.
- 3.14 It is recommended for the Swanscombe and Northfleet Policy Unit (which includes the site area) that the defences will need to be raised to 8.00 mAOD by 2070. However, the actual dates of defence raising are yet to be decided due to the uncertainty in climate change predictions and the associated increase in sea level.

River Wall Impact Assessment (RWIA)

- 3.15 Walsh have been appointed to undertake a RWIA and to advice on the river wall matters related to the development. This is included as Appendix G of this report.
- 3.16 Through consultation with the EA it has established that the development proposals will include a 16 m “setback”. It has also been noted by the EA that the development will need to include a new tidal defence structure or mechanism with a defence level of 8 mAOD to account for climate change impacts and see that the development is sustainable from a flood defence perspective for the next 100 years.
- 3.17 These proposals have been incorporated into the landscape strategy although the actual details of the riparian public realm are not the subject of the proposed outline planning application and will be a reserved matter. In this regard, the RWIA is focused on seeing that the strategy can be delivered and maintained and further detail will form part of subsequent submissions.
- 3.18 To demonstrate that the proposals are achievable and sustainable, Walsh have developed a number of options and sections that could be implemented for the new river wall and they all have the following common key design features;
- riparian area 16 m from waterfront to be free from development;
 - top of defence level set at 8.00mAOD;
 - edges to tie into defences on either end of the wall to ensure continuous defence;
 - access provided for maintenance vehicles;
 - 100-year design life;
 - existing river wall considered sacrificial from a flood defence perspective; and
 - Typically, 6m-8m wide service area behind the new defence line to enable emergency and maintenance works.
- 3.19 Given that the detailed design will focus on the “terracing” of the riparian land Walsh have outlined several options that will form a “design code” for the development of the detailed design and these are included within Appendix G.

- 3.20 Given that the river wall is believed to be a cantilevered sheet pile wall, lowering the wall will reduce the stress and thus increase its residual life. In this regard, the lowering of the existing wall in some way is likely to form a fundamental part of the proposals as this not only has structural benefits but it is in line with the EA desire to make the river more accessible. Should the need arise additional tie rods will be installed to enhance the residual design life.
- 3.21 Visual inspections would be possible from the riverside walk and from the river. Technology such as drones could also be used to provide a visual inspection. Such inspections would need to be undertaken regularly (i.e. every two years). A more detailed inspection will be required every five to six years. This may also include minor maintenance and access for a detailed inspection the river wall will generally be via the river itself at low tide but could also be via the use of specialist access equipment and plant which is readily available.
- 3.22 Access for equipment and associated transport would be via the site access road at the north where it could be dropped close to the riverside path. Major maintenance and repairs may be required and it is likely that planned major maintenance will be required every 10-15 years. For such tasks, a lorry up to 30T could access via the site highways and materials distributed along the river edge with “dumpers” and forklift type equipment. It is for these sorts of vehicles that the minimum width of 8 m should be provided for the upper terrace of each design option.

EA Breach and Inundation Analysis

- 3.23 Whilst the site is anticipated to benefit from the River Thames flood defences for its operational lifetime, it is necessary to consider if the proposed development could be affected by a breach in the flood defences.
- 3.24 Detailed flood data has been extracted from the Thames Tidal Downriver Breach Inundation Modelling Study 2018 completed by Atkins Ltd. The downstream inundation modelling is a representation of ‘at risk’ areas assuming no defences. The modelling is based on the 2008 TE2100 in-channel levels for the 0.5% AEP and the 0.1% AEP events. The modelling represents all downstream tidal breach locations based on low floodplain topography.
- 3.25 The results of the Thames Tidal Downriver Breach Inundation Modelling Study (2018) identify that the site is located within the modelled breach zone for the 0.5% AEP events (refer to Appendix F). Figure 6 within Appendix F shows the flood nodes throughout the site and the corresponding 0.5% AEP flood levels for the year 2115 for these nodes. Table 3.4 sets out the 0.5% AEP flood levels for the nodes throughout the site (Nodes, 2, 10, 13, 16, 30).

Table 3.2: 0.5% AEP Flood Levels

MODELLED FLOOD LEVELS (mAOD)	
2005	2115
<i>Tidal Breach Inundation Scenario (Node 2)</i>	
4.58	5.11
<i>Tidal Breach Inundation Scenario (Node 10)</i>	

MODELLED FLOOD LEVELS (mAOD)	
2005	2115
4.66	5.56
<i>Tidal Breach Inundation Scenario (Node 13)</i>	
5.35	6.02
<i>Tidal Breach Inundation Scenario (Node 16)</i>	
4.84	5.41
<i>Tidal Breach Inundation Scenario (Node 26)</i>	
4.32	5.27

- 3.26 The site could flood to a maximum depth of 2.08 m in the vicinity of node 26 during a breach event in the 2014 epoch. A few areas along the eastern and western boundaries are located outside of the breach extent in the 2014 epoch as this part of the site is at a higher elevation.
- 3.27 With an allowance for climate change, the 0.5% breach flood level varies from 5.11 mAOD in the western corner to a level of 6.02 mAOD in the north along the bank of the River Thames and, therefore, the flood levels vary significantly across the site (refer to Appendix F). Based on a review of LiDAR, the flood depths during the 0.5% breach event in the year 2115 vary between 0.004 m located along Stonebridge Road and the eastern boundary and 3.19 m in the south-eastern corner (refer to Appendix F).

Fluvial Flood Risk

- 3.28 The River Ebbsfleet Model (Capita URS, 2015) received from the EA indicates that the site is located within fluvial Flood Zone 1 as it is not affected by the 1% or 0.1% AEP flood events (refer to Appendix F).
- 3.29 The latest guidance on climate change for the Medway Management Catchment states that a central climate change allowance of 27% should be used for 'more vulnerable' development. The 1% AEP plus 27% climate change flood level was not provided by the EA; however, the 1% plus 35% climate change scenario is available. This indicates that the site is located outside of this flood extent and, therefore, the site is not located within future Flood Zone 3 (refer to Appendix F).
- 3.30 A 75% blockage scenario during the 50% and 20% AEP events were undertaken for the Long Culvert and Grove Road Culvert and this indicates that the site would remain unaffected during these blockage scenarios (refer to Appendix F).
- 3.31 Consultation with the EA indicates that this model is '*inaccurate and the model should not be used as the only assessment of fluvial flood risk at this site*' (refer to Appendix B). Following this, JBA Consulting were commissioned to undertake a hydraulic modelling study of the River Ebbsfleet. During pre-application consultation, the EA raised concerns with the current understanding of fluvial flood risk in the study area. It was recommended that a new flood modelling exercise was undertaken to provide an improved understanding of flood risk for the proposed development.

- 3.32 The Northfleet Flood Modelling Technical Note (included as Appendix H) has been produced to provide a summary of the flood modelling works that have been completed as well as providing an analysis of the modelling results. The document also includes discussion on the assumptions and uncertainties that are present within the model.
- 3.33 The new hydraulic model of the River Ebbsfleet is a 1D-2D linked Flood Modeller – TUFLOW model. The previous study included a detailed groundwater analysis which was undertaken to derive a suitable baseflow boundary for application to the hydraulic model. A groundwater level of 4.3 mAOD was found to have an annual probability of 0.025 and represents the upper 95% confidence interval. The 4.3 mAOD groundwater level was applied to the model as a time invariant level using a head-time boundary (HTBDY) and a Bernoulli loss unit. Consideration was given to applying a groundwater level and Bernoulli loss unit as per the previous study, updating the analysis to use the latest data. However, findings from the current study concluded that this is not recommended, and instead a fluvial only approach has been adopted.
- 3.34 Storm duration testing has been completed to determine the critical storm duration, resulting in the largest flood extent and highest water levels throughout the modelled study area. Storm durations of 15-hour, 23-hour, and 31-hour were used for this testing. The 31-hour duration produced the largest flood extent and the highest water levels and therefore this has been adopted for the final design event simulations. For the storm duration testing, the application of the tidal boundary has been included as the potential for tide locking is critical for understanding the flood mechanism impacting the study area.
- 3.35 The Environment Agency model review questioned whether a longer duration than the 31-hour should have been tested. The FEH Calculation Record has been updated to summarise the limitations associated with using longer storm durations as they become less representative of real storm events. To provide further justification that the testing of longer storm durations is not required, the storm duration testing results have been presented and discussed with the Environment Agency which showed only negligible differences in maximum water level between the 23-hour and 31-hour results. The difference in the maximum water level between the 23-hour and 31-hour storm duration outputs is very small (up to 6mm) in the downstream portion of the model extent where the primary interest of this study focuses on. Given the negligible differences in modelled water levels, the Environment Agency have agreed that no further storm duration testing is required.
- 3.36 To account for the impact of sea level rise during climate change scenarios, the Mean High Water Spring (MHWS) levels were uplifted by 1.078 m (Higher Central allowance) based on the Environment Agency's guidance on Flood risk assessments: climate change allowances.
- 3.37 The updated baseline scenario has been simulated for a range of design events including the 3.33%, 1%, and 0.1% AEP present day events and the 1% AEP event plus climate change with uplifts of 27%, 37%, and 62% to represent the Medway Management Catchment peak river flow allowances.

- 3.38 The new flood modelling indicates that there is currently no fluvial flood risk to the site in any design event. The reason there is no flooding to the site is due to the location of the raised road embankments located upstream of the long culvert. Water is stored upstream of the A226 road embankment and is prevented from flowing northwards to the site.

Culvert Realignment and Daylighting

- 3.39 Consultation with the EA has determined that the development is an opportunity to de-culvert and naturalise the river channel providing enhancement to the site. Therefore, an outline design of daylighting the existing culvert has been developed.
- 3.40 An above ground topographical survey of the area surrounding the culvert has been undertaken and, where possible, manholes have been lifted to measure the depth of the culvert at points where access was possible. The survey results are included as Appendix I. The surveyed information confirms that the culvert is at significant depth and, at a minimum, the water level is 1.71 m below ground level in the south-eastern part of the site and at a maximum 3.29 m deep in the north-east.
- 3.41 HLM Architects prepared a Proposed River Daylighting Sections plan and Proposed Daylighting Zone plan which shows the indicative daylighted river location and cross-sections within the site (refer to Appendix J). These plans show that the majority of the River Ebbsfleet within the site is proposed to be daylighted, there is a small section of the channel to the south of B2175 that will remain within the existing culvert, two bridges are proposed to allow for highways access over the daylighted section. It proposed that the bridge crossings will be clear spanning with soffit levels that are greater than the bank elevations and further details will be provided at the detailed design stage and controlled through a suitably worded planning condition. It will be ensured that the culverted section within the site will be maintained throughout the operational lifetime of the development and if required the culvert will be increased in size to accommodate the flows during the design flood flows.

Easements

- 3.42 The buildings adjacent to the watercourse have been moved to the east to provide space for daylighting the culvert and the indicative daylighted sections will comprise of landscaped banks, stepped banks and walls in order to accommodate the daylighted section within the layout. A minimum easement of 3.5 m from the top of the banks of the watercourse to the ground and first floors of the buildings would be provided in line with the EA's suggestion during the meeting that *'the maintenance buffer of 8 m could be reduced if the river is daylighted'*. A maintenance access of over 8 m can be provided on the western side of the daylighted culvert which includes the boulevard and, therefore, the River Ebbsfleet can be maintained from this side. Additionally, sections of the proposed buildings to the east of the daylighted culvert will comprise of public walkways at ground level which will provide an increased easement from the watercourse in these areas and will be open across two levels, which can allow for vehicles to enter from the east should this be necessary (refer to the indicative cross sections shown within Appendix J).

Daylighting Modelling

- 3.43 This outline daylighting design has been tested within the Hydraulic model (refer to Appendix H) to understand the potential fluvial flood risk constraints. To represent the daylighted reach as accurately as possible, a 1D-2D linked approach has been adopted with the long culvert cut down and new open channel river sections added into Flood Modeller. In the event of the channel capacity being exceeded, the 1D reach has been linked to TUFLOW to allow spilling into the floodplain with HX boundary conditions applied along the right and left bank locations and along the upstream and downstream faces at the entry and exit of the daylighted reach.
- 3.44 For the representation of the open channel sections in the 1D domain, each channel section has been represented using a Flood Modeller river channel section unit. A consistent approach to the Manning's n roughness coefficients has been adopted with a bed roughness of 0.035 and a bank roughness of 0.05. The exact bed and bank material will need to be confirmed but these values were chosen to reflect a more naturalised river channel as requested by the Environment Agency.
- 3.45 Analysis of the model outputs has shown that no spilling will occur from the proposed daylighted channel in any of the design event simulations. This is shown in Figure 4-5 of Appendix H which shows the maximum flood depth outputs for the 0.1% AEP event. All floodwater is contained within channel for all design event simulations.
- 3.46 To further demonstrate that spilling will not occur in any of the modelled design events, the maximum water level from the daylighted reach at section B-B has been tabulated and is shown in Table 3.3 below. This location has been chosen for comparison as it has the lowest top of bank elevations and is therefore most susceptible to out of bank flooding. The bank heights at this location have been set to 4.1 mAOD which is well above the maximum modelled water levels shown in Table 3.3.

Table 3.3: Maximum Water Levels with Daylighted Reach (Extracted from Table 4.1 of Appendix H)

Design Event AEP	Maximum Water Level (Maod)
1%	3.90
1% plus climate change (27%)	3.86
1% plus climate change (37%)	3.86
1% plus climate change (62%)	3.87
0.1%	3.82

Robins Creek Managed Realignment

- 3.47 The 2015 flood modelling included a scenario called 'managed realignment'. This removed the tidal wall separating Robins Creek from the River Thames to allow tidal ingress and installation of a tide flap on the long culvert to prevent the tide backing-up the structure. The Environment Agency requested that this scenario was tested as part of the current modelling study to understand any potential implications for the daylighted reach of channel.

- 3.48 The management realignment results in an increase in water levels through the daylighted reach but, importantly, it does not result in any out of bank flooding in any design event or climate change scenario (refer to Appendix H).

Sensitivity Testing

- 3.49 The Environment Agency interim review of the hydraulic modelling noted that the REVA flood modelling deliverable did not include any sensitivity testing; this has been undertaken for the revised REVB submission. It was decided to complete the sensitivity testing on the daylighted reach model scenario to understand how the model parameterisation could affect the assessment of flood risk for the proposed scheme. The sensitivity testing has been completed on the 1% AEP plus climate change (27%) event as this is considered most important for the flood risk assessment.
- 3.50 The sensitivity testing of the Manning's n roughness indicates that this is having very little impact on the modelled flood risk throughout the study area. Due to the tide locking flood mechanism, the channel conveyance and roughness coefficients are having less of an impact. Through the proposed daylighted reach, the change in roughness results in minimal change to water levels (+/-4mm) meaning that this parameter has no significant bearing on the assessment of flood risk for the proposed development.
- 3.51 The downstream boundary sensitivity testing has shown that altering the MHWS tide curve will have a significant influence within Robins Creek as would be expected but this does not propagate upstream. Through the proposed daylighted reach, the application of the downstream boundary is having a negligible impact on the modelled water levels and has no bearing on the modelled flood extents.
- 3.52 As part of their final review of the model, the Environment Agency requested that blockage testing was completed looking at the culvert located at the downstream end of the proposed daylighted reach. This is to understand the potential impact that a blockage would have on water levels within the daylighted reach and to determine whether this would result in out of bank flooding to the proposed development area.
- 3.53 Analysis of the results have shown that the reduction in opening area of the culvert due to the application of 50% blockage is not having a significant impact on water levels through the daylighted reach and doesn't result in any out of bank flooding. This appears to have occurred due to a combination of the of tide locking on the River Ebbsfleet watercourse which limits the discharge of the River Ebbsfleet, and the constriction of the culverted unit located further downstream which acts as a control on water levels upstream.

Surface Water Flood Risk

- 3.54 The majority of the site has a very low surface water flood risk; however, areas of low, medium and high surface water flood risk are located throughout the site particularly in the southern part of the site (refer to Figure 3.3).
- 3.55 The EA's surface water flood risk mapping shows what *"happens when rainwater does not drain away through the normal drainage systems or soak into the ground, but lies on or flows over the ground instead."* It is noted that this type of flooding is difficult to predict and is based on the best information available to the EA regarding ground levels and drainage.

- 3.56 The low surface water flood risk is beyond the 1% AEP design event and, therefore, no mitigation is required for this surface water flood event.
- 3.57 There are areas of localised ponding throughout the site which have between a medium and high surface water flood risk. However, with the adoption of the drainage strategy outlined in Section 4, it is considered that surface water flooding would not adversely affect the proposed development and the surface water flood risk is considered to be less significant than the tidal risk. As such, the mitigation discussed below for tidal flooding is also relevant to this source.

Groundwater Flood Risk

- 3.58 A review of Kent County Council's Local Flood Risk Management Strategy (LFRMS) concludes that groundwater flooding in the area is known to occur in areas underlain by major aquifers and is localised with floodplain sands and gravels. According to BGS groundwater flooding susceptibility, the site has up to a '*high risk of groundwater flooding*'.
- 3.59 From reviewing BGS mapping, a borehole record located in the centre of the site (BGS reference: TQ67SW791) was drilled to a depth of 21.34 m and groundwater was not encountered. A review has been undertaken of other nearby boreholes and a borehole located approximately 200 m south-west of the site along the railway line (BGS reference: TQ67SW865) was dug to a depth of 10 m and this encountered groundwater at 5.70 metres below ground level (mbgl) within the upper chalk. Two adjacent borehole records (TQ67SW580 and TQ67SW599) encountered groundwater at 4.60 mbgl and 5.10 mbgl.
- 3.60 Pre-application consultation has been undertaken with Gravesham Borough Council (GBC; refer to Appendix C). This states that the "*site conditions identified from mapping show the underlying geology as Upper Chalk with groundwater likely to be seated at less than 3m below the ground surface, which may be subject to seasonal variation*".
- 3.61 There are no specific records of groundwater flooding in the vicinity of the site and no basements are proposed. Given the chalk aquifer underlying the site as well as gravels and the proximity of the site to the River Thames, it should be considered, as a worst case scenario, that groundwater levels are relatively shallow on site. With this in mind, it is considered that any risk of groundwater flooding can be mitigated alongside the measures proposed to protect the site from tidal flooding.

Mitigation Measures

Finished Floor Levels

- 3.62 The EA recommends that the '*finished floor level of more vulnerable units should be set no lower than 600mm above the design flood level for the site*' (refer to Appendix B).

- 3.63 The majority of the 'more vulnerable' land uses will be located on the first floor or above to ensure that they are located above the design breach flood levels, this includes all sleeping accommodation (refer to figure 3.4). Although some of the 'more vulnerable' land uses are located below the design flood level, these will include ancillary uses such as entrances and service rooms for the 'more vulnerable' land uses located above (refer to Figure 3.5). The proposed entrances will not include waiting rooms and all of the 'more vulnerable' land uses at the ground floor will have access to internal staircases which lead to the second floor (i.e. above the design flood level).
- 3.64 It is proposed to incorporate flood resilient techniques on the ground floor where FFLs cannot be raised above the design flood level.

Flood Resilience

- 3.65 Flood resilience measures aim to construct the building in a way that flood water may enter a building but its impact is reduced. Flood resilience measures are proposed for the ground floors of the proposed buildings which are not raised 600 mm above the breach levels with the aim of providing additional protection.
- 3.66 The Department of the Communities and Local Government (DCLG) published a report entitled '*Improving the flood performance of new buildings: flood resilient construction*'¹⁵ in 2007. This document provides guidance on building materials, floors, walls, doors and windows, fittings and services. It is recommended that the detailed design of the ground floor elements of the development to consider the advice and guidance set out in this report.
- 3.67 Simple measures such as setting electrical sockets and vulnerable infrastructure 300 mm above the design flood level (where possible) would ensure that these buildings would remain operational during a flood event.
- 3.68 Furthermore, the ground floor levels of these buildings would be designed to allow water to drain away after flooding and access to all spaces would be provided to allow drying and cleaning.

Flood Warnings

- 3.69 As the proposed development is at risk of tidal flooding, the occupants of the residential units and the managers of the other land uses would register to the EA's flood warning service for the local area, to ensure as far as possible that sufficient warning is provided in the event of an extreme flood. This will ensure that, should the EA issue a flood warning for the area, all occupants would have sufficient time to safely leave the site.
- 3.70 The site users will be responsible for acting on flood warnings and the procedures to be followed in the event of a flood. These measures will be set in a Flood Evacuation Plan, which would be submitted to the EA and Council for approval prior to commencement of the proposed development.

¹⁵ Improving the Flood Performance of New Buildings [Online]. [Accessed December 2020]. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/7730/flood_performance.pdf

Safe Access/Egress

Tidal Flooding

- 3.71 It has been demonstrated that the site is protected from the current and future extreme water levels due to the presence of the Thames defences. However, the site is at risk of flooding during the breach events for the present and climate change scenarios.
- 3.72 The EA's Thames Tidal Breach Hazard Mapping indicates that the safe access/egress route along High Street to the east has a 'very low hazard' rating, the route along Galley Hill Road has a maximum hazard rating of a 'danger for most' and the route along Thames Way has a maximum hazard rating of a 'danger for all' (refer to Appendix F).
- 3.73 A 'very low hazard' is defined as a caution for access/egress. A 'danger for most' is defined as a danger for the general public. A 'danger for all' is defined as a danger for the general public including the emergency services.
- 3.74 Should sufficient flood warning be given, it would be possible to evacuate occupants of the site to land located outside of the breach zone, which is situated adjacent to the eastern boundary along Stonebridge Road, approximately 35 m to the west of the site along Galley Hill Road and approximately 150 m to the south-east of the site along High Street. Tidal flooding is more predictable than fluvial flooding and it is anticipated that a flood warning could be issued several hours in advance providing sufficient time to evacuate the site.
- 3.75 Should sufficient flood warning not be possible, then an internal safe refuge would be available within each unit with a floor level at least 600 mm above the 0.5% breach flood levels in the year 2115. Additionally, safe refuge areas would be available on the podium levels for example around the football stadium. The occupants within the podium tunnel could evacuate via the entrances or through the emergency accesses to the podium level. On this basis, it is concluded that future occupants of the development would be safe in the event of a tidal breach flood event for the operational lifetime of the development.

Surface Water Flooding

- 3.76 When reviewing the EA's surface water flood map, it has been identified that the access/egress route for the site via Thames Way has up to a high surface water flood risk and High Street has up to a medium surface water flood risk.
- 3.77 During the medium risk scenario, it is identified that High Street has maximum estimated flood depth of less than 150 mm and Thames Way has a maximum estimated flood depth of between 150 mm and 300 mm (refer to Figure 3.6).
- 3.78 As the estimated flood depths are less than 300 mm, it is considered that safe access/egress from the site would still be possible. On this basis, it is concluded that future occupants of the development would be safe in the event of a surface water flood event for the operational lifetime of the development.

Other Considerations

Flood Risk Activity Permit

- 3.79 The proposed diversion of the River Ebbsfleet would be subject to a Flood Risk Activity Permit (FRAP) or registration of the appropriate exemption with the EA.

Land Use Vulnerability

- 3.80 Annex 3 of the NPPF sets out a schedule of land uses based on their vulnerability or sensitivity to flooding. As set out in Table 2, the residential, hotel, non-residential including education, nursery and health services development are classified as land uses that are 'more vulnerable' to flooding. Office, business, retail, restaurants, cafes, leisure (i.e. football stadium) and community uses are classified as land uses that are 'less vulnerable' to flooding.
- 3.81 Referring to Table 3 of the NPPF PPG, 'more vulnerable' land uses are considered appropriate within Flood Zone 3a subject to passing the Sequential and Exception Tests. 'More vulnerable' land uses are considered appropriate within Flood Zone 2 subject to passing the Sequential Test. 'Less vulnerable' land uses are considered appropriate within Flood Zones 2 and 3 subject to passing the Sequential Test.
- 3.82 The Gravesham Local Plan identifies that the site is located within the Northfleet Embankment and Swanscombe Peninsula East Opportunity Area and within the Grove Road and Lower Ebbsfleet Area (sub-area 1.3) which '*has the potential for residentially-led regeneration*'. The site proposes a residential-led development in line with the Opportunity Area requirements. Therefore, it is considered that the Sequential Test is passed.
- 3.83 Therefore, on the basis of land use vulnerability, the development should be deemed appropriate in planning policy terms in its proposed location.

4 DRAINAGE ASSESSMENT

Introduction

- 4.1 A drainage strategy has been prepared in accordance with Defra's "*Non-statutory technical standards for sustainable drainage systems*" (March 2015) to ensure that the proposed development does not increase flood risk to the site or elsewhere and where practicable reduces flood risk over the lifetime of the development.
- 4.2 Peak rainfall intensity is expected to increase as a result of climate change and, as such, storage calculations have included a 40% increase in rainfall depths in accordance with current climate change guidance.
- 4.3 The outline surface water drainage strategy has been prepared by Pitman Associates in collaboration with RMA Environmental Ltd and is provided in Appendix K.

Summary

- 4.4 The site is brownfield comprising a mix of commercial and industrial warehouses and yards, as well as Ebbsfleet football stadium. Currently, any surface water runoff generated within the majority of the site flows in a southerly direction and runoff from the south-eastern corner flows in a northerly direction and is assumed to flow into the existing drainage system and the public surface water sewer along Stonebridge Road. Surface water runoff from the northern part of the site flows in a northerly direction and is assumed to flow into the River Thames and the runoff from the western part of the site is assumed to flow in a northerly direction into the Swanscombe Marshes.
- 4.5 The feasibility of infiltration-based SuDS will be confirmed via infiltration testing which was not completed at this stage of the development given that the planning application is for outline permission and other reasons detailed below.
- 4.6 It has not been possible to undertake any intrusive site investigation at this stage at the site; this is not only because of the active and busy operational nature of the site (as an established and highly active industrial area) but also the associated access restrictions with vehicle traffic, ownership and localised operations.
- 4.7 Additionally, the site is located within a Zone 2 outer protection zone groundwater SPZ. A Phase 1 Land Contamination Assessment (LCA) has been undertaken for the site which shows that the land uses on site have included (but are not limited to) cement works, a windmill, football ground, tramway and railway tracks, ponds, depots, industrial estates, electrical substations and garages. Given the extensive industrial land uses present on site, the likelihood of contaminants such as metals, asbestos, Polycyclic Aromatic Hydrocarbons (PAHs) and other hydrocarbons cannot be ruled out.
- 4.8 Consultation with the LLFA has identified that '*the BGS information also shows that for this area there is a very significant potential for one or more geohazards associated with infiltration. The underlying geology of Upper Chalk can present a significant soluble rock hazard*' (refer to Appendix C).

- 4.9 Therefore, it is considered that infiltration-based SuDS features would not be appropriate for this site. It is proposed to conduct infiltration testing in accordance with BRE365 at the detailed design stage.
- 4.10 As infiltration techniques are considered to be unfeasible, an attenuation-based strategy has been provided for the 1 in 100 year storm including a 40% allowance for climate change.
- 4.11 A survey of the existing drainage network within the site was not undertaken at this stage due to the active industrial uses on-site resulting in areas being inaccessible for surveys. The drainage network and the invert levels of the existing discharge points are proposed to be established at the pre-commencement stage through a detailed drainage survey. Therefore, a connection into the existing drainage network has not been proposed.
- 4.12 The discharge point for the site is in the vicinity of the confluence of the River Thames and the Ebbsfleet and, therefore, the effect of the high tides on the outflows from the site have been considered (refer to Appendix K). This is in line with the guidance from the LPA provided in consultation which stated that *“subject to it being demonstrated that infiltration is not feasible we accept an unrestricted outflow to the river Ebbsfleet dependent on it being demonstrated that tidal lock is not a concern”*.
- 4.13 As the majority of the site is below the highest astronomical tide, a pumped discharge has been proposed as a precautionary approach. The drainage strategy includes three sub-catchments and sub-catchments A and B will have a pumped discharge into Robins Creek and sub-catchment C will drain via gravity into Robins Creek via a swale.
- 4.14 The proposed SuDS features within the site are as follows (refer to DR-001 in Appendix K):
- roof runoff from the residential buildings will be harvested and re-used which will reduce the discharge to sewers;
 - runoff from podium areas will be attenuated in low-profile attenuation tanks;
 - roof runoff from the football stadium will be captured for re-use (i.e. irrigation) in a low-profile tank located beneath the pitch;
 - green roofs with low-profile attenuation tanks are proposed on the other buildings;
 - park areas will be profiled to provide attenuation for rainfall events in excess of the 30 year return period rainfall event;
 - parking spaces will be constructed of permeable paving;
 - low-traffic roads will be constructed of permeable paving or drain to tree pits or swales; and
 - other roads will drain to tree pits or swales.

Water Quality Requirement

- 4.15 One of the guiding principles of SuDS is the appropriate management of water quality and the use of pollution prevention techniques to improve the quality of runoff from developed sites. The SuDS Manual recommends the use of a management train whereby a series of consecutive treatment stages are employed to remove pollutants from runoff.

- 4.16 The recommended number of treatment stages is dependent on the type of development and sensitivity of the discharge receptor and the mitigation indices of proposed SuDS features. Surface water requiring treatment will come from the roofs, access road, driveways and parking areas. In this instance, mitigation with an index or combined indices of more than 0.7 for Total Suspended Solids (TSS), 0.6 for metals and 0.7 for hydrocarbons is acceptable (refer to Appendix K).
- 4.17 The permeable paving, tree pits and swales will meet the water quality requirements required for the proposed development.

Designing for Exceedance Events

- 4.18 If the proposed drainage system was to become blocked or an event above the design event occur, it is considered likely that some additional storage would be provided in the form of shallow flooding of hard-paved areas. Any water leaving the site would be routed along the road network towards the River Ebbsfleet, River Thames and Swanscombe Marshes. This would mimic what would occur naturally on the site in its existing condition and would ensure that the proposed development is safe during an exceedance event.

Long Term Maintenance of SuDS

- 4.19 It would be the responsibility of the developer to either maintain the SuDS features themselves or to negotiate with and secure the agreement of a third party to maintain the sustainable drainage system.
- 4.20 The maintenance requirements of the proposed SuDS features for use in the drainage strategy are detailed in the SuDS Manual and would be carried out accordingly (refer to Appendix L).

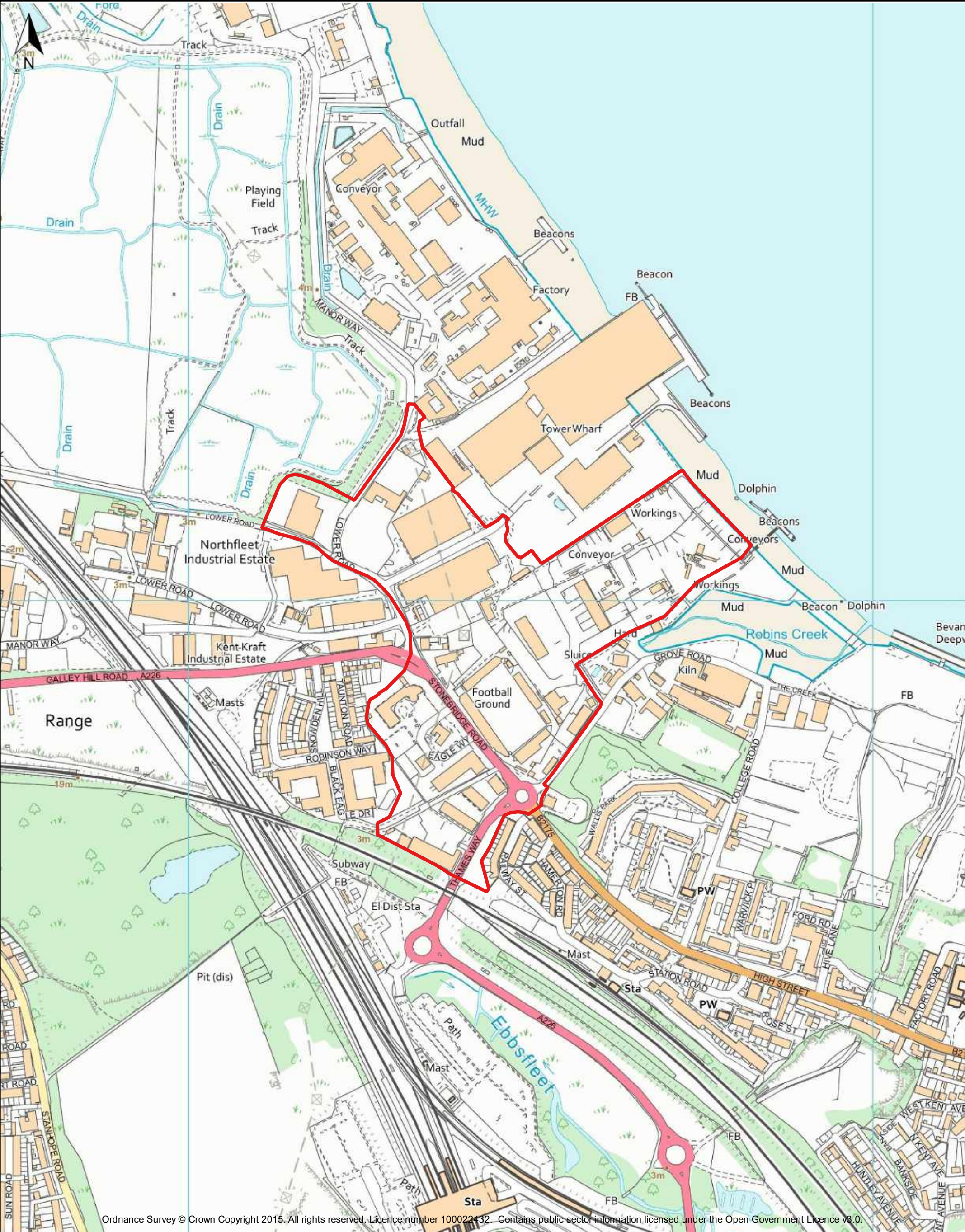
5 CONCLUSIONS

- 5.1 The requirements for Flood Risk Assessment are provided in the National Planning Policy Framework and its associated Planning Practice Guidance, together with the Environment Agency's Guidance Notes. This policy and associated guidance have been followed in the preparation of this FRA.
- 5.2 The EA's flood map for planning indicates that the majority of the site lies within Flood Zone 3 (high risk) and there are small areas of Flood Zone 2 (medium risk) throughout the site. However, the site is shown to lie within an area benefitting from flood defences.
- 5.3 The majority of the site has a very low risk from surface water flooding with a low, medium and high flood risk of surface water flooding throughout the site. The low surface water flood risk is beyond the 1% AEP design event; therefore, no mitigation is required for this surface water flood event. With the adoption of the drainage strategy, it is considered that medium and high surface water flood risk would not adversely affect the proposed development and the surface water flood risk is considered to be less significant than the tidal risk.
- 5.4 According to BGS Groundwater flooding susceptibility, the site has up to a '*high risk of groundwater flooding*'. Given the chalk aquifer underlying the site as well as gravels and the proximity of the site to the River Thames, it should be considered, as a worst case scenario, that groundwater levels are relatively shallow on site. With this in mind, it is considered that any risk of groundwater flooding can be mitigated alongside the measures proposed to protect the site from tidal flooding.
- 5.5 The site is at risk of sewer flooding; however, the risk from these sources is considered to be low.
- 5.6 The site will benefit from the River Thames flood defences for its operational lifetime, based on the proposed increases to defence levels. A RWIA has been undertaken and this outlines several options that could be implemented for the new river wall which includes providing a riparian area 16 m from the waterfront free from built development and the top of the defence level being set at 8 mAOD. However, during a breach event the site could flood to a maximum depth of 3.19 m in the 2100 epoch.
- 5.7 JBA Consulting were commissioned to undertake a hydraulic modelling study of the River Ebbsfleet. The new flood modelling indicates that there is currently no fluvial flood risk to the site in any design event. The reason there is no flooding to the site is due to the location of the raised road embankments located upstream of the long culvert. Water is stored upstream of the A226 road embankment and is prevented from flowing northwards to the site.

- 5.8 Consultation with the EA has determined that the development is an opportunity to de-culvert and naturalise the river channel providing enhancement to the site. Therefore, an outline design of daylighting the existing culvert has been developed. HLM Architects prepared a Proposed River Daylighting Sections plan and Proposed Daylighting Zone plan which shows the indicative daylighted river location and cross-sections within the site. These plans show that the majority of the River Ebbsfleet within the site is proposed to be daylighted and two bridges are proposed over the daylighted section. It proposed that the bridge crossings will be clear spanning with soffit levels that are greater than the bank elevations and further details could be provided through a suitably worded planning condition.
- 5.9 A minimum easement of 3.5 m from the top of the banks of the watercourse to the buildings would be provided and a maintenance access of over 8 m can be provided on the western side of the daylighted culvert which includes the boulevard and, therefore, the River Ebbsfleet can be maintained from this side. Additionally, sections of the proposed buildings to the east of the daylighted culvert will comprise of public walkways at ground level which will provide an increased easement from the watercourse in these areas.
- 5.10 This outline daylighting design has been tested within the Hydraulic model to understand the potential fluvial flood risk constraints. Analysis of the model outputs has shown that no spilling will occur from the proposed daylighted channel in any of the design event simulations.
- 5.11 The majority of the 'more vulnerable' land uses will be located on the first floor or above to ensure that they are located above the design breach flood levels, this includes all sleeping accommodation. Although some of the 'more vulnerable' land uses are located below the design flood level, these will include ancillary uses such as entrances and service rooms for the 'more vulnerable' land uses located above. The proposed entrances will not include waiting rooms and all of the 'more vulnerable' land uses at the ground floor will have access to internal staircases which lead to the second floor (i.e. above the design flood level).
- 5.12 During the design breach flood event, the access route has a maximum hazard rating of a 'danger for all'. However, should sufficient flood warning be given, it would be possible to evacuate occupants of the property to land located outside the breach zone, which is situated adjacent to the eastern boundary along Stonebridge Road, approximately 35 m to the west of the site along Galley Hill Road and approximately 150 m to the south-east of the site along High Street.
- 5.13 Should sufficient flood warning not be possible, then an internal safe refuge would be available within each unit with a floor level at least 600 mm above the 0.5% breach flood levels in the year 2115. Additionally, safe refuge areas would be available on the podium levels for example around the football stadium. The occupants within the podium tunnel could evacuate via the entrances or through the emergency accesses to the podium level. On this basis, it is concluded that future occupants of the development would be safe in the event of a tidal breach flood event for the operational lifetime of the development.
- 5.14 During the medium risk scenario, the estimated surface water flood depths along High Street and Thames Way are less than 300 mm so it is considered that safe access/egress from the site would still be possible.

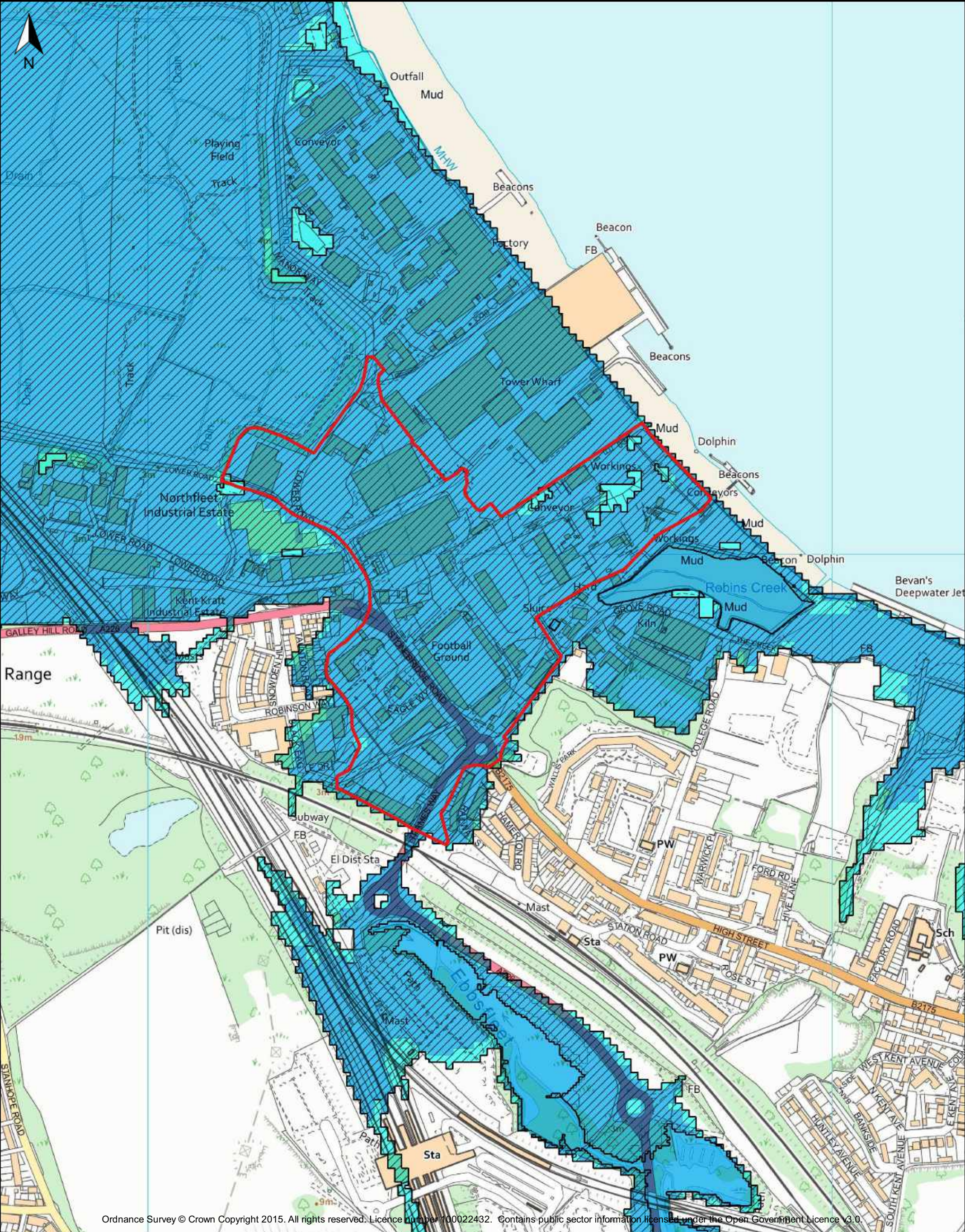
- 5.15 It is considered that infiltration-based SuDS features would not be appropriate for this site and this would be determined through testing at the detailed design stage. The surface water drainage strategy proposes sub-catchments A and B will have a pumped discharge into Robins Creek and sub-catchment C will drain via gravity into Robins Creek via a swale. The proposed SuDS features will include rainwater harvesting, low-profile attenuation tanks, green roofs and profiled park areas.
- 5.16 This FRA has therefore demonstrated that the proposed development will be safe and that it would not increase flood risk elsewhere. The proposed land uses are classified as 'more vulnerable' and 'less vulnerable' development and are considered appropriate in relation to the flood risk vulnerability classifications set out in Table 3 of the NPPF subject to passing the Sequential and Exception Tests.

Figures

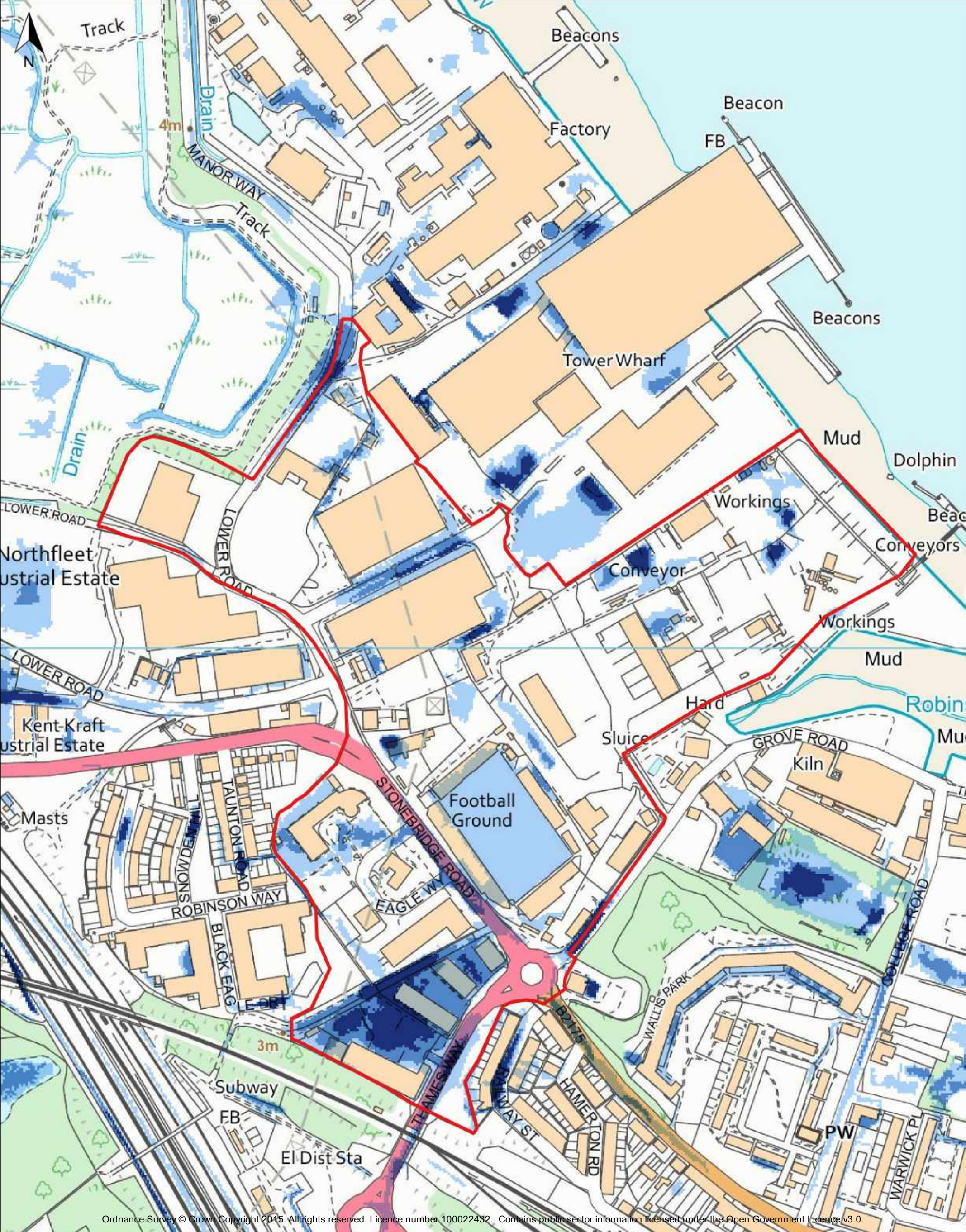


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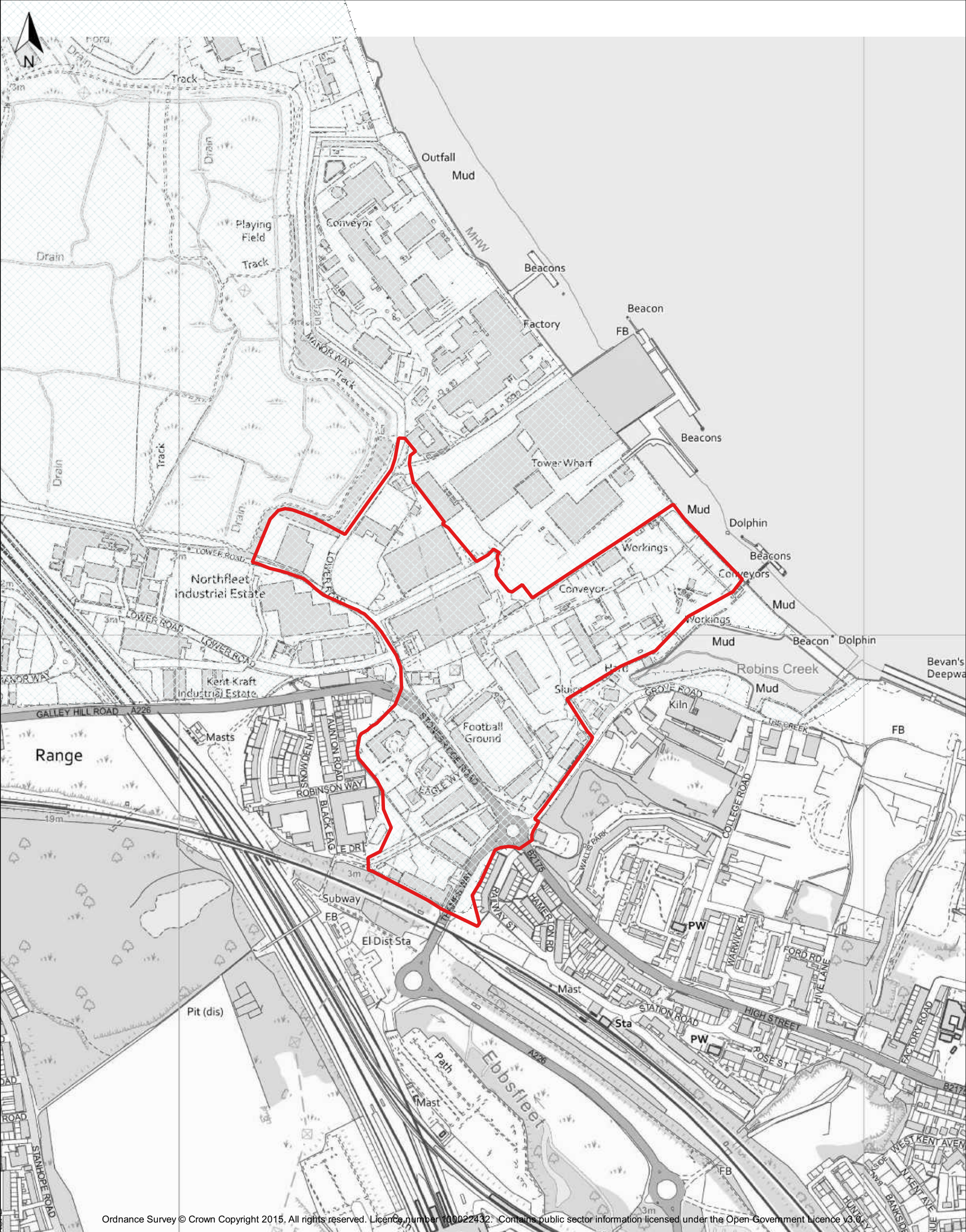
Key Red Line Boundary	Figure 1.1: Site Location Plan					
	Client:	Northfleet Central 1 Ltd				
	Project:	Northfleet Harbourside, Gravesham				
	Project No.:	C2402				
			Drawn: RT	Checked: RM	Date: 27/09/2022	Scale: 1:5,000@A3



Key Red Line Boundary Flood Zone 2 Flood Zone 3 Area Benefitting from Flood Defences	Figure 3.1: EA's Flood Map for Planning		RMA ENVIRONMENTAL			
	Client: Northfleet Central 1 Ltd					
	Project: Northfleet Harbourside, Gravesham		Drawn: RT	Checked: NY	Date: 28/09/2022	Scale: 1:5,000@A3
	Project No.: C2402					



Key Red Line Boundary Low Risk Medium Risk High Risk	Figure 3.2: EA's Surface Water Flood Map		RMA ENVIRONMENTAL			
	Client: Northfleet Central 1 Ltd					
	Project: Northfleet Harbourside, Gravesham		Drawn: RT	Checked: NY	Date: 27/09/2022	Scale: 1:3,000@A3
	Project No.: C2402					



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Key

Red Line Boundary

Historic Flood Extent

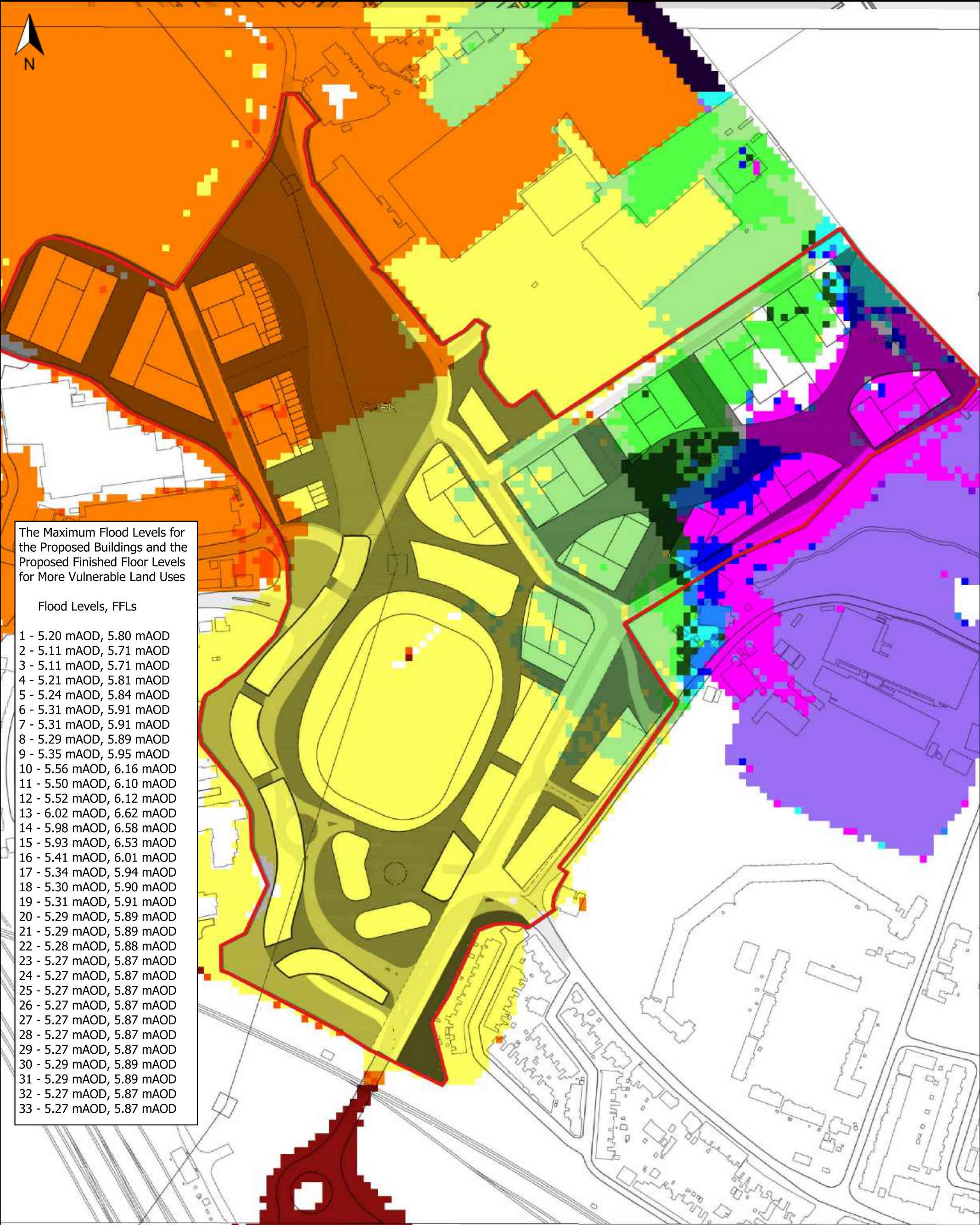
Figure 3.3: EA's Historic Flood Extent Map

Client:	Northfleet Central 1 Ltd
Project:	Northfleet Harbourside, Gravesham
Project No.:	C2402

RMA

ENVIRONMENTAL

Drawn: RT	Checked: NY	Date: 27/09/2022	Scale: 1:5,000@A3
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The Maximum Flood Levels for the Proposed Buildings and the Proposed Finished Floor Levels for More Vulnerable Land Uses

Flood Levels, FFLs	
1	5.20 mAOD, 5.80 mAOD
2	5.11 mAOD, 5.71 mAOD
3	5.11 mAOD, 5.71 mAOD
4	5.21 mAOD, 5.81 mAOD
5	5.24 mAOD, 5.84 mAOD
6	5.31 mAOD, 5.91 mAOD
7	5.31 mAOD, 5.91 mAOD
8	5.29 mAOD, 5.89 mAOD
9	5.35 mAOD, 5.95 mAOD
10	5.56 mAOD, 6.16 mAOD
11	5.50 mAOD, 6.10 mAOD
12	5.52 mAOD, 6.12 mAOD
13	6.02 mAOD, 6.62 mAOD
14	5.98 mAOD, 6.58 mAOD
15	5.93 mAOD, 6.53 mAOD
16	5.41 mAOD, 6.01 mAOD
17	5.34 mAOD, 5.94 mAOD
18	5.30 mAOD, 5.90 mAOD
19	5.31 mAOD, 5.91 mAOD
20	5.29 mAOD, 5.89 mAOD
21	5.29 mAOD, 5.89 mAOD
22	5.28 mAOD, 5.88 mAOD
23	5.27 mAOD, 5.87 mAOD
24	5.27 mAOD, 5.87 mAOD
25	5.27 mAOD, 5.87 mAOD
26	5.27 mAOD, 5.87 mAOD
27	5.27 mAOD, 5.87 mAOD
28	5.27 mAOD, 5.87 mAOD
29	5.27 mAOD, 5.87 mAOD
30	5.29 mAOD, 5.89 mAOD
31	5.29 mAOD, 5.89 mAOD
32	5.27 mAOD, 5.87 mAOD
33	5.27 mAOD, 5.87 mAOD

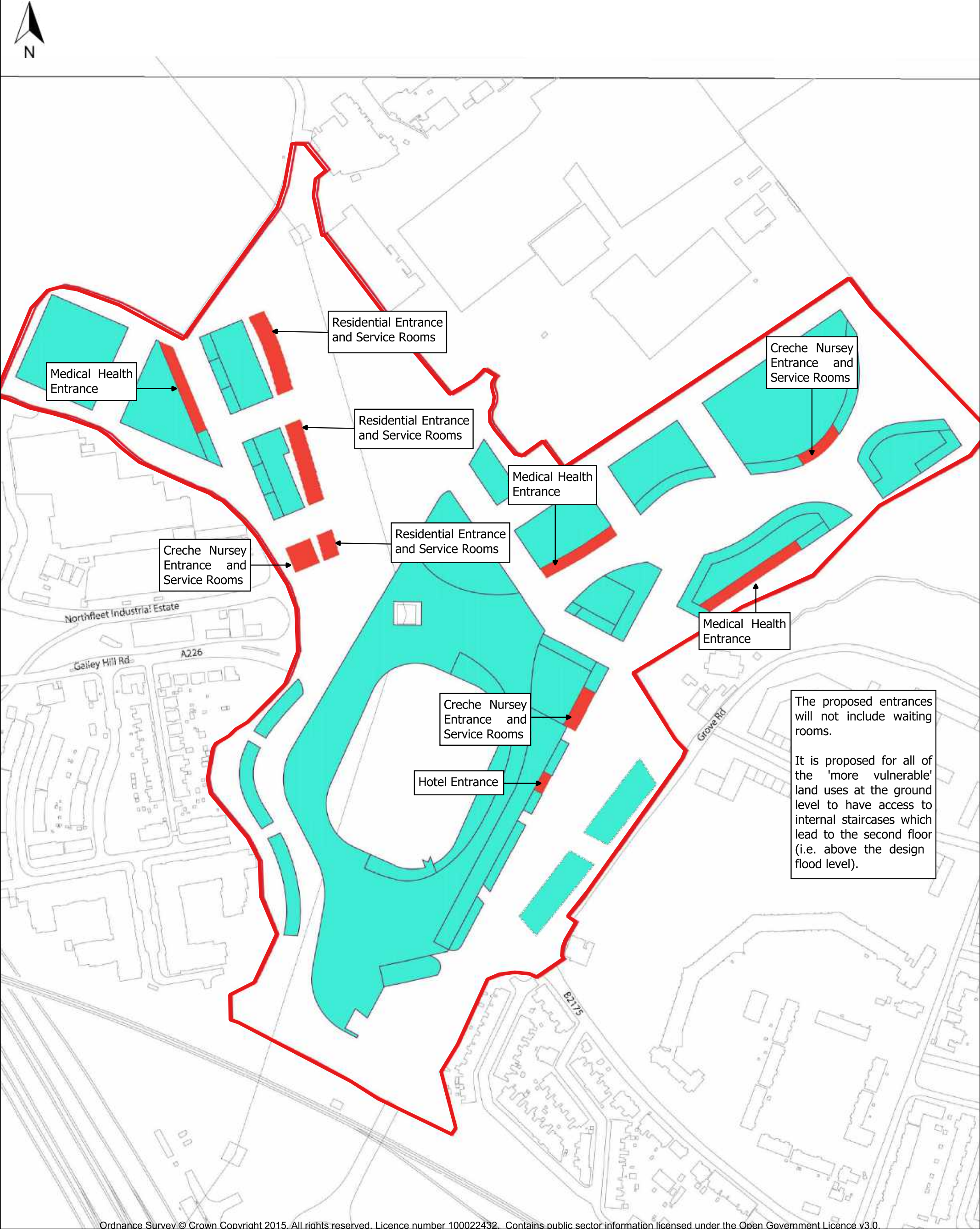
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	Red Line Boundary		5.3 - 5.4		5.9 - 6.0
Tidal Breach Flood Levels (mAOD)					
	Less than 5.0		5.4 - 5.5		6.0 - 6.1
	5.0 - 5.1		5.5 - 5.6		6.1 - 6.2
	5.1 - 5.2		5.6 - 5.7		Greater than 6.2
	5.2 - 5.3		5.7 - 5.8		
			5.8 - 5.9		

Figure 3.4:	EA's 0.5% AEP Tidal Breach Flood Levels in the Year 2115
Client:	Northfleet Central 1 Ltd
Project:	Northfleet Harbourside, Gravesham
Project No.:	C2402

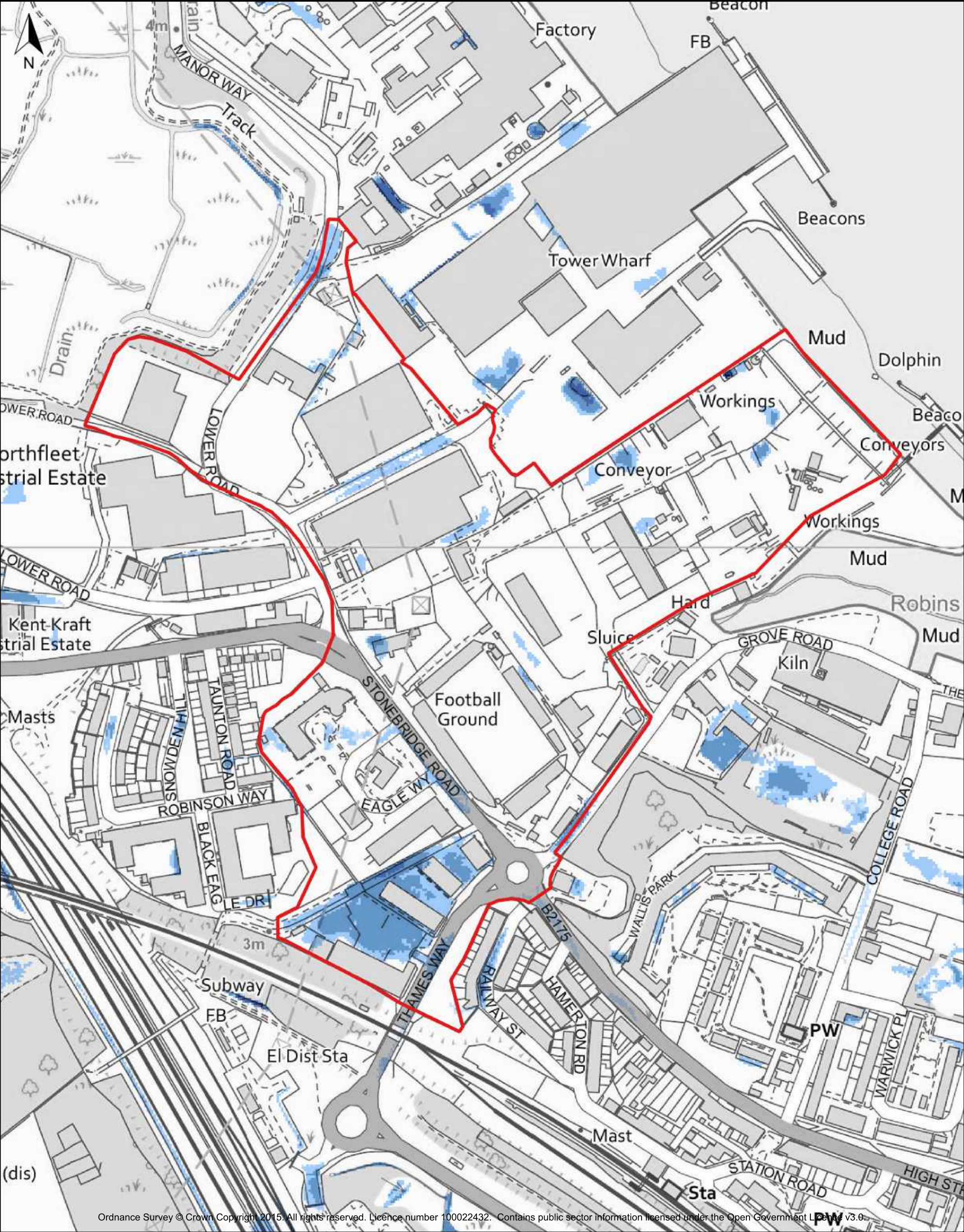


Drawn: RT	Checked: MS	Date: 10/04/24	Scale: 1:2,500@A3
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Key Red Line Boundary Land Use Classification Less Vulnerable More Vulnerable	Figure 3.5: More Vulnerable Land Uses on Ground Floor		RMA ENVIRONMENTAL			
	Client: Northfleet Central 1 Ltd					
	Project: Northfleet Harbourside, Gravesham		Drawn: RW	Checked: MS	Date: 10/04/2024	Scale: 1:2,500@A3
	Project No.: C2402					



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Key		Figure 3.6: EA's Medium Surface Water Flood Depth Map			
 Red Line Boundary	 300 mm - 600 mm	Client: Northfleet Central 1 Ltd			
Flood Depths	 600 mm - 900 mm	Project: Northfleet Harbourside, Gravesham			
 Below 150 mm	 900 mm - 1200 mm				
 150 mm - 300 mm	 Over 1200 mm				
		Project No.: C2402		Drawn: RT	Checked: NY
				Date: 27/09/2022	Scale: 1:3,000@A3

Appendix A: Proposed Development Layout



- Site boundary (19.0 Ha)
- Park
- Public Realm within plots
- Pocket Park
- Pocket Park within Plots

R01 25.03.24 GJ Plots 6,7,8 and highway layout revised
Rev Date By Description

Project:
Northfleet Harbourside
Northfleet, UK

Drawing Title
Public realm

Project Status
Preliminary Masterplan

Client Logo
Northfleet
Central 1 Ltd

Client:
Northfleet Central 1

Project Number
P23-111

Date
25.03.24

Drawing Number/Identifier
1012

Drawing Number
NFH-CGL-MAST-DR-1012

28A Easton Street
London, WC1X 0DS



Contract Number
1:1500

Drawn By
ED

Revision
R01

020 7539 1200
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Appendix B: EA Consultation

15th August 2022

Sustainable Places
Environment Agency

Via email

Our Ref: RMA/LC2402 – Northfleet Central EA Consultation

Dear Enquiries,

**RE: PROPOSED REDEVELOPMENT OF LAND AT GROVE ROAD IN NORTHFLEET, KENT
DA11 9AX – EA PRELIMINARY OPINION REQUEST**

RMA have been commissioned to prepare a Flood Risk Assessment (FRA) and drainage strategy for an outline planning application for a proposed redevelopment scheme on land at Grove Road in Northfleet, Kent. We are writing to the EA to request a formal preliminary opinion with regard to hydrology and flood risk.

The site comprises a mix of industrial warehouses and yards as well as Ebbsfleet football stadium. The site extends to an area of 19.03 hectares (ha) and is located at National Grid Reference TQ 61539 75079 (refer to Figure 1). The River Thames and associated flood defences are located along the north-eastern site boundary. The River Ebbsfleet is culverted within the site along the southern part of the eastern boundary and flows in a northerly direction into Robins Creek and then into the River Thames. There are flood defences along Robins Creek to the north-east of the site.

According to LiDAR data and the spot levels within the site, the majority of the site slopes in a southerly direction towards the south-eastern corner, although the western part of the site slopes in a northerly direction. The south-eastern corner and the northern part of the site slope in a northerly direction towards the River Thames (refer to Appendix A).

The redevelopment of the site will include phased demolition and redevelopment of 3,500 residential units, leisure facilities, football club facilities for Ebbsfleet Football Club, retail and employment uses, community uses, creation of new public spaces, landscaping and associated works. The indicative block plan for the proposed development is included as Appendix B. The Gravesham Local Plan identifies that the site is located within the Northfleet Embankment and Swanscombe Peninsula East Opportunity Area and within the Grove Road and Lower Ebbsfleet Area (sub-area 1.3) which '*has the potential for residentially-led regeneration*'. The site proposes a residential-led development in line with the Opportunity Area requirements.

Appropriate Easements

The proposed buildings including the structural support of any buildings/structures along the northern boundary will be set back more than 16 m from the River Thames defences and the Robins Creek defences (refer to Figure 2) and structural supports for buildings and structures will be completely separate of any river wall supports. This therefore, provides an appropriate easement that is free from buildings to allow for access and maintenance of the flood defences and the potential future upgrade of the defences in line with the Thames Estuary 2100 Plan.

The River Ebbsfleet is a culverted watercourse that flows through the site along the eastern boundary. It is important to note that a number of existing buildings are located above this culvert. Where possible, the redevelopment project will ensure that an 8 m easement either side of the culvert is provided that is free from any built development. However, due to design constraints, the proposed development includes three blocks to the eastern extent of the site that are proposed to overlie the route of the culvert. In order to ensure there is suitable access for future management of the culvert,

it is proposed to provide additional manholes either side of the proposed buildings to allow for access for maintenance and inspection. As well as this the scheme will commit to a management regime of the culvert which will include regular inspection of the culvert, repairs and removal of any debris where required. These measures will be written into the Design Code submitted with the planning application to ensure that the detailed design that comes forward (subject to Reserved Matters Applications) includes such measures. It's important to note that a surface water drainage strategy will be provided as part of the planning application, this will ensure that any discharge to the Ebbsfleet will be at a reduced rate when compared to the existing site prior to discharging into the culvert, thus providing a betterment in capacity of the culvert. This will be detailed in the surface water drainage strategy.

Flood Levels and Floor Levels

From reviewing the EA's flood map for planning, the majority of the site lies within defended Flood Zone 3 and there are small areas of Flood Zone 2 throughout the site. The site is within an area benefitting from flood defences along the River Thames. Detailed flood data has been received from the EA. The River Ebbsfleet Model (Capita URS, 2015) indicates that the site is located within fluvial Flood Zone 1 as it is not affected by the 1% AEP plus 35% climate change or 0.1% AEP flood events (refer to Figure 3).

The Thames Tidal Downriver Breach Inundation Modelling Study 2018 indicates that the site is located within the modelled breach zone for the 0.5% AEP and the 0.1% AEP events (refer to Figure 4). The 0.5% breach flood level in the year 2115 varies from 5.08 mAOD along the western boundary in the area of Lower Road to a level of 6.11 mAOD in the north along the bank of the River Thames and, therefore, the flood levels vary across the site (refer to Figure 5). The flood depths during the 0.5% breach event in the year 2115 vary between 0.004 m located along Stonebridge Road and the eastern boundary and 3.19 m in the south-eastern corner (refer to Figure 6).

It is proposed that the residential uses will be located on the first floor and above (i.e. a minimum floor level of approximately 6.82 mAOD). Therefore, all of the proposed residential units will be raised at least 300 mm above the design breach levels.

Figure 7 shows a number of blocks where 'more vulnerable' land uses, which may comprise nursery/creche or medical facilities given the flexible use (Use Class E) sought for approval for some development plots, and hotel located at ground level and below the breach level. Although these areas will be below the design flood level, they will include internal safe access/egress to an area above the flood level should a breach flood event occur. The hotel use will locate all of the sleeping accommodation above the design flood level.

Where possible, the ground floor Finished Floor Levels (FFLs) will be raised 300 mm above the breach levels. However, given that significant flood depths may occur in some areas of the site (refer to Figure 7), it will not be possible to raise the ground floor FFLs 300 mm above the breach levels in all areas. As such, in the lower parts of the site, where it is not possible to raise the ground floor 300 mm above the breach levels, it is proposed to incorporate flood resilience measures with the aim of providing additional protection.

The EA's Thames Tidal Breach Hazard Mapping indicates that the safe access/egress route along Stonebridge Road to the east has a 'very low hazard' rating, the route along Galley Hill Road has a maximum hazard rating of a 'danger for most' and the route along Thames Way and Lower Road has a maximum hazard rating of a 'danger for all' (refer to Figure 8). However, should sufficient flood warning be given, it would be possible to evacuate occupants of the site to land located outside of the breach zone, which is situated adjacent to the eastern boundary along Stonebridge Road, approximately 35 m to the west of the site along Galley Hill Road, approximately 150 m to the south-east of the site along Thames Way and approximately 650 m to the north-west of the site.

Should sufficient flood warning not be possible, then an internal safe refuge would be available within each unit with a floor level at least 300 mm above the 0.5% breach flood levels in the year 2115. Additionally, safe refuge areas would be available on the podium levels. On this basis, it is concluded that future occupants of the development would be safe in the event of a tidal breach flood event for the operational lifetime of the development.

Part of the site proposal includes a raised podium area as shown within the plan included within Appendix B; the raised area is the yellow area around the football stadium. This area is a continuous raised structure with an approximate level of 10.62 mAOD (approximately 5.35 m above the design flood level for that area). This area will provide an area of safe refuge above the design flood level should the design flood event occur.

Infiltration

The bedrock geology of the Chalk Formation is classified by the EA as a Principal Aquifer. When reviewing online EA data sources, it is confirmed that the site is located within a Zone 2 outer protection zone groundwater Source Protection Zone (SPZ). A Phase 1 Land Contamination Assessment (LCA) has been undertaken for the site which shows that the land uses on site have included (but are not limited to) cement works, a windmill, football ground, tramway and railway tracks, ponds, depots, industrial estates, electrical substations and garages. Given the extensive industrial land uses present on site, the likelihood of contaminants such as metals, asbestos, Polycyclic Aromatic Hydrocarbons (PAHs) and other hydrocarbons cannot be ruled out. Similarly, there are a number of historic and existing potentially contaminative land uses within a 250 m radius of the site including electricity substations, wharfs, historical tanks and depots.

Consultation with the LPA has identified that *'The BGS information also shows that for this area there is a very significant potential for one or more geohazards associated with infiltration. The underlying geology of Upper Chalk can present a significant soluble rock hazard'*.

Therefore, it is considered that infiltration-based SuDS features would not be appropriate for this site. The drainage strategy will focus on a strategy where part of the site discharges at an attenuated rate to the River Ebbsfleet with the remainder discharging at an unattenuated rate to the River Thames.

The above measures will be detailed in a Flood Risk Assessment and Surface Water Drainage Strategy that will be submitted as part of the planning application for this site. In the mean time it would be appreciated if the EA could clarify the following points:

- the acceptability of the maintenance buffers proposed alongside the River Thames and Robins Creek flood defences;
- the acceptability of the mitigation measures proposed in relation to the access and building locations associated with the River Ebbsfleet culvert;
- the acceptability of the proposed land uses within the site and comments on the appropriateness of the proposed finished floor levels for 'less vulnerable' and 'more vulnerable' elements of the development;
- comments on the suitability of infiltration-based SuDS in relation to groundwater sensitivity and existing contamination risk; and
- whether the EA can provide any information on the condition and residual life of the current flood defences on site as well as any information on the condition of the culvert and any outfalls that may be present.

I trust that the information supplied in this letter is sufficient to allow you to prepare a preliminary opinion; however, should you have any further questions or comments, please do not hesitate to contact me.

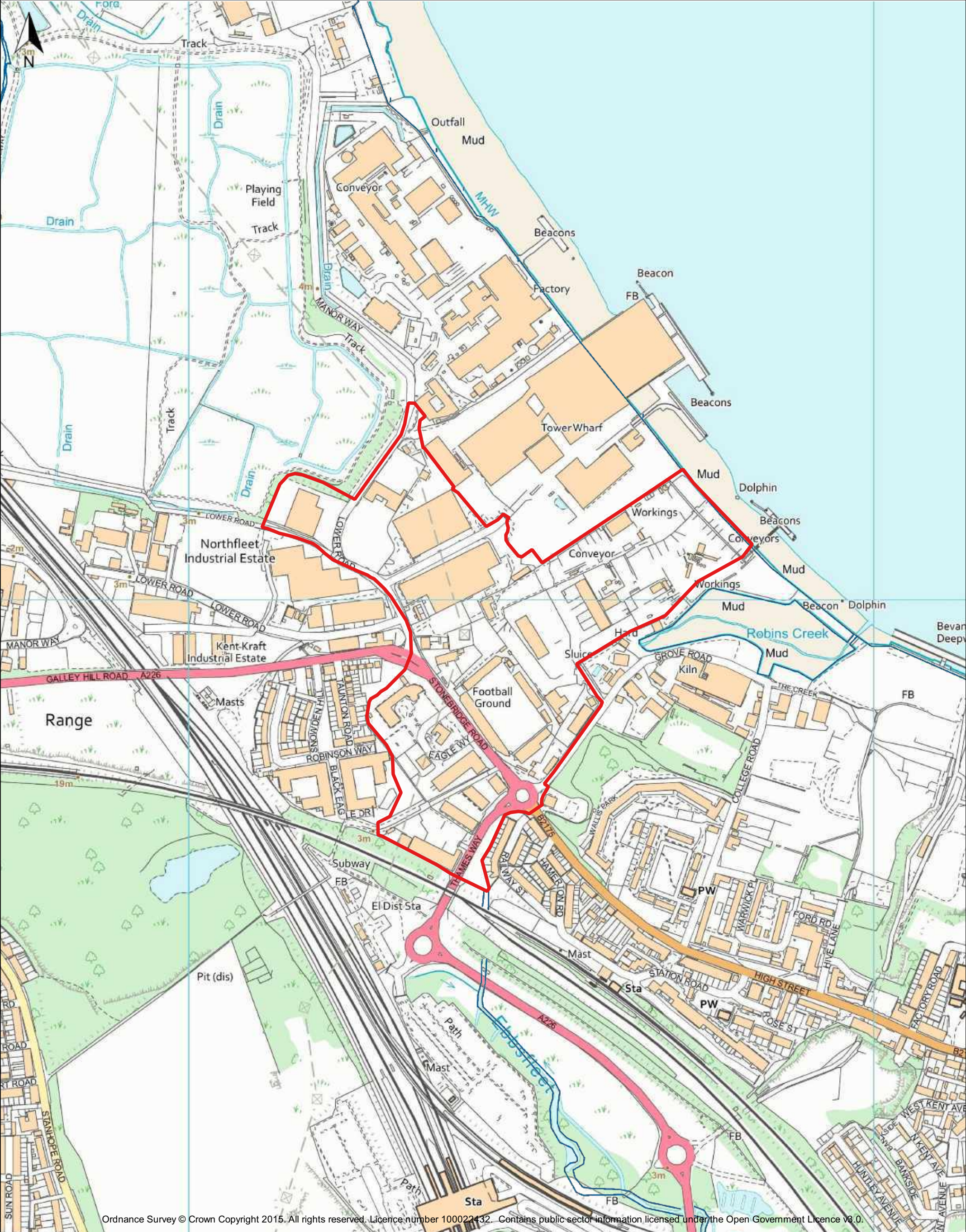
Yours sincerely

A handwritten signature in dark ink, appearing to read 'M Seymour', is positioned above the printed name.

Melissa Seymour
Senior Consultant

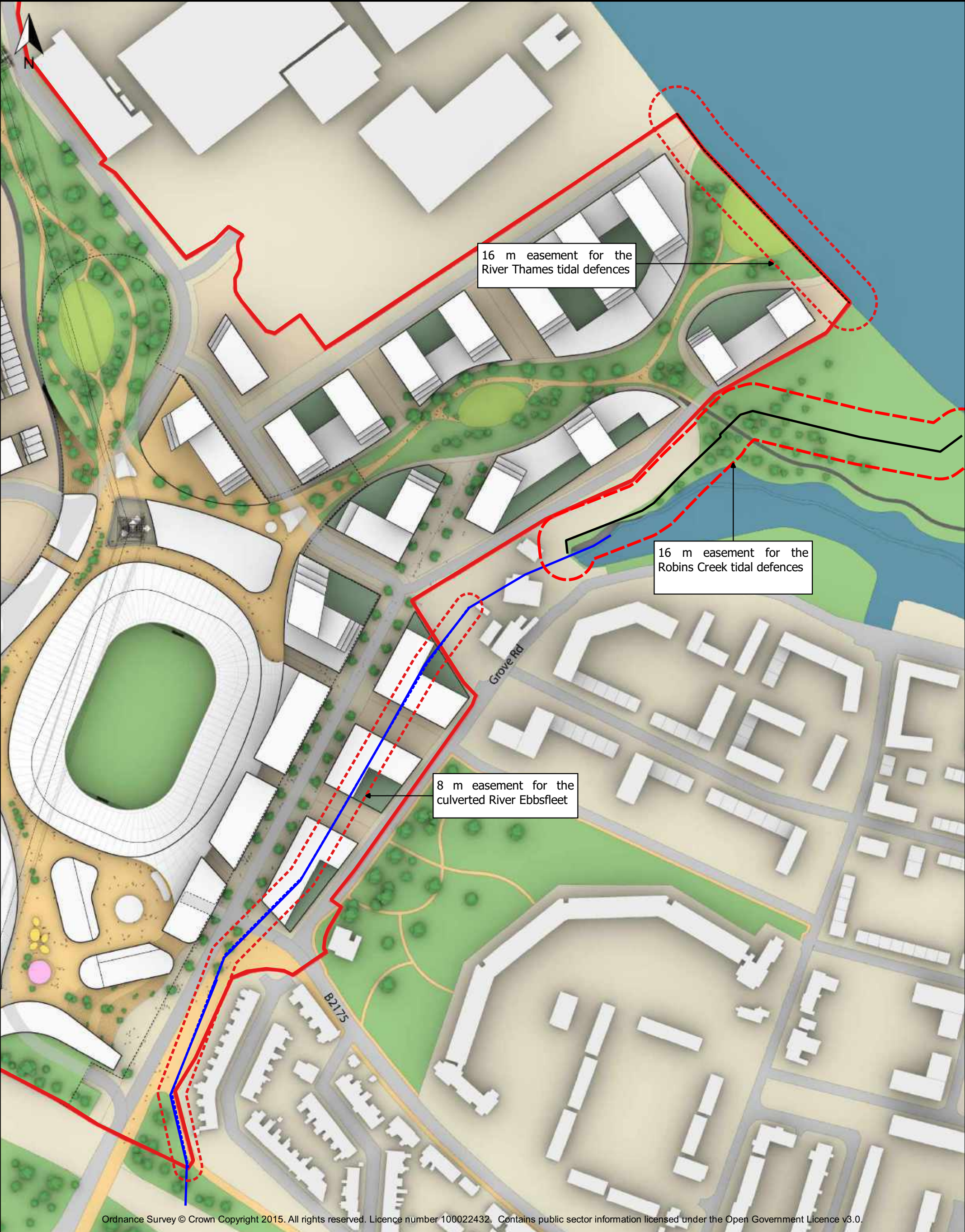
Encs: Figure 1 – Site Location Plan
Figure 2 – Easement Buffers Post-development
Figure 3 – EA's Fluvial Flood Extents
Figure 4 – EA's 0.5% AEP Tidal Breach Flood Extents
Figure 5 – EA's 0.5% AEP Tidal Breach Flood Levels in the Year 2115
Figure 6 – EA's 0.5% AEP Tidal Breach Flood Depths in the Year 2115
Figure 7 – More Vulnerable Development Mitigation
Figure 8 – Flood Hazard Ratings during the Design Breach Flood Event
Appendix A – Topographical Survey
Appendix B – Indicative Block Plan

Figures



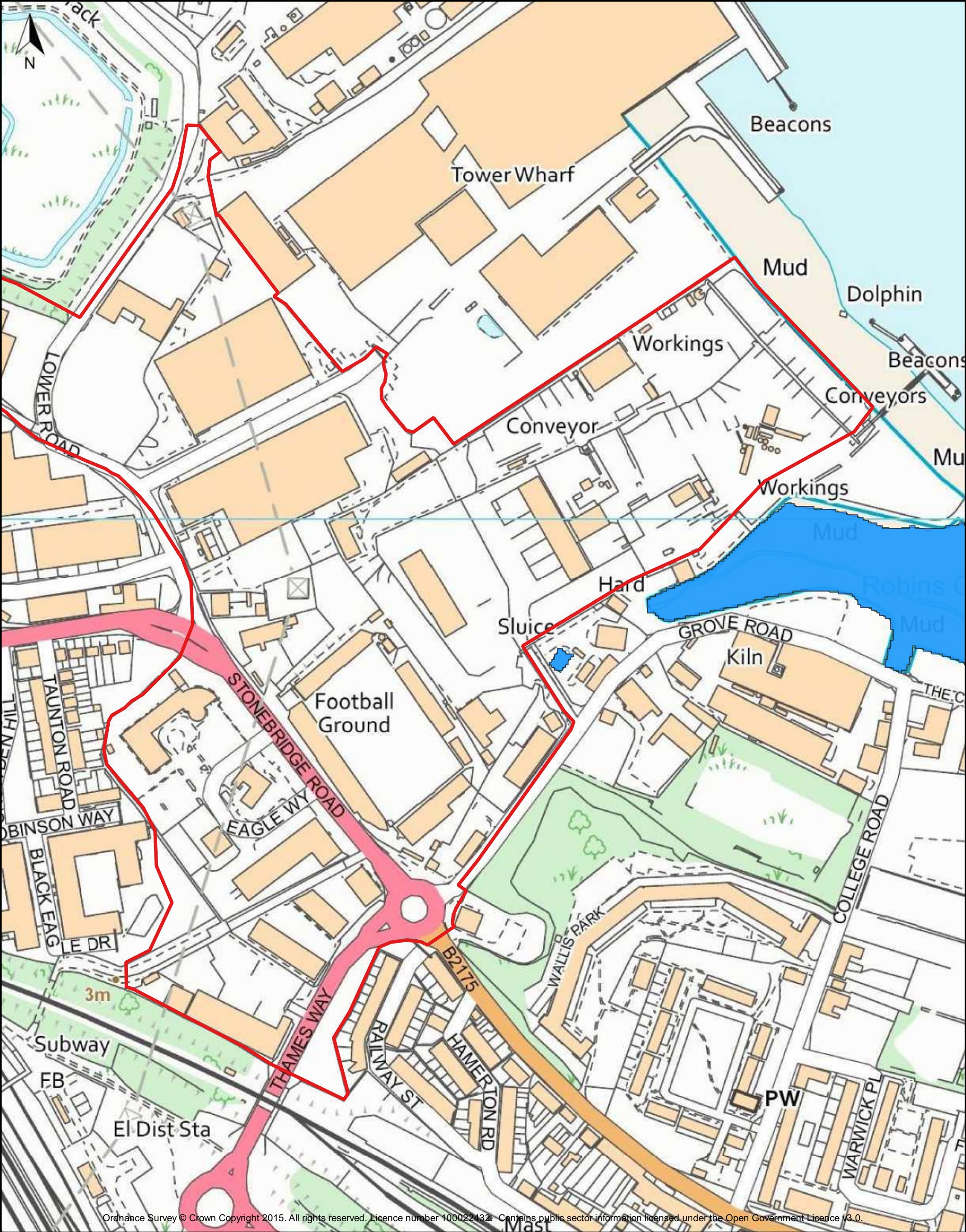
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Key Red Line Boundary	Figure 1: Site Location Plan		RMA ENVIRONMENTAL			
	Client:	Kuwaiti European Holding Group (KEH)				
	Project:	Northfleet Central				
	Project No.:	C2402				
			Drawn:	Checked:	Date:	Scale:
			MS	RM	20/07/22	1:5,000@A3



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Key  Red Line Boundary	Figure 2: Easement Buffers Post-development				
	Client: Kuwaiti European Holding Group (KEH)				
	Project: Northfleet Central				
	Project No.: C2402	Drawn: RT	Checked: MS	Date: 03/08/2022	Scale: 1:2,000@A3



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- Key**
- Red Line Boundary
 - 1% AEP plus 35% Climate Change Flood Extent
 - 0.1% AEP Flood Extent

Figure 3: EA's Fluvial Flood Extents

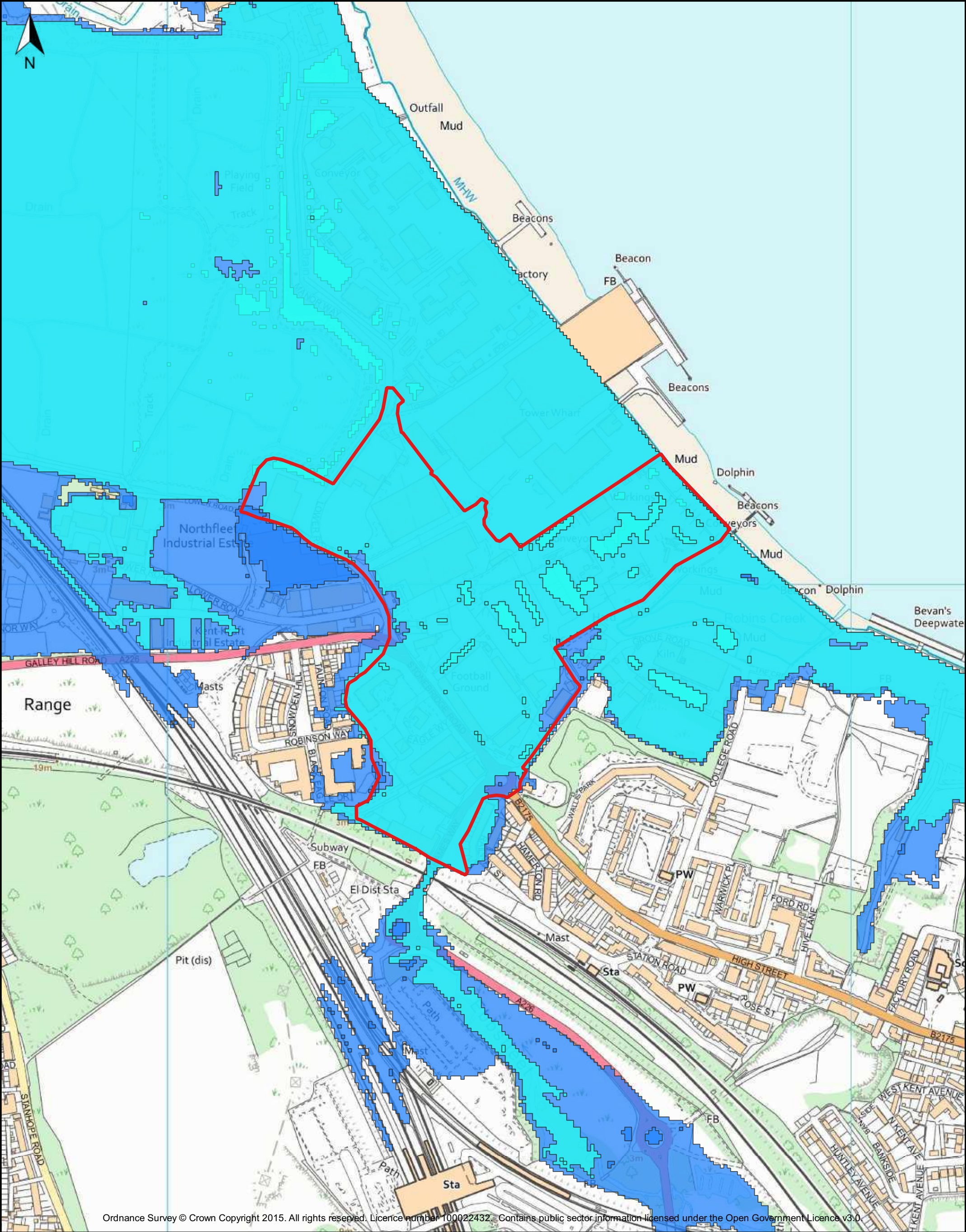
Client: **Kuwaiti European Holding Group (KEH)**

Project: **Northfleet Central**

Project No.: **C2402**



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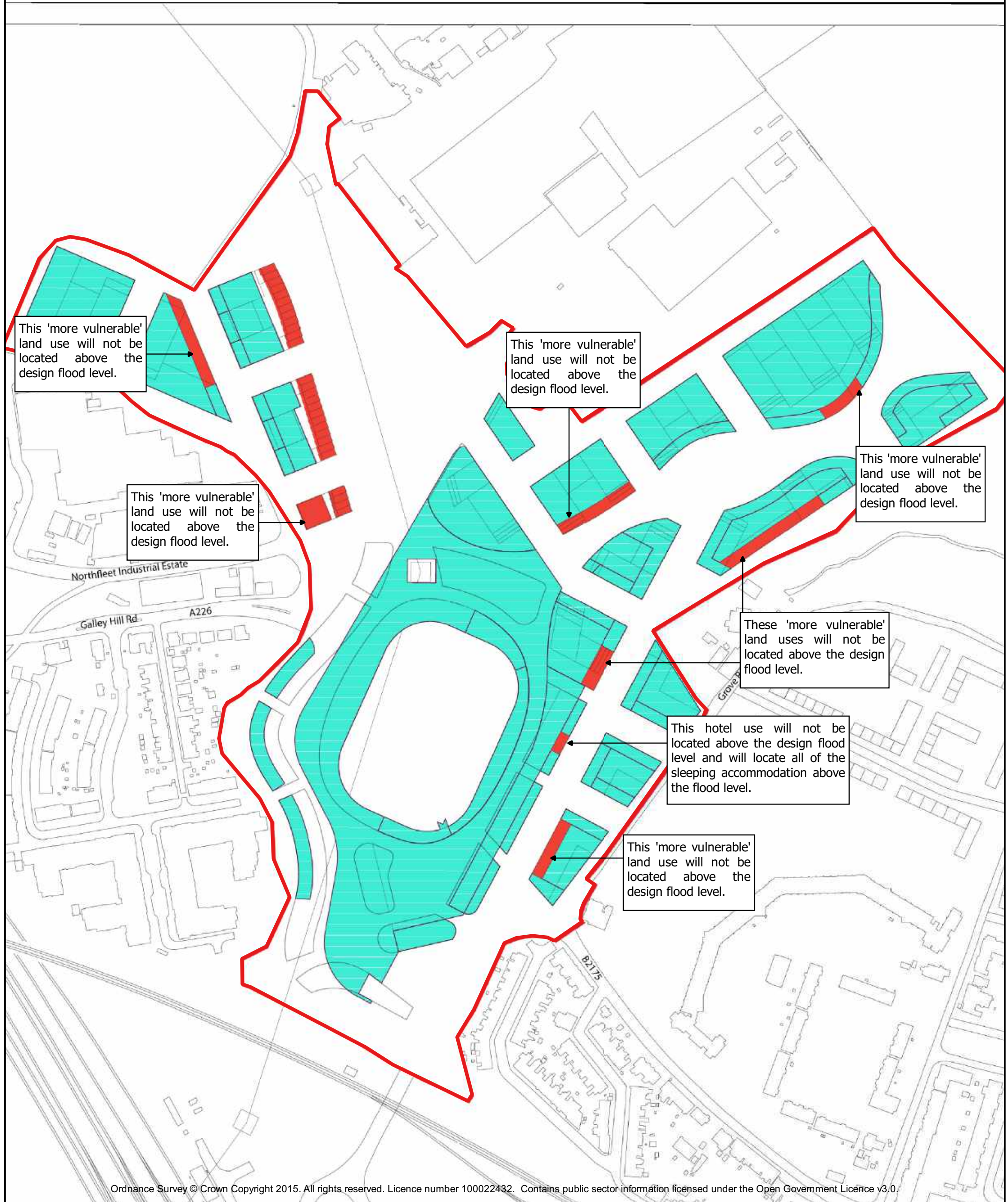
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- Key**
- Red Line Boundary
 - 0.5% AEP Breach Flood Extent in Current Scenario
 - 0.5% AEP Breach Flood Extent in the Year 2115

Figure 4:	EA's 0.5% AEP Tidal Breach Flood Extents
Client:	Kuwaiti European Holding Group (KEH)
Project:	Northfleet Central
Project No.:	C2402



Drawn: RT	Checked: MS	Date: 26/07/2022	Scale: 1:5,000@A3
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Key

 Red Line Boundary  Less Vulnerable  More Vulnerable

Figure 7: **More Vulnerable Development Mitigation**

Client: **Kuwaiti European Holding Group (KEH)**

Project: **Northfleet Central**

Project No.: **C2402**



Drawn:
RT

Checked:
MS

Date:
02/08/2022

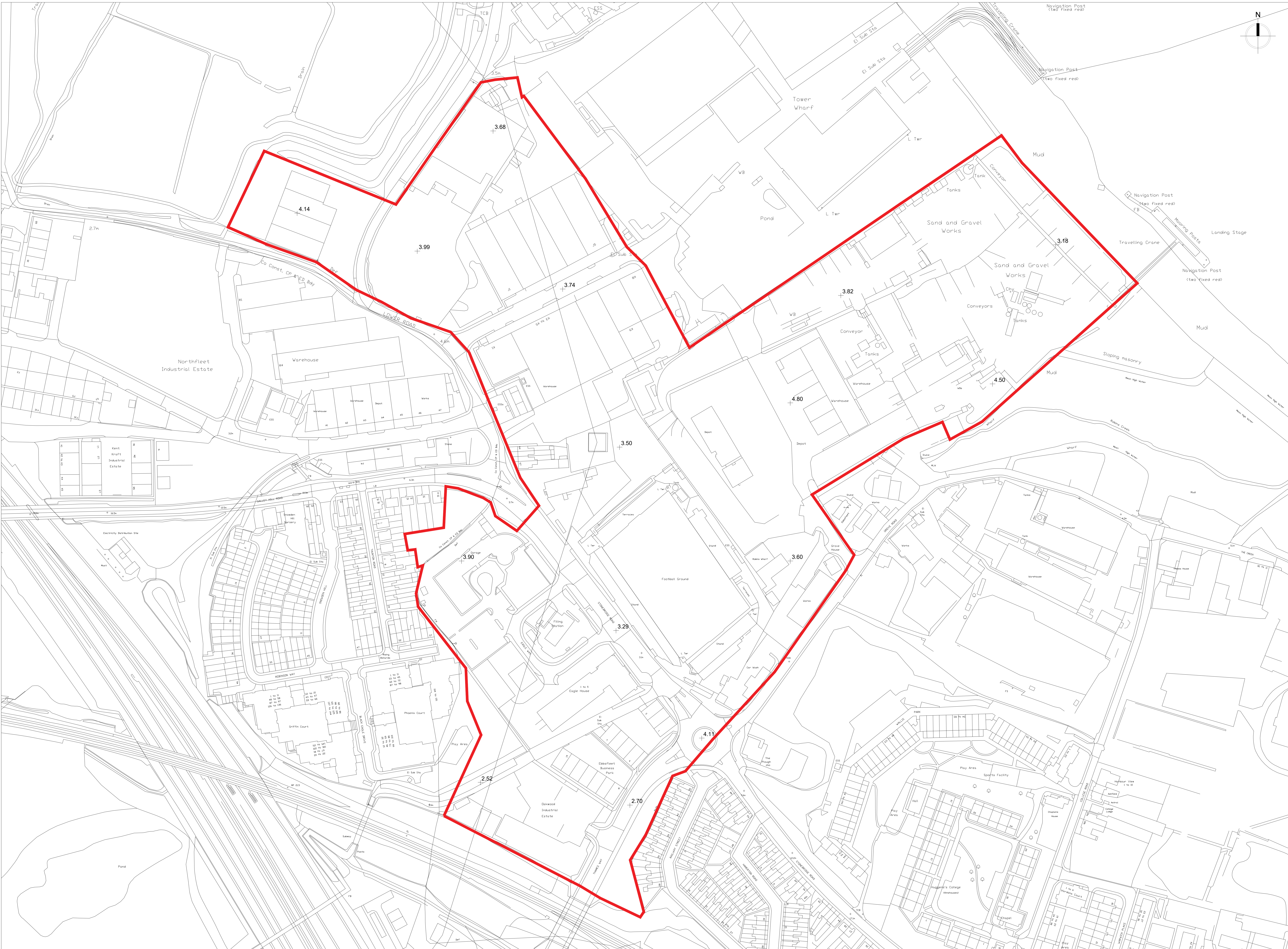
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Key Red Line Boundary Flood Hazard Ratings Danger for Most Danger for Some Danger for All	Figure 8: Flood Hazard Ratings during the Design Breach Flood Event		RMA ENVIRONMENTAL							
	Client:	Kuwaiti European Holding Group (KEH)								
	Project:	Northfleet Central	Drawn:	RT	Checked:	MS	Date:	02/08/2022	Scale:	1:2,500@A3
	Project No.:	C2402								

Appendix A: Topographical Survey



O.S. Map
1:1000

Metres
0 10m 20m 30m 40m 50m
Centimetres
0 1cm 2cm 3cm 4cm 5cm
SCALE 1:1000

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NOTES:

DESIGN INTENT DRAWING

DRAFT

Client:
Project:
NORTHFLEET CENTRAL, GRAVESHAM, UK

Drawing Title:
O.S. MAP

Drawn	Checked	Paper Size	Scale	Date
EB	EB	A0	As Indicated	@A0 06/05/22
Project No.	Drawing No.	Revision		
PE22040	0001	P01		

File Name:
PE22040-CW0-ZZ-ZZ-DR-A-0001

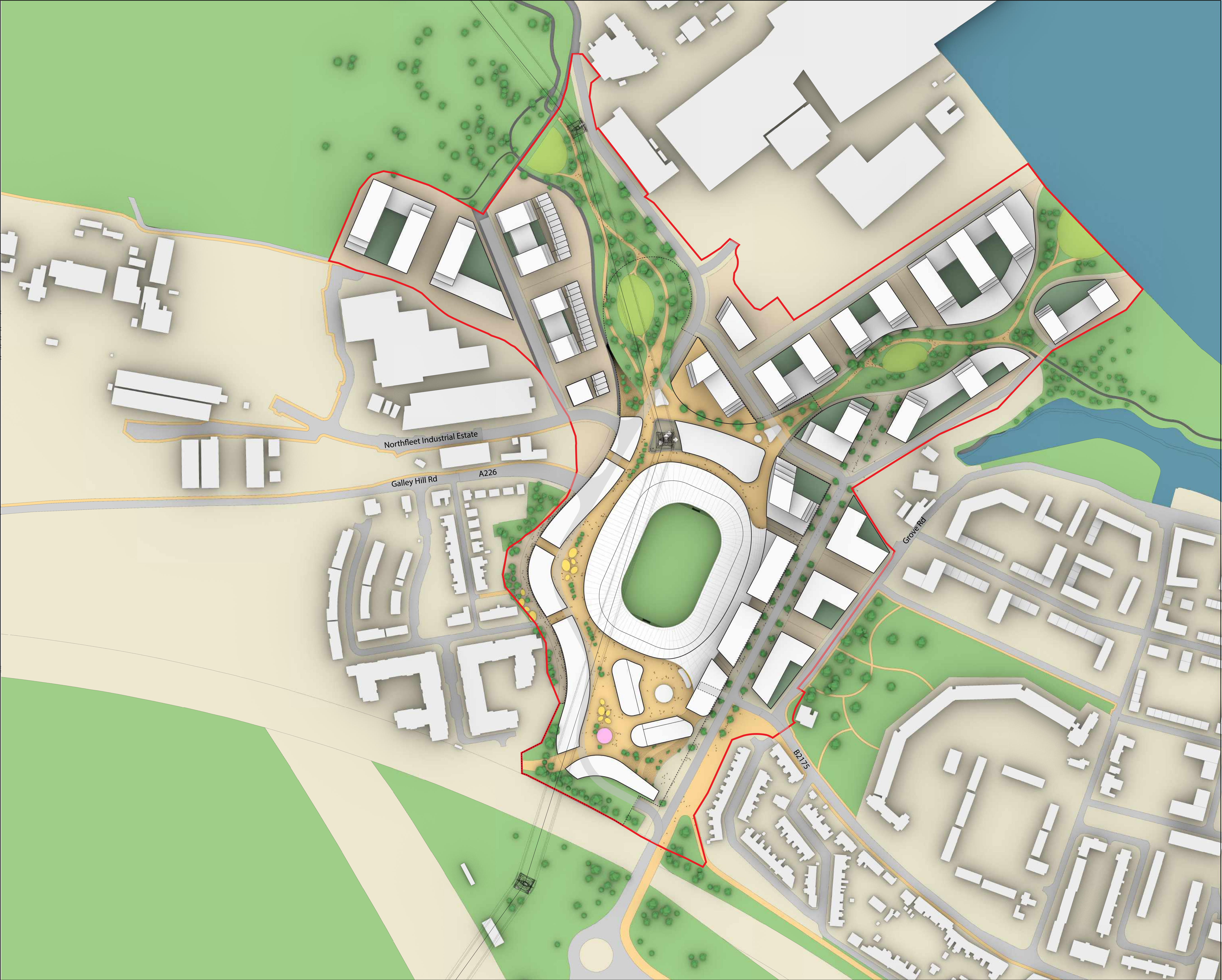
Status:
S3 - Suitable for review and comment

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ARCHITECTS

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Dublin | Cork | Galway | London | UK & Europe +
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Appendix B: Indicative Block Plan



Site boundary
(18.3 Ha)

**Northfleet
Central 1 Ltd**

client
Northfleet Central 1 Ltd
Kufink Stadium
Stonebridge Road
Kent, DA11 9GN
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**uns
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F + 31 (0)20 570 20 41
info@unstudio.com
www.unstudio.com

project name Northfleet Harbourside		project number 2022-088	
location Northfleet, UK		sector	
phase Preliminary Masterplan		format A1	
status	date 29-07-2022	revision R00	scale 1:1500

drawing code
NFH-UNS-MAST-DR-1015
title
Illustrative Masterplan

description / disclaimer



- Site boundary (18.3 Ha)
- Car Park
- Sports, Recreation, Fitness
- Medical Health
- Creche Nursery
- Local Services
- F&B
- Community
- Stadium facilities
- Hotel
- Residential

Northfleet Central 1 Ltd

client
Northfleet Central 1 Ltd
Kufink Stadium
Stonebridge Road
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project name Northfleet Harbourside		project number 2022-088	
location Northfleet, UK		sector	
phase Preliminary Masterplan		format A1	
status	date 29-07-2022	revision R00	scale 1:1500

drawing code
NFH-UNS-MAST-DR-1003
title
Ground floor uses

description / disclaimer



- Site boundary
(18.3 Ha)
- More vulnerable*

- Hospitals
 - Residential institutions such as residential care homes, children's homes, social services homes, prisons and hostels.
 - Buildings used for **dwelling houses**, student halls of residence, drinking establishments, nightclubs and **hotels**
 - Non-residential uses for **health services, nurseries** and educational establishments.
 - Landfill* and sites used for waste management facilities for hazardous waste.
 - Sites used for holiday or short-let caravans and camping, subject to a specific warning and evacuation plan.

- Less vulnerable*

- Police, ambulance and fire stations which are not required to be operational during flooding.
 - Buildings used for **shops**, financial, professional and other services; **restaurants, cafes and hot food takeaways; offices**, general industry, storage and distribution; non-residential institutions not included in the 'more vulnerable' class; and assembly and leisure.
 - Land and buildings used for agriculture and forestry.
 - Waste treatment (except landfill* and hazardous waste facilities).
 - Minerals working and processing (except for sand and gravel working).
 - Water treatment works which do not need to remain operational during times of flood.
 - Sewage treatment works, if adequate measures to control pollution and manage sewage during flooding events are in place.
 - **Car parks**.

*Source: National Planning Policy Framework, Annex 3: Flood risk vulnerability classification

Northfleet
Central 1 Ltd

client
Northfleet Central 1 Ltd

Kulfrink Stadium
Stonebridge Road
Kent, DA11 9GN

T +965 2299 6515



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info@unstudio.com
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project name Northfleet Harbourside		project number 2022-088	
location Northfleet, UK			
phase Preliminary Masterplan	sector		
		format A1	scale 1:1500
status	date 29-07-2022	revision R00	

drawing code
NFH-UNS-MAST-DR-1003
title
Flood Risk Vulnerability

description / disclaimer

Northfleet Central 1 Limite
Stonebridge Road
Northfleet
Gravesend
DA11 9GN

Our ref: KT/2022/129955/02-L01
Your ref: ENVPAC/1/KSL/00566
Date: 20 September 2022

Dear Sir/Madam

THE REDEVELOPMENT OF THE SITE WILL INCLUDE PHASED DEMOLITION AND REDEVELOPMENT OF 3,500 RESIDENTIAL UNITS, LEISURE FACILITIES, FOOTBALL CLUB FACILITIES FOR EBBSFLEET FOOTBALL CLUB, RETAIL AND EMPLOYMENT USES, COMMUNITY USES, CREATION OF NEW PUBLIC SPACES, LANDSCAPING AND ASSOCIATED WORKS.

LAND AT GROVE ROAD IN NORTHFLEET, KENT, DA11 9AX

Thank you for consulting us. Having reviewed the submitted report ('Northfleet Central EA Consultation', reference: RMA/LC2402, dated: 15th/08/2022) we **object** to the proposed development.

Tidal Thames defence raising

The referenced report does not include any consideration for the condition, residual design life and required raising of the site's Tidal Thames flood defences.

As the development has a 100 year design life, the proposal must demonstrate that the site's flood defences will provide the required degree of protection for this design life. The Thames Estuary 2100 Plan (TE2100) sets out the required flood defence crest level to maintain a sufficient standard of protection whilst accounting for the impacts of climate change. For this site, the tidal defences must be raised to a crest level of 8.00mAOD by 2070. Due to the requirement for the development to apply a 100-year design life, a proposal for the raising of the tidal defences to 8.00mAOD must be included as part of the development.

In addition to providing defence raising, it must be shown that the defence has a design life of 100 years. This would require that, either a new flood defence is constructed or that it can be demonstrated that the existing flood defence could be raised to a minimum of 8.00mAOD and provide the required degree of protection for at least the developments design life. Any proposal which included the existing river wall would have to demonstrate sufficient residual design life of the asset through an extensive series of surveys and testing. It is our experience that such defences rarely have sufficient design life and a new asset would likely be required to meet the

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requirements of the National Planning Policy Framework (NPPF).

Any proposal for defence raising and/or a new defence should consider how the defence line would integrate with the defence line immediately up and downstream of the site. It should be noted that Robins Creek and much of the Northfleet river frontage is currently under development.

If a retreated defence is proposed, the development should seek opportunities to provide additional outcomes such as by creating inter-tidal habitat. If a realigned defence relies on the existing river wall (for example, to form part of the defence's toe) then the river wall must be considered part of the overall flood defence line and should be demonstrated to have at least 100 years residual design life following the development.

Proximity to main River and Tidal flood defence assets

Figure 2 ('Easement Buffers Post-development') of the referenced report indicates that development would not only encroach within the required easement distances, but would also include building over the culverted Main River Ebbsfleet. This would create an unacceptable degree of risk to the culvert during construction in addition to likely reducing the residual design life of the main river asset.

We would object to any proposal which featured encroachment to within 8 metres of a main river or 16 metres of a tidal river and associated assets.

It should be noted that flood defence assets (such as flood walls and culverts) often feature buried elements. These should be surveyed to determine the most landward extent of the asset and the easement values measured from these points.

The current condition of the river Ebbsfleet culvert is not accurately known. It would be the riparian owner's responsibility to provide repairs and maintenance. Due to the 100-year design life of the proposed development, it is very unlikely that the culvert would provide the required standard of protection for this period. Deculverting of the River Ebbsfleet must be considered as part of this proposal. Where, existing structures prevent daylighting of the culvert, we would likely support redirecting of the channel. Where parts of the culvert must remain in place, a 100-year residual design life for such assets, would again be required.

The downstream side of the river wall features a flood gate. We would require confirmation regarding the developments use of this feature. Flood gates form a weakness within a flood defence and we would look for this to be fully decommissioned; replacing the flood gate with a section of flood defence which should feature a crest level of no less than 8.00mAOD.

Flood Modelling

We have carried out catchment level modelling of the main river Ebbsfleet in 2015. The existing model indicates a very low level of flood risk to the site. However, this is likely to be inaccurate and the model should not be used as the only assessment of fluvial flood risk at this site. A site-specific flood risk model must be submitted with

any planning application to demonstrate that the site can be considered sufficiently safe from flood risk whilst not displacing flood risk to the surrounding area. This should consider fluvial and tidal flood risk in addition to surface water. A site-specific flood model should consider options for deculverting of the river Ebbsfleet and the resulting change in flood risk to the site.

Insufficient Freeboard to the modelled climate change level

Figure 7 of the report ('More Vulnerable Development Mitigation') indicates that the site would feature more vulnerable development with finished floor levels (FFL) set below the design flood level. This does not follow a sequential method and would not meet the requirements of the exception test.

Finished floor level of more vulnerable units should be set no lower than 600mm above the design flood level for the site. Where flood levels vary across the site, the supporting FRA should indicate why a given value was chosen. The design flood level for this proposal would be either: the downstream Tidal Thames Breach level for the year 2100 or the fluvial 1% Annual Exceedance Probability (AEP) flood level with allowance for climate change, whichever is highest. In the case of fluvial flood risk, a freeboard of 300mm would be consistent. As previously noted, site specific flood modelling would likely be required for this site to better represent fluvial flood risk.

We recommend that the ground floors of the proposed development are used for less vulnerable usage; limiting more vulnerable usage to the first floor and above. We further recommend that the finished floor level for all ground floors is raised to 600mm above the design flood event to reduce the impact of flooding from all sources. It is recommended to raise land levels across much of the site to provide the mentioned FFL levels. This would provide a high level of protection. To enable such raising, tunnel spoil may be possible to source from projects such as HS2.

Adjacent Development

Much of the Northfleet area is undergoing development. We recommend that the developer seeks opportunities to communicate with neighbouring developments and planning authorities, notably, Ebbsfleet Development Corporation (EDC). This may provide efficiencies for the development especially with regards to flood defence raising, deculverting and flood modelling.

We would require confirmation of the relationship of the applicants site and the Robins Creek. As part of this, please confirm the offset between the red line boundary and the creek defence and the nearest element of the creeks wall.

Yours faithfully

David Sankar
Planning Advisor

From: Melissa Seymour
Sent: 23 September 2022 10:45
To: Enquiries, Unit
Cc: Abbey Musker; Jack Douglas; Rosie Tutton; Gary Cooper; Jon Bradburn; Polly Mason
Subject: FW: Cost Recovered Advice: Northfleet (Harbourside) Project : ENVPAC/1/KSL/00566
Attachments: ENVPAC_1_KSL_00566_NORTHFLEET.pdf; Figure 10 Indicative Realignment Route.pdf

Good Morning David,

Firstly, many thanks for providing the comments on the scheme at Northfleet. I have provided a response to each of the four many queries you raised below and given the timeframes and planning application submission being imminent, I would welcome a phone discussion to chat through our responses.

1. **Tidal Defence Upgrades:** *The River Thames tidal flood wall is located outside of the Northfleet's developments red line boundary and therefore these defences are not located within the Applicants control and any future upgrades to the defences are not included within the proposed development outline application. However, futureproofing of the site and the flood defences has been duly considered in the development design, with the inclusion of a 19m set back (standard being 16m) that is free from any built development in the northern extent of the site up to the northern boundary. There is commitment within this application to provide new flood defences within the 19 m set back to meet the Thames Estuary 2100 (TE2100) standards that is required. Given the outline nature of the proposal, details with regards to the design, existing condition of the current defences and structure will be provided at reserved matters stage.*
2. **Culvert location** *Presently, due to the lack of information and documentation, including specific and clear as-built survey information of the culvert, coupled with the inaccessibility of the area in question, the exact alignment of the culvert is currently unknown. The current alignment shown on Figure 10 is taken from EA main river spatial data and this shows buildings overlaying part of the culvert. Given the outline nature of the proposed scheme, a detailed culvert survey will be undertaken at reserved matters stage (controlled by a suitably worded planning condition). This is considered a reasonable, proportionate approach given the flexibility within the design. However, an indicative resolution is proposed which includes the diversion of the culvert along the road to the west of the site, as shown within the attached indicative Figure 10. The realignment details would be confirmed following a detailed survey of the culvert to understand its depth, width and conditions and this would stipulate any realignment route. This approach would provide a betterment when compared to the existing scenario as there will be opportunities to widen the culvert, increasing its capacity thereby reducing flood risk. This approach would also ensure that there is a suitable 8m easement predominantly free of built development to allow for access and maintenance. Opportunities for de-culverting and partial decelerating will also be considered following the culvert survey that will be undertaken at reserved matters stage.*
3. **Flood Model** – *The River Ebbsfleet Flood model (2015) was provided to us by the Environment Agency when we requested the product 4 data for the FRA on 18th July 2022. It was not stipulated at the time that this was inappropriate to use for this site and should have been highlighted. The 2015 model is an upgrade to the previous 2005 model which was considered inappropriate and the 2015 model is understood to include the culvert within the model and therefore it would be good to understand how and where the model is considered inappropriate. As committed to in Point 2 above, given the outline nature of the proposed scheme, a detailed culvert survey will be undertaken at reserved matters stage (controlled by a suitably worded planning condition), and on receipt of this, the model can be updated to validate the 2015 model with the culvert survey. It's important to note that the current 2015 model includes both the 1% AEP plus 35% climate change allowance and the 1% AEP event plus 70% climate change allowance and for both of these scenarios, the site is not affected by flooding. When reviewing the EAs most recent climate change*

allowances guidance that were updated in July 2021, for a 'more vulnerable' development at this site we are required to use a climate change allowance of just 27% for the 1% AEP scenario. This suggests that the current model assesses a worst-case scenario and shows our site would not be affected by flooding for a much higher climate change allowance (i.e. 35 % and 70%). It is considered that the realignment of the culvert and increase in capacity of the culvert will provide a betterment in flood risk terms and therefore will not create an increase in fluvial flood risk at the site at shown within the 2015 model.

4. **Flood levels and Floor Levels** – *All Finished Floor Levels of 'more vulnerable' development will be raised 600 mm above the tidal breach 2100 flood level for each building. There will be some areas where reception areas and entrances will be required to be located at ground level, below the flood level, however the sensitive areas of these land uses will be raised above the flood levels where appropriate. The EAs comment regarding raising ground floor levels above the flood level is not possible given the extent of flood depths at the site and amount of ground raising required which would result in massive implications on all other technical disciplines at the site. Raising the 'more vulnerable' elements above the flood level is considered to be feasible and appropriate for the residual flood risk at the site.*

I am hopeful that the above responses to your comments are acceptable and would allow for the EA to accept the application going forward and look forward to a discussion on these prior to the application begin submitted next week.

Should you require any further information in the meantime, please do not hesitate to get in touch.

Kind Regards,
Melissa Seymour

(m) 07808 645 365

From: KSLPlanning <KSLPLANNING@environment-agency.gov.uk>

Sent: 20 September 2022 15:14

To: Melissa Seymour <Melissa.seymour@rma-environmental.co.uk>

Subject: Cost Recovered Advice: Northfleet (Harbourside) Project : ENVPAC/1/KSL/00566

Hi Melissa

Please see attached

Kind Regards

David Sankar

Sustainable Places Planning Advisor (Kent)

Environment Agency,

Kent, South London and East Sussex Area

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Melissa Seymour
RMA Environmental Limited
78 York Street
London
W1H 1DP

Our ref: KT/2022/129955/05-L01
Charged agreement ref:
ENVPAC/1/KSL/00566
Date: 29 June 2023

Dear Melissa,

Redevelopment of the site including phased demolition and redevelopment of 3,500 residential units, leisure facilities, football club facilities for Ebbsfleet football club, retail and employment uses, community uses, creation of new public spaces, landscaping and associated works.

Land at Grove Road in Northfleet, Kent, DA11 9AX.

Thank you for requesting pre-application advice regarding the above site, and for meeting with us on 12 June 2023.

As part of this consultation, we have also reviewed the following document:

- “Response to Environment Agency”, dated 26 May 2023, ref: MA/LC2402g_2– EA Response Letter

Please see below our additions and amendments to the meeting minutes sent by yourselves. We have also added additional points of clarification not raised in the meeting itself, where we feel this is necessary.

Meeting minutes review

Flood Defences and Upgrades

- The EA seemed positive on the options provided in the River Wall Impact Assessment. It was confirmed that the intertidal terrace could be below the Mean High Water Springs levels and further details will be determined at the detailed design stage;
- We discussed the tie-in features to the adjacent defence levels within the red line boundary and further details can be provided at a later stage. It will be ensured that the proposed defences will not inhibit development elsewhere;
- Walsh confirmed that new defence would be independent of the existing defence and it is proposed to reduce the levels behind the defence to reduce the stress on the wall. The new defence and any residual element of the existing wall will have a 100 year lifetime;
- The EA noted that the distance from the proposed flood defense to the building on one of the sections was 3m and that this would not provide sufficient maintenance space. Walsh noted that the wall would be cantilevered

(and thus would not have tie rods) and that the IA notes that the new defense would be maintained from the riverside of the defense and that access was provided thus. Walsh also noted that if the EA required a greater distance between defense and building the wall would need to be moved not the building. The EA appeared to be receptive of this.

- The EA noted that they would like for concrete to be excluded from the intertidal terrace to increase the ecological habitat within the river however Walsh noted that they may have misinterpreted the drainage and it was not the intention for the inter-tidal terrace to be concreted. Walsh noted that there were three nominal levels proposed, a tidal terrace which would flood daily but have minimal access, a lower terrace which would flood occasionally and be accessible for most and an upper terrace which would flood rarely and be accessible to all. The EA were in agreement with his and asked if the terraces could be linked with a “zig-zag” terrace which Walsh noted was definitely feasible and would be considered.

Environment Agency Comments

Please note that the development must not prevent future maintenance and management of the flood defences, including any retreated defence.

Culvert Realignment and Daylighting

- The EA stipulated the importance of daylighting the River Ebbsfleet as much as practicable. The culvert would need to be replaced over the lifetime of the development, be a 100 year asset, include an allowance for climate change and have a 8 m maintenance buffer either side of the culvert and, therefore, work on the Ebbsfleet will be required over the lifetime of the development and the deculverting option is preferred by the EA. Therefore, the buildings over the culvert are recommended to be moved or the river diverted to achieve these stipulations. The development may be considered a keystone development if the Ebbsfleet is exposed allowing users of the site to appreciate the natural environment and sport. The 10% biodiversity net gain is required to include the river system and this determines the minimum stretch of channel to be deculverted subject to the EA's agreement that no further areas could be reasonably daylighted.
- The maintenance buffer of 8 m could be reduced if the river is daylighted. The EA suggested that if there is limited space once the river is deculverted the intertidal frontage could be reduced within the layout subject to further discussions and evidence provided by the developer.

Environment Agency Comments

It should be noted that we are seeking for the entirety of the Main River Ebbsfleet to be de-culverted (allowing for free spanning bridges and short sections of culvert as required). We understand that a section of culvert runs

next to the A226 which is within the site boundary, and this should be included in any de-culverting proposals.

Any section of culverted main river would need to have a 100-year design life as part of the proposed development. This is to ensure that the lifetime of the culvert is commensurate with that of the proposed development and thus safe for its lifetime from flooding, in line with the requirements on the NPPF (paragraph 164).

We also highlighted Policy CS06: Ebbsfleet (Gravesham) Opportunity Area at this stage of the meeting, which requires the improvement and management of the Ebbsfleet stream corridor.

- It was discussed if the deculverted channel could be meandered by locating it on the west side of the road however, this is unlikely to be feasible due to the steps leading to the stadium but should be considered by the design team. The EA suggested that a cantilevered path could be utilized to create this meandering channel.

Environment Agency Comment

Whilst the option of a cantilevered path was discussed with our biodiversity officer during the meeting, we would like to highlight that we would likely oppose a cantilevered path from a flood risk perspective given this would significantly negatively impact future maintenance and management of assets required for flood risk management

It was queried at this stage of the meeting what level of detail would be required in order for us to request a condition on the outline application detailing the design of a deculverted channel. Whilst it is difficult to say at this stage of the design, we stated that any condition we request would need to pass the 6 tests for planning conditions as outlined in the National Planning Policy Framework (NPPF) <https://www.gov.uk/guidance/use-of-planning-conditions>. A sufficient level of detail needs to be provided for us to be request conditions that pass these tests.

- The EA suggested that a discussion with the Council's Archaeology Team, themselves and the client's advisors could be undertaken to discuss the balance of deculverting the Ebbsfleet and the archaeological sensitivities within the site.
- The suitability of deculverting the Ebbsfleet is also subject to the results from the flood modelling as the tidal locking in Robins Creek could result in the need for a substantial channel. Once we have received the modelling and confirmation on if the buildings over the watercourse can be removed, this should be discussed with the Team.
- **Next Steps/Actions:**

- Design Team to relook into the daylighting design considering there is potentially some compromise on buffers/setback.
- Run the flood model with any daylighting scenario.

Flood Modelling

- The EA discussed that groundwater would be useful to include within the modelling as there has been changes to the extraction volumes as the area has been developed. However, JBA identified that there are significant limitations to trying to include a groundwater input to the hydraulic model. This includes uncertainty regarding the location of the borehole used in the previous study and that, regardless of this, the borehole is not located at the location where the groundwater level is being applied to the model. This means that there cannot be confidence that the level being applied to the model (and converted to flow within the model) is representative of the actual groundwater level at the upstream model extent. Analysis of data from two boreholes for which data is available on the EA's Hydrology Data Explorer suggests that there is large variation in peak levels across the area.

The way the groundwater level is converted to flow in the model is dependent only on the level provided, it does not account for spatial variation, so flow is very dependent on the borehole used for the analysis. There is no groundwater flow data for this area and no river flow data against which to compare the groundwater response. This means that flow generated from groundwater level is highly uncertain as there is no data against which to verify it.

Due to these and several other limitations, there is substantial uncertainty in the results of the groundwater level analysis and how representative the groundwater level being applied to the model is. It therefore offers no benefit to the study in terms of understanding the groundwater input and impact on flood risk and does not increase confidence in the model predictions of flood extent and depth. In contrast to the 2015 study, JBA propose to apply a fluvial-only flow to the upstream extent of the model. This is a more standard approach, can more easily be justified, and offers no greater uncertainty than the previous approach.

- JBA enquired what the uncertainties within the model are, regarding the groundwater input, that the EA has referred to, for example, is the 2015 study input thought to be an overestimate or an underestimate?. The EA said they would try and talk to their modelling team and forward contact details to JBA to see if any further information is available on the uncertainties within the model and provide thoughts on the identified limitations (above) and the proposed approach.

Environment Agency Comment

In the first instance, we would like to highlight the opportunity to link up with Ebbsfleet Development Corporation and their flood risk consultants Stantec, given they are also modelling the Ebbsfleet also as part of the Ebbsfleet Central development. We strongly recommend a joined-up approach, as this would likely provide cost and time efficiencies for all parties.

Given the limited available data, we accept the proposed pre-development modelling method with the caveat that our Evidence and Risk (flood modelling) team will have the final say on suitability when they are consulted on the full flood model. Their review would be either as part of the statutory consultation on any application, or outside the statutory process through our cost recovery service.

Our Evidence and Risk team are also able to review detailed methodologies and provide a written response, also as part of our cost recovery service – please contact us for further information. Due to our Evidence and Risk team's national workload, we carry out an internal consultation process and we would not be able to pass on individual contact details.

Where there are uncertainties regarding modelled flood outputs on site, we would typically require a greater freeboard to mitigate risk.

Tidal Flood Levels and Floor Levels

- The EA have confirmed that it is acceptable to have the entrances and ancillary uses for the 'more vulnerable' development below the breach level. They clarified that these ancillary uses should not result in 'more vulnerable' users spending a long time below the flood level (i.e. waiting rooms) as it is possible a breach of the defences surrounding the site could occur.
- **Next Steps/Actions:**
 - Design Team to provide some drawings clarifying what 'more vulnerable' uses are below the flood level.
 - Confirmation from the EA that these uses below the flood level are acceptable.

Environment Agency Comments

Please send us drawings outlining what "more vulnerable" uses are below the flood level and we'd be happy to provide clarification on the above point.

Advice to Applicant

Pre-app enquiry caveat

Please note that the view expressed in this letter is a response to a pre application enquiry and does not represent our final view in relation to any future planning application made in relation to this site. We reserve the right to change our position in relation to any such application. You should seek your own expert advice in

relation to technical matters relevant to any planning application before submission.

Should you have any queries regarding this response, please contact me.

Yours sincerely,

George Goodby
Sustainable Places Planning Specialist

Mobile +447879802840

E-mail kslplanning@environment-agency.gov.uk

Melissa Seymour
RMA Environmental
78a York Street
London
W1H 1DP

Our ref: KT/2022/129955/06-L01 /
ENVPAC/1/KSL/00566
Your ref: Northfleet Harbourside
Date: 13 October 2023

Dear Melissa,

Redevelopment of the site including phased demolition and redevelopment of 3,500 residential units, leisure facilities, football club facilities for Ebbsfleet football club, retail and employment uses, community uses, creation of new public spaces, landscaping and associated works.

Land at Grove Road in Northfleet, Kent, DA11 9AX.

Thank you for contracting us for advice regarding the above site.

As part of this consultation we have reviewed the following document:

- RMA/LC2402g_1 – EA Response Letter August, dated 24 August 2023.

We are also currently reviewing the submitted flood modelling and associated reports, we will be providing comments on this element of the submission in due course.

Daylighting of the River Ebbsfleet

From a biodiversity perspective, we are supportive of the proposals to de-culvert the river Ebbsfleet at this location.

From a flood risk perspective, we will need to complete our review of the submitted modelling before commenting further.

Proposed setback from River Ebbsfleet

Our preferred option would be an undeveloped 8m buffer zone either side of the daylighted culvert. However, given the likely overall benefits achieved by de-culverting at this location, we are satisfied with the setback distances as outlined in the submitted report.

We note that the eastern bank will have a minimum of 3.5m easement provided – this is acceptable given that 8m offset will be provided from the western bank.

We note that the eastern bank may be at a particularly acute angle in places, meaning there is a greater chance of it being washed out. Given this, careful consideration will need to be given to using geotextile and other more engineered solutions to achieve stability.

As a potential alternative, we would suggest a two-stage channel if the gradient on the east bank is too acute (if more than 45 degrees). The two-stage channel approach incorporates a terrace(d) or gently sloping plateau from the waters edge to a vertical back edge. This approach additionally can provide improved flood storage.

Finished floor levels

The proposed levels are acceptable, with all accommodation located above the breach level. While there are some "more vulnerable" uses on the ground floor there is access to internal safe refuge at a minimum of 300mm above the breach level. We would likely condition the implementation of these floor levels at the outline application stage, to ensure this is secured.

Flood Defences and Upgrades

Please provide confirmation of how much space, as a minimum would be left behind the new proposed defence.

We are pleased to see the provision of the 8m service area but there needs to be dry access behind the new defence line to enable essential emergency and maintenance works as well. From the provided report it is not entirely clear how much clear space is behind the new defence. In some sections the service area is in front of the new defence line.

Closing comments

Please note that the view expressed in this letter is a response to a pre application enquiry and does not represent our final view in relation to any future planning application made in relation to this site. We reserve the right to change our position in relation to any such application. You should seek your own expert advice in relation to technical matters relevant to any planning application before submission.

Should you have any queries regarding this response, please contact me.

Yours sincerely,

George Goodby
Sustainable Places Planning Specialist

Mobile +447879802840

E-mail kslplanning@environment-agency.gov.uk

Melissa Seymour
RMA Environmental
78a York Street
London
W1H 1DP

Our ref: KT/2022/129955/07-L01 /
ENVPAC/1/KSL/00566
Your ref: Northfleet Harbourside
Date: 10 November 2023

Dear Melissa,

Redevelopment of the site including phased demolition and redevelopment of 3,500 residential units, leisure facilities, football club facilities for Ebbsfleet football club, retail and employment uses, community uses, creation of new public spaces, landscaping and associated works.

Land at Grove Road in Northfleet, Kent, DA11 9AX.

Thank you for contracting us for advice regarding the above site.

As part of this consultation we have reviewed the submitted hydrology report and hydraulic modelling (baseline and post-development) that we received on 1 September 2023.

Please see the attached output detailing our technical comments on the model files provided:

- LIT 17617 - Non-real time Hydraulic Model Review_NorthFleetHarbourside.xlsm
- LIT 66039 - Flood Estimation Calculation Review Template_NorthFleetHarbourside.xlsx

Environment Agency Position

There are several “amber” rated comments in the above referenced spreadsheets, which should be addressed (or justified) before we would consider the submitted modelling suitable to support the proposed development.

Additionally, the model should be used to carry out a further exercise to demonstrate that the proposed development will not hinder the Water Framework Directive (WFD) Action for tidal realignment of Robin’s Creek being achieved. This scenario was included in the Environment Agency Ebbsfleet Model which was used as the basis for your model.

Please see below guidance for further rationale for this exercise and suggested options for what this should entail.

Impact on Water Framework Directive (WFD) Action at Robins Creek

Our Catchment Planning System lists actions to improve the water environment across the whole country. Those actions that have gone through a cost-benefit analysis and are proven cost-beneficial are copied into the publicly available River Basin Management Plans and appear in the Catchment Data Explorer. For estuaries, there was never a working cost-benefit process and therefore limited actions are available for the Tidal Thames. The limited opportunities that exist are mainly where docks or tributaries can be reopened to the tide to form naturally sloping banks with marsh at their rear and/or an input of fresh water can be upheld as important ecologically mainly because they act as refugia for migratory and/or nursery grounds for juvenile fish.

For the Thames Middle waterbody, once such action is:

29752 Robins Creek - manage realign to create tidal creek

Re-development around Robin's Creek relies on the causeway flood defence structure across the mouth of the creek to provide the tidal flood defence. Lower ground levels around the side and rear of the creek make a high enough retreated flood defence difficult to achieve with projected sea level rise and the Thames Barrier remaining located upstream on the Tidal Thames. However, it is likely possible to deliver a partial form of this action of managed realignment by introducing a scheme of regulated tidal exchange. Projects/work which make the achievement of the WFD action/regulated tidal exchange more difficult would constitute as hydromorphological harm under the Water Resources Act 1991 (Amendment) (England and Wales) Regulations 2009 because they jeopardise delivery of our environmental objectives.

Future projects both inland up the River Ebbsfleet and around the creek could have complex interactions with the saline intrusion into Robins Creek. Modelling is required to understand these complex interactions which we suggest should entail:

1. Establishing the highest tidally received water level within Robin's Creek that would not increase flood risk to existing built environment via fluvial or surface water.
2. Superimposing any channel changes and the proposed development in combination with the highest water level in Robin's Creek established from point 1.
3. If the results show that the allowable level in Robin's Creek without increasing flood risk is reduced, then the development jeopardises/hinders delivery of our environmental objectives and should be reconfigured. The flood model should be used as a design tool to make any needed changes so that the development in point 2 does not decrease the maximum tidally received water level in Robin's Creek.

We will also consider alternative methodologies if these successfully demonstrate that the development is not hindering achievement of the WFD objective. For example, you could choose to model an in-principle design of a regulated tidal

exchange scheme for Robin's Creek to show that it is workable and with a somewhat lower receiving water level within the creek and would not:

- increase flood risk including during an extreme event in the Tidal River Thames, or
- include moving parts except flap valves.

One possible option could be to relocate the tidal flap to outlet of the Grove Road culvert with the Thames Tidal level in Robin's Creek, as was included as a scenario in our 2015 modelling.

We would be happy to meet to discuss these requirements in further detail.

Closing comments

Please note that the view expressed in this letter is a response to a pre application enquiry and does not represent our final view in relation to any future planning application made in relation to this site. We reserve the right to change our position in relation to any such application. You should seek your own expert advice in relation to technical matters relevant to any planning application before submission.

Should you have any queries regarding this response, please contact me.

Yours sincerely,

George Goodby
Sustainable Places Planning Specialist

Mobile +447879802840

E-mail kslplanning@environment-agency.gov.uk

Melissa Seymour
RMA Environmental
78a York Street
London
W1H 1DP

Our ref: KT/2022/129955/08-L01/
ENVPAC/1/KSL/00566
Your ref: Northfleet Harbourside
Project
Date: 19 December 2023

Dear Melissa,

The redevelopment of the site will include phased demolition and redevelopment of 3,500 residential units, leisure facilities, football club facilities for Ebbsfleet football club, retail and employment uses, community uses, creation of new public spaces, landscaping and associated works.

Land At Grove Road, Northfleet, Kent, DA11 9AX

Thank you for your request for advice regarding the above site.

Flood modelling for Water Framework Directive (WFD) action to realign Robin's Creek

We have reviewed the submitted modelling and we are satisfied that this meets the requirements outlined under the heading "Impact on Water Framework Directive (WFD) Action at Robins Creek" in our letter dated 10 November 2023 (ref: KT/2022/129955/07-L01).

River wall Impact Assessment

Thank you for providing us with the revised document:

- River Wall Impact Assessment, prepared by Walsh, Revision 02, dated 23 November 2023

We understand that revisions have been made to this document following our comments concerning dry access under the heading "Flood Defences and Upgrades" in our letter dated 11 October 2023 (ref: KT/2022/129955/06).

Our concerns remain regarding access to the back of the new defence. It appears that this may also conflict with available space for tidal terracing- in the diagrams titled "alternate retaining wall conditions" the 8m access removes the available space for tidal terracing.

It is likely that as part of the outline application, we would request a condition setting the parameters for the design of a new flood defence. Part of this condition would include the minimum offset to any built form on the landward side. If there is a large variance in the offset provided (e.g. 4m at certain "pinch points", but otherwise "typically" 6m- we request that this is provided in an indicative plan. We could then refer to this in the wording of any condition.

We would not be comfortable requesting a condition whereby it is specified only that a minimum of 4m offset is provided. We are concerned that this would lead to a scheme which provides inadequate landward offset overall at the detailed design stage (e.g. a scheme could come forward proposing 4m offset along the entire length of the defence).

We have previously stated in our letter 29 June 2023 (ref: KT/2022/129955/05-L01) that "the development must not prevent future maintenance and management of the flood defences, including any retreated defence."

We also have the following comments on the report:

- **Option 1 (page 10)**
 - at 4-4.5mAOD the defence may become at least partly inundated several times a year. This likelihood will increase with sea level rise. So we feel the assessment that this will have a "very low risk flooding from tidal waters" is not wholly accurate.
 - In previous discussions you have stated that the existing defence will be "sacrificial". We would not be comfortable if the only means of access were supported by a sacrificial element.
- **4.3 Links to adjoining flood defence**
 - It would be preferential if the connection points were at 8mAOD, because if adjacent sites raise the defence in its existing position, the connection points would also need to be raised
- **Table 5**
 - We have concerns that the 4m offset may not be enough, especially if the tree/ planting work (as shown in Figure 9) narrows access further. As mentioned above, we would seek further clarification on this.

De-culverted River Ebbsfleet

Please ensure that any final design considers routine channel maintenance (e.g. vegetation management) and ad-hoc works such as blockage clearance.

Pre-app enquiry caveat

Please note that the view expressed in this letter is a response to a pre application enquiry and does not represent our final view in relation to any future planning application made in relation to this site. We reserve the right to change our position in relation to any such application. You should seek your own expert advice in relation to technical matters relevant to any planning application before submission.

We would be happy to meet to discuss any of the above points in more detail. We feel this would likely be the most time-efficient approach for both parties.

Yours sincerely,

George Goodby
Sustainable Places Planning Specialist
E-mail kslplanning@environment-agency.gov.uk

Appendix C: LLFA Consultation

Rosie Tutton

From: Rosie Tutton
Sent: 14 September 2022 16:56
To: Rosie Tutton
Subject: FW: enquiry NORTHFLEET
Attachments: RE: ENQUIRY: Northfleet ; Kent Pre-application advice 2021.pdf

From: KSLPlanning <KSLPLANNING@environment-agency.gov.uk>
Sent: 01 August 2022 11:56
To: Melissa Seymour <Melissa.seymour@rma-environmental.co.uk>
Subject: RE: enquiry NORTHFLEET

Hi Melissa

I have not heard back from Rebecca Ellsmore at Ebbsfleet Development Corporation so at present this work has not started. An acknowledgement was sent, see attached, for the site known as Grove Road.

However on review this morning I note the red line boundary is to the East of Grove Road/ Robin's Creek. This is not within the Ebbsfleet Garden City boundary and previous comments may not apply. I believe this site has been referred to as Northfleet Harbourside, I would be grateful if you could confirm this.

Please see below for our preliminary opinion advice.

Dear Melissa Seymour

Thank you for consulting us with your proposal.

Please find attached our pre-application advice note which provides information and guidance about issues within our remit at the planning application stage. Please note, in addition, that Robin's Wharf is an operational wharf and is safeguarded for minerals transportation in the KCC minerals and Waste Local Plan. There is also a culverted WWTW outfall to the east of your site boundary.

Current arrangements for the River Ebbsfleet mean that the river is not tidal, but is tidelocked when the Thames is in full tide.

If, following a review of the information attached, you decide that you do wish to obtain more detailed pre-application advice from us, please contact us via the e-mail address shown below to enquire about the cost recovery service we offer for detailed pre-planning advice.

Kind regards

Sophie Page

Sophie Page
Planning Specialist
Sustainable Places Kent and South London
Environment Agency

020 8474 8030
~~Environment Agency, Orchard House, Endeavor Park, London Road, Addington, Kent, ME19 5SH~~
Please note I am currently working from home.

Working days: Monday to Thursday 9.30 – 15.30

From: Melissa Seymour <Melissa.seymour@rma-environmental.co.uk>
Sent: 01 August 2022 08:44
To: KSLPlanning <KSLPLANNING@environment-agency.gov.uk>
Cc: Rosie Tutton <rosie.tutton@rma-environmental.co.uk>; Hattie Robinson <hattie.robinson@triumenv.co.uk>
Subject: RE: ENQUIRY: Northfleet

Good Morning,

Please can you advise when we are likely to receive a response to the below?

Kind Regards,
Melissa

From: Melissa Seymour
Sent: 29 June 2022 09:30
To: kslplanning@environment-agency.gov.uk
Cc: Rosie Tutton <rosie.tutton@rma-environmental.co.uk>; Hattie Robinson <hattie.robinson@triumenv.co.uk>
Subject: ENQUIRY: Northfleet

Dear Kent, South London and East Sussex Planning Team,

We are working on the FRA and surface water drainage strategy for the redevelopment of land at Grove Road in Northfleet, Kent, DA11 9AX (National Grid Reference – TQ 61539 75079). The indicative red line boundary is attached. Ebbsfleet, a 'main river', is culverted along the eastern boundary of the site and the River Thames is located along the north-eastern boundary of the site.

Please can you confirm the required development easements required for this culverted main river (Ebbsfleet) and for the River Thames.

The site is proposing to discharge into Ebbsfleet in the south and surface water flow from the development does not need to be restricted in accordance with the Non-Statutory Technical Standards for Sustainable Drainage Systems (DEFRA, 2015), as where the drainage system discharges to a surface water body that can accommodate uncontrolled surface water discharges (e.g. sea, tidal waters of rivers), the peak flow standards and volume control technical standard need not apply. The Ebbsfleet is tidally influenced at this point and, therefore, surface water runoff from the development does not need to be restricted. Please confirm that this would be acceptable to the EA.

It would also be good to understand if the EA hold any survey data of the section of Ebbsfleet that is culverted through the site that is available to share.

Kind Regards,
Melissa

Melissa Seymour
Senior Environmental Consultant

ENVIRONMENTAL PLANNING - FLOOD RISK ASSESSMENT | DRAINAGE | ENVIRONMENTAL IMPACT ASSESSMENT | WATER QUALITY | PHASE 1
CONTAMINATION | UTILITIES APPRAISAL

(m) 07808 645 365



Website: www.rma-environmental.co.uk

Exeter Office: 1 Emperor Way, Exeter Business Park, Exeter, EX1 3QS
Phone: 01392 576227

London Office: 78 York Street, Marylebone, London, W1H 1DP
Phone: 020 3292 0534

Registered Office: RMA Environmental Limited, 2 Chartfield House,
Castle Street, Taunton, TA1 4AS - Registered in England No: 6915388

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Genna Henry
Gravesham Borough Council
Civic Centre
Windmill Street
Gravesend
Kent
DA12 1AU

Flood and Water Management

Invicta House
Maidstone
Kent
ME14 1XX

Website: www.kent.gov.uk/flooding
Email: suds@kent.gov.uk
Tel: 03000 41 41 41
Our Ref: GBC/2022/091379
Date: 25 August 2022

Application No: 20220852

Location: Land Surrounding Ebbsfleet United Football Club, Bounded By Lower Road, Railway Line, Grove Road And The River Thames, Northfleet, Gravesend,

Proposal: Request for Scoping Opinion pursuant to Regulation 15 of the Town and Country Planning (Environmental Impact Assessment) Regulations 2017 in respect of a proposed outline planning application with all matters reserved, except for means of access, for a mixed-use redevelopment involving the demolition of existing buildings and structures including site preparation/remediation works, and the development of up to 3,500 residential units (Use Class C3), up to 55,000 sq.m (GEA) of Use Class E including up to 32,000 sq.m (GEA) floorspace for retail, food, and beverages and up to 18,000 sqm (GEA) office floorspace, up to 15,000 sq.m (GEA) floorspace for a new 8,000-seater football stadium with associated business and leisure facilities, up to 20,000 sq.m (GEA) floorspace for a hotel (Use Class C1), up to 4,000 sq.m (GEA) floorspace for community uses (Use Class F), delivery of circa 3.8 hectares of open space and the realignment of the A226 Galley Hill Road / Stonebridge Road. Redevelopment of the site will also include some sui generis uses, with hard/soft landscaping, car and cycle parking, highways works, infrastructure provisions with ancillary works.

Thank you for your consultation on the above referenced planning application. Kent County Council as Lead Local Flood Authority have reviewed the EIA Scoping Opinion Request report (July 2022) prepared by Trium Environmental Consulting and raise no objections or requirements for surface water drainage at this stage.

The LLFA understand from the Water Resources and Flood Risk Chapter (including surface water drainage) that these considerations are taken out of the EIA Scoping Opinion and will instead be covered in a separate report as part of any future planning submission. We accept this approach and will await for those details to be provided as part of a formal planning application.

The LLFA acknowledge statements 409,424 and 428 in regards to adhering to national and local planning guidance, incorporation of SuDS measures into the development and further consultation with the LLFA will be undertaken to discuss flood risk.

In addition to those policies referenced in statement 409, the LLFA would request the following KCC Policies are considered for designing a future surface water drainage scheme:

- Kent County Council's Drainage and Planning Policy Statement (2019)

- Kent Design Guide Making it Happen- Appendix C2 Drainage Systems

This response has been provided using the best knowledge and information submitted as part of the planning application at the time of responding and is reliant on the accuracy of that information.

Yours faithfully,

Daniel Hoare

Flood Risk Project Officer
Flood and Water Management



Melissa Seymour

Flood and Water Management

Invicta House

Maidstone

Kent

ME14 1XX

Website: www.kent.gov.uk/flooding

Email: suds@kent.gov.uk

Tel: 03000 41 41 41

Our Ref: NON/2022/090788

Date: 14 July 2022

Application No: pre app

Location: Land at Grove Road in Northfleet, Kent, DA11 9AX

Proposal: Outline application for a mixed-use development on the 19 ha site

Thank you for your enquiry in relation to the above site.

We have reviewed our records that we hold for your site and we can provide you with the following information:

Site Conditions

The site conditions identified from mapping show the underlying geology as Upper Chalk with groundwater likely to be seated at less than 3m below the ground surface, which may be subject to seasonal variation.

British Geological Survey mapping available to the LLFA notes that this area of interest suggest that the bedrock permeability is likely to be free draining, but seasonal variation should be investigated.

The site is situated within a SPZ2 zone indicating the groundwater may be vulnerable to contamination, risks associated with transport of contaminants to ground water should be considered prior to any suds installation and appropriate treatment.

Flood Zone mapping provided by the Environment Agency shows that the location is listed as being within flood zone 2 and a majority of the site also within flood zone 3. Please refer to the Environment Agency for further guidance.

Surface water flood mapping provided by the Environment Agency appears to show that this area may be susceptible to surface water flooding in some areas.

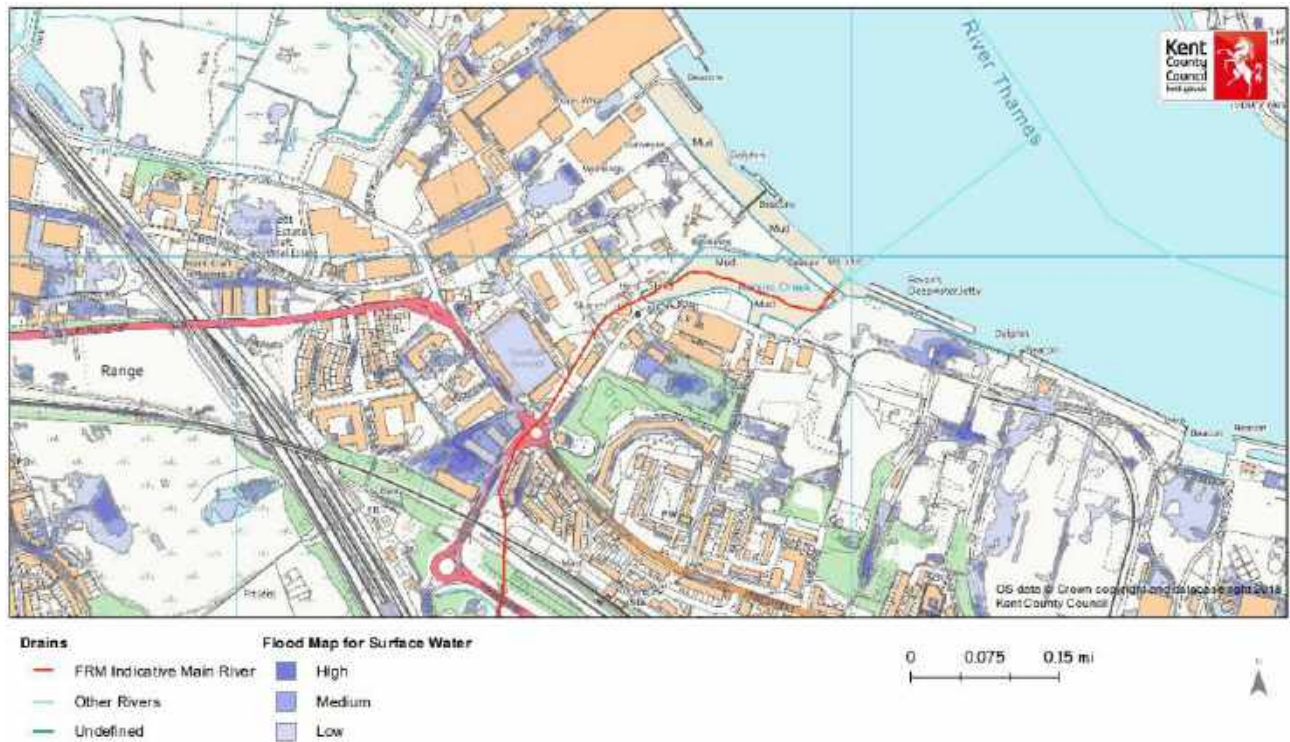


Figure 1: Surface water flood mapping overlain with Ordnance Survey map to show areas identified as at risk from surface water flows

EA National Flood Risk Assessment shows that this area is at low to medium risk of flooding from rivers, the sea, groundwater, reservoirs, and surface water.

Figure 2 below shows the location highlighted as at risk on the National Flood Risk Register:

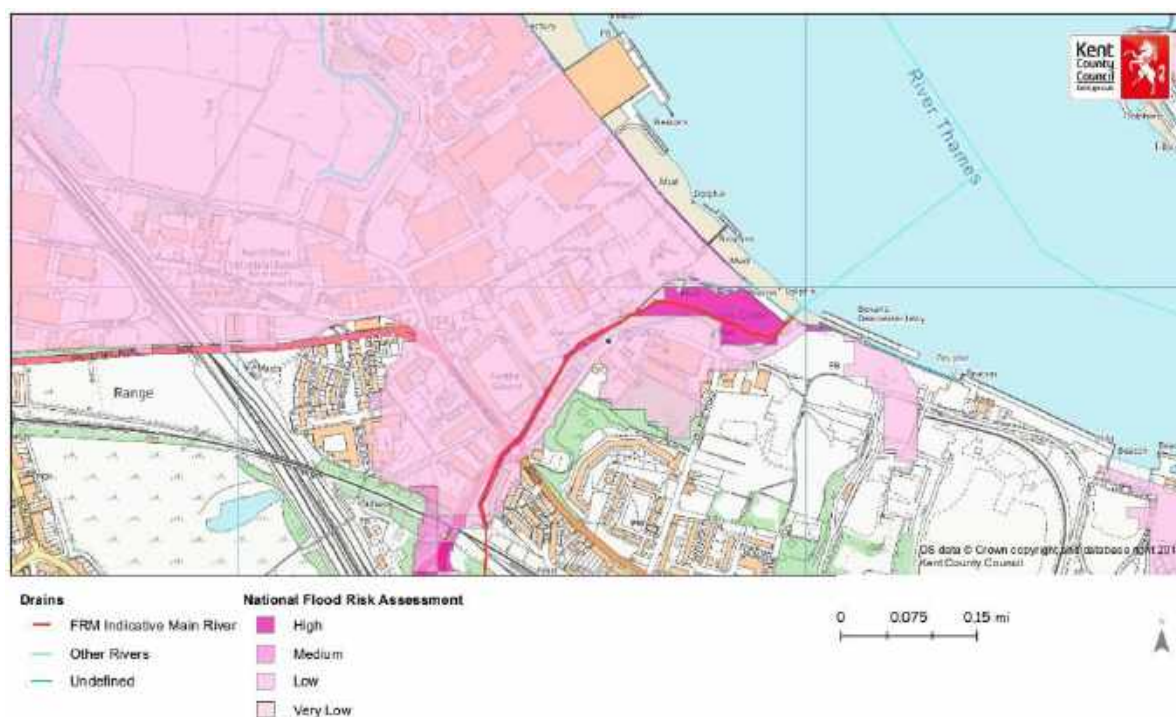


Figure 2: Surface National Flood Risk mapping overlain with Ordinance Survey map to show areas identified as at risk from surface water flows

Historic flood events

An extensive flood history search from our highway database has been undertaken of the roads and surrounding areas. Our database records reports of flooding to the highway only, unless additional information is provided. KCC do not keep records or details of private assets. A breakdown of the flood events can be found below:

THAMES WAY

- Multiple reports along Thames Way specifically underneath the bridge of flooding during and after rainfall causing problems for traffic and pedestrians spanning between 19/12/2019 and 17/06/2021.
- Multiple reports of flooding along Thames Way between 13/01/2013 and 17/06/2021.
- Multiple reports along Thames Way of blocked gullies/ beany blocks spanning between 18/09/2013 and 14/01/2021.
- Report on 13/06/2016 of a blocked drain on Thames Way outside number 33. During heavy rainfall water has gone into the property damaging the walls.

STONEBRIDGE ROAD

- Multiple reports on Stonebridge Road of blocked drains/ gullies spanning between 23/02/2009 and 15/03/2022.
- Report on Stonebridge Road outside the football club of 1ft deep flood hiding a hole in the road on 30/11/2009.

- Report on the junction between Stonebridge Road, Lower Road, and Gally Hill Road of a burst water main flooding the road on 21/10/2010.
- Report on Stonebridge road of damaged beany blocks on roundabout contributing to flooding issues on 26/02/2020.

EAGLE WAY

- Eagle Way before and after the stadium and roundabout report of the path/ road going across full of water and weeds on 05/11/2021.
- Multiple reports on Eagle Way spanning between 11/07/2021 and 01/09/2021 of remedial works being carried out to blocked gullies.

GROVE ROAD

- Multiple reports on Grove Road of Kerbs/ beany blocks broken, and drainage blocked due to vehicle overrun spanning between 18/02/2019 and 02/09/2021.
- Multiple reports on Grove Road of blocked Gullies spanning between 16/12/2011 and 19/05/2022.
- Multiple reports of flooding on Grove Road spanning between 12/06/2017 and 27/12/2021.

LOWER ROAD

- Multiple reports of flooding on Lower Road around the industrial units spanning between 11/10/2013 and 16/06/2020 possibly due to blocked drains/ gullies. however it appears that the highways team have carried out remedial works to ease the surface water flooding at this location.
- Multiple reports of blocked drains/ gullies on Lower Road spanning between 11/10/2013 and 14/01/2021, however it appears that the highways team have carried out remedial works to ease the surface water flooding at this location.

Local surface water features and drainage assets

The River Ebbsfleet is culverted through the site and is classified as Main River, any works within 8m of this culvert may require a permit to work from the Environment Agency and we would recommend contacting them at your earliest convenience further information can be found here: Check if you need permission to do work on a river, flood defence or sea defence - GOV.UK (www.gov.uk) or you can email them at enquiries@environment-agency.gov.uk

Further to this a wall is also present running along the northeastern boundary of the site that the Environment Agency are responsible for.

Figure 3 below shows the approximate route of the River Ebbsfleet along the eastern boundary of the site:

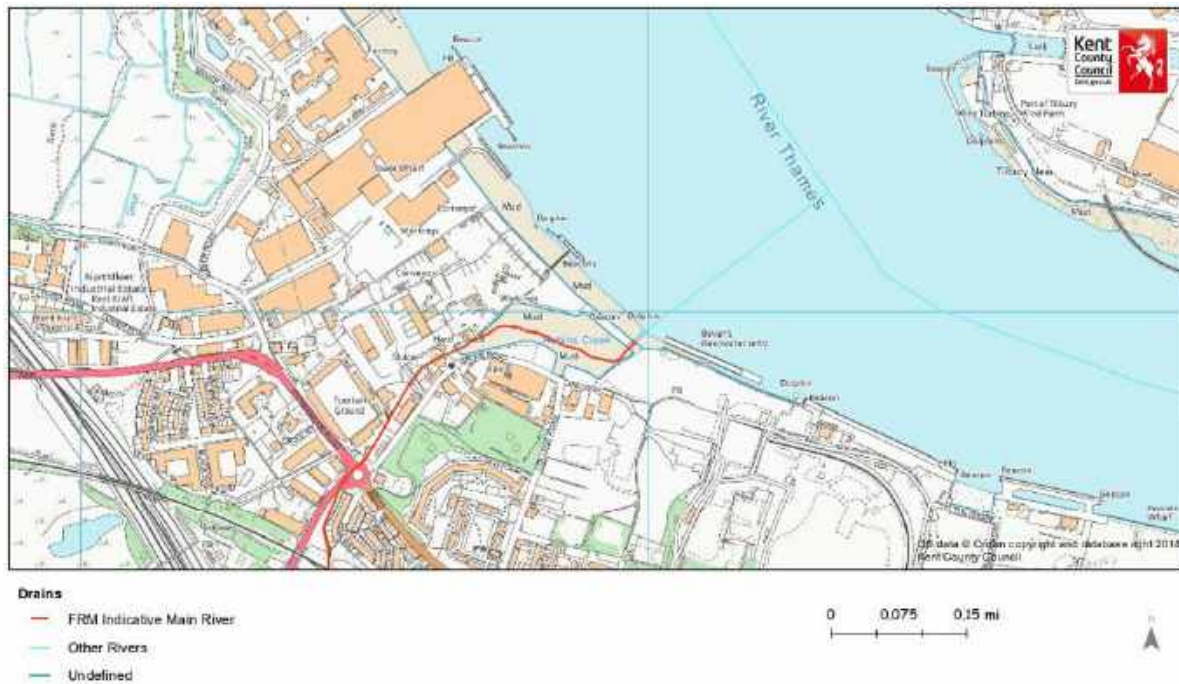


Figure 3: River Ebbsfleet flowing through site, assumed to be culverted given location.

If there are any OWC's within the site or on the boundary in addition to the River Ebbsfleet, these would be classed as Ordinary Watercourse under Land Drainage Act 1991 and Land Drainage consent may be required for the proposed development.

Please note that any feature capable of conveying water can be considered to fall under the definition of an 'ordinary watercourse' and we would urge the applicant to contact us prior to undertaking any works that may affect any watercourse/ditch/stream or any other feature which has a drainage or water conveyance function. Any works that have the potential to affect the watercourse or ditch's ability to convey water will require our formal flood defence consent (including culvert removal, access culverts and outfall structures). Please contact flood@kent.gov.uk for further information.

Our records also show that other drainage assets present on site are a number of foul sewer lines and a surface water sewer towards the south of the site along Stonebridge Road and Eagle Way shown on figure 4 below:

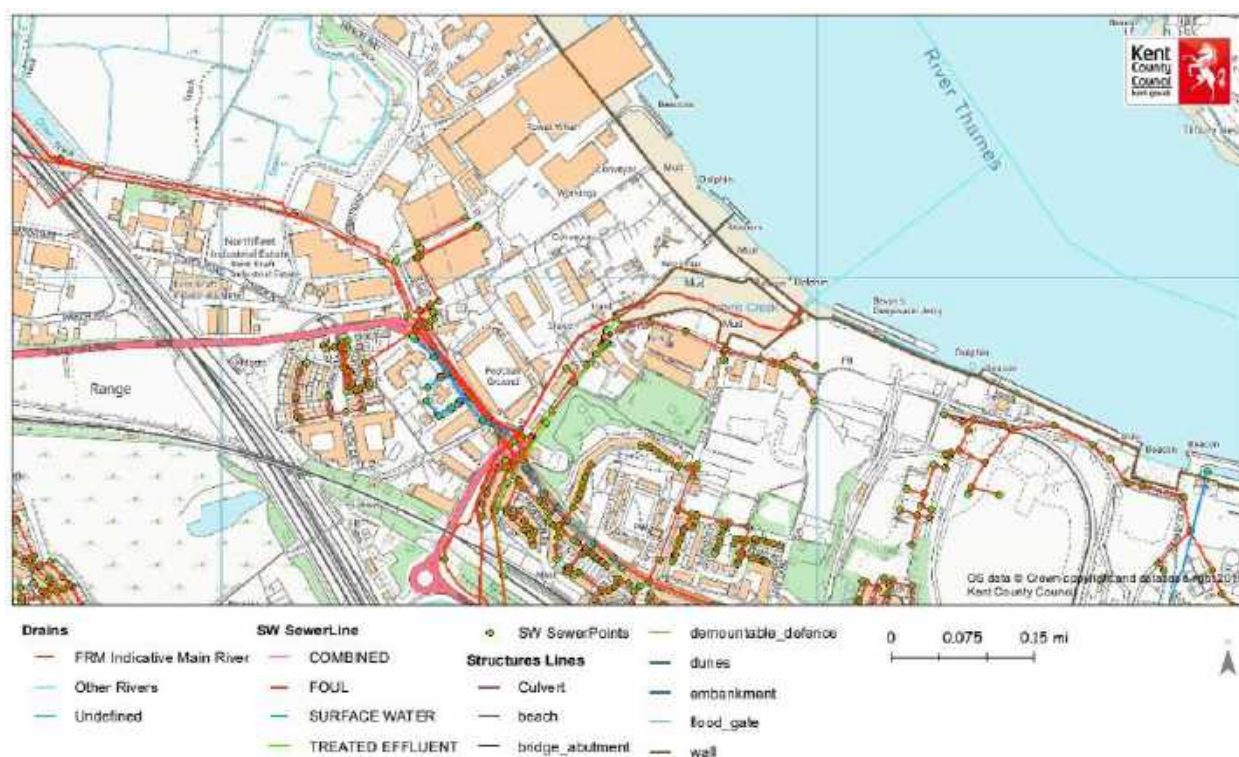


Figure 4: Sewer lines and points flowing through site.

Other identified flood issues or ground conditions

The BGS information also shows that for this area there is a very significant potential for one or more geohazards associated with infiltration.

The underlying geology of Upper Chalk can present a significant soluble rock hazard. The BGS website indicates that over part of the site the risk of soluble rocks is present, it is recommended that the site investigation should consider whether the potential for or the consequences of ground instability are significant. It is strongly advised that a full ground investigation is undertaken to ascertain the rate of infiltration across the site should works be proposed. The infiltration testing should be undertaken in accordance to BRE:365 standard, with the main requirement being for three tests to be undertaken at the location of any proposed soakaways or infiltration basin.

Ground instability is a risk that should be managed appropriately. Kent County Council guidance recommends separation distances that reflect the depth of the drainage measures i.e. 5m for conventional soakaways and 10m for deep bored soakaways. The CIRIA report C574D "Engineering in Chalk" recommends specifically:

- in areas where dissolution features are known to be prevalent, soakaways should be avoided, if at all possible, but if unavoidable, should be sited at least 20 m away from any foundations.
- Where the chalk is of low density, or its density is not known, soakaways should be site at least 10 m away from any foundations
- Where the chalk is of medium density (or higher), the closest part of the soakaway should be at least 5 m from any foundation.

We would expect to see demonstrated that surface water is managed appropriately, and that any new system complies with the required total treatment levels as detailed within Ciria Suds Manual (2015) Part E, Section 26 and this should be demonstrated within the future drainage strategy report.

Climate Change Allowances

For the future design of a drainage strategy, please note that as of the 10th of May 2022, the Environment Agency's climate change allowances have been updated. As part of this update, revisions have been made to the 'Peak Rainfall Intensity Allowances' that are used in applying climate change percentages to new drainage schemes. The LLFA would now seek the 'upper end' allowance is designed for both the 30 (3.3%) and 100 (1%) year storm scenarios.

The latest information on the allowances and map can be found at the following link:
<https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances>

Level of information advised for each planning stage

With regards to the level of drainage detail required at the planning stage please see the below table from our Drainage and Planning Policy:

Information required	Outline	Full	Reserved Matters	Discharge of Condition	Verification condition ¹¹
Identification of discharge destination					
Development information including location plan, site layout, and drainage schematic					
Surface water drainage strategy report or statement					
Calculation assumptions and results including impermeable areas, infiltration rates, network calculations and models					
Existing and proposed drainage arrangements			12		
Existing and proposed discharge rates					
Ground investigation reports/survey and soakage testing results					
Maintenance programs and access arrangements					13
As built drawings or tender construction drawings				14	
Exceedance plan ¹⁵					
Catchment plans					
Water quality index					
Watercourse condition and connectivity					
Proposed detailed drainage network plans and cross-sections including cover and invert levels, locations of flow controls (Critical Drainage Assets)					
Attenuation device details including cross-sections					
Landscape Plan					
Discharge agreements, consents and/or evidence of third-party agreement for discharge to their system					
Phasing plan					
Identification or designation of maintaining authority/ organisation					

¹¹ specific requirement for confirmation of drainage. Please see section 4.3.5

¹² as required, where not already demonstrated in the original application

¹³ require greater design detail than previous planning stage ¹⁴ Greatest amount of detail required

¹⁵ Specific for each critical drainage asset

¹⁶ Drawings of proposed construction

¹⁷ Includes conveyance, volume and depths

Figure 5: Table showing the Submission Requirements for stages of planning.

Recommendation on surface water management within the development

For an outline stage application ground investigation and soakage testing is not necessary but will be required at detailed design stage. As per the drainage hierarchy, we would actively pursue infiltration to be first considered. Whilst we understand that there are issues with contamination associated with this site it has not been demonstrated where these areas are and that they conflict with possible areas of infiltration.

As identified above, the underlying geology from BGS mapping identified this area to be of Upper Chalk and whilst we accept it may not be possible to utilise infiltration in areas of contamination we would expect at this stage for it to be considered. Until it has been categorically demonstrated that it is not possible to utilise infiltration we would request that an assumed rate of infiltration as per table 25.1 of the CIRIA SuDS Manual (2015) be used.

Having said this, the agreement of the Environment Agency will also be required for the use of infiltration to ground, particularly as this site is in a source protection zone, and for any remedial works required in association with contamination.

Subject to it being demonstrated that infiltration is not feasible we would accept an unrestricted outflow to the river Ebbsfleet dependant on it being demonstrated that tidal lock is not a concern. Due to this being a main river, if a connection is to be made in the future, the Environment Agency should be contacted to gauge whether a connection is permissible.

Further to this as this area is highlighted as being within both flood zones 2/3, it is our recommendation that the finished floor levels are raised above fluvial flood extents and further discussions of this required height should be confirmed with the Environment Agency.

Within Kent County Councils Drainage and Planning Policy Statement 2019, we ask that developments safeguard water quality through providing pollution controls on site which provide treatment prior to discharge to watercourses. We would expect to see demonstrated that surface water is managed appropriately, and that any new drainage system complies with the required total treatment levels as detailed within Ciria Suds Manual (2015) Part E section 26 and is detailed within the future drainage strategy report.

Kent County Council does not accept the infilling or culverting of existing ditches (except where essential to allow highways and/or other infrastructure to cross) and instead would promote retaining and enhancing these features where possible.

We support the provision of information to delineate drainage strategies and endeavour to respond to all enquiries. If this information raises further questions please do not hesitate to contact us. Depending upon the size and nature of your development other authorities may need to be consulted. Information and advice may also be needed from the Environment Agency, Internal Drainage Board or sewerage undertaker.

I trust this information assists with your enquiries.

Yours faithfully,

Emily Neale
Graduate Flood Risk Officer
Flood and Water Management

Appendix D: Southern Water Maps



(c) Crown copyright and database rights 2022 Ordnance Survey 100031673
Data updated: 16/06/22

Scale: 1:1250
Map Centre: 561339.174892
Date: 04/07/22
Our Ref: 892603 - 2
Wastewater Plan A2
Powered by digdat

rosie.tutton@rma-environmental.co.uk

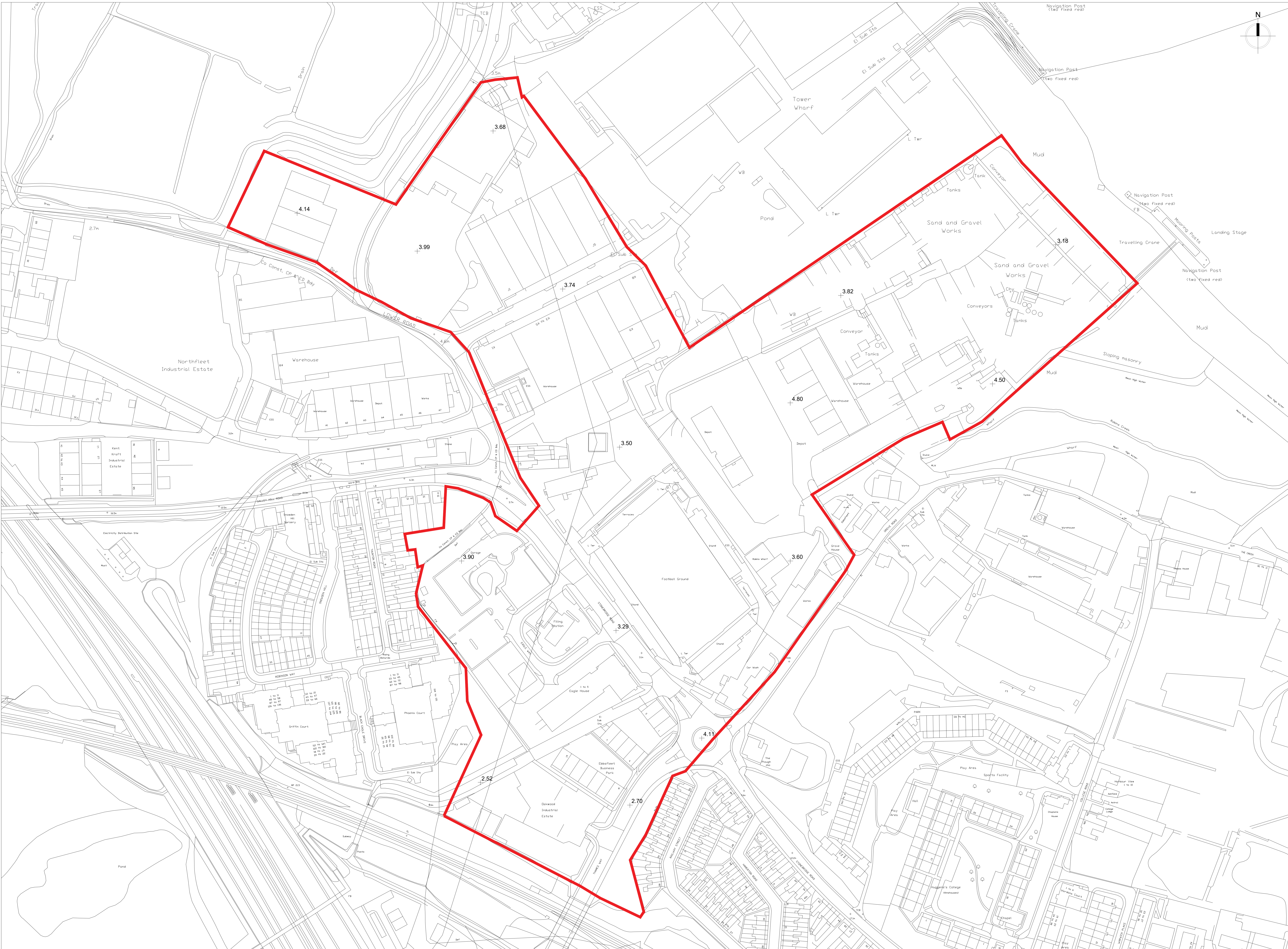
Northfleet1



The positions of pipes shown on this plan are believed to be correct, but Southern Water Services Ltd accept no responsibility in the event of inaccuracy. The actual positions should be determined on site. This plan is produced by Southern Water Services Ltd (c) Crown copyright and database rights 2022 Ordnance Survey 100031673. This map is to be used for the purposes of viewing the location of Southern Water plant only. Any other uses of the map data or further copies is not permitted.

WARNING: BAC pipes are constructed of Bonded Asbestos Cement.
WARNING: Unknown (UNK) materials may include Bonded Asbestos Cement.

Appendix E: Topographical Survey



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NOTES:

DESIGN INTENT DRAWING

DRAFT

Client:
Project:
NORTHFLEET CENTRAL, GRAVESHAM, UK

Drawing Title:
O.S. MAP

Drawn	Checked	Paper Size	Scale	Date
EB	EB	A0	As Indicated	@A0 06/05/22
Project No.	Drawing No.	Revision		
PE22040	0001	P01		

File Name:
PE22040-CW0-ZZ-ZZ-DR-A-0001

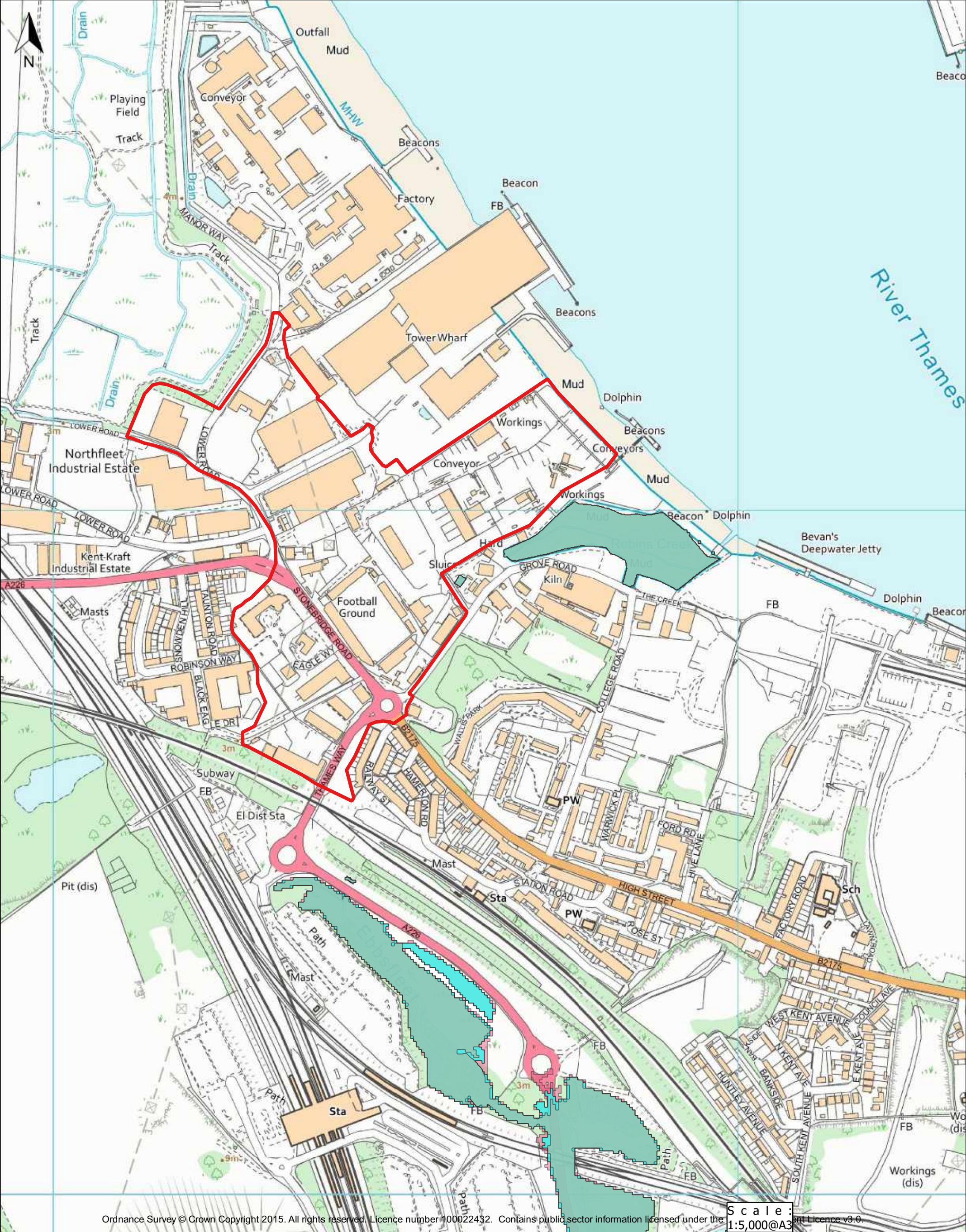
Status:
S3 - Suitable for review and comment

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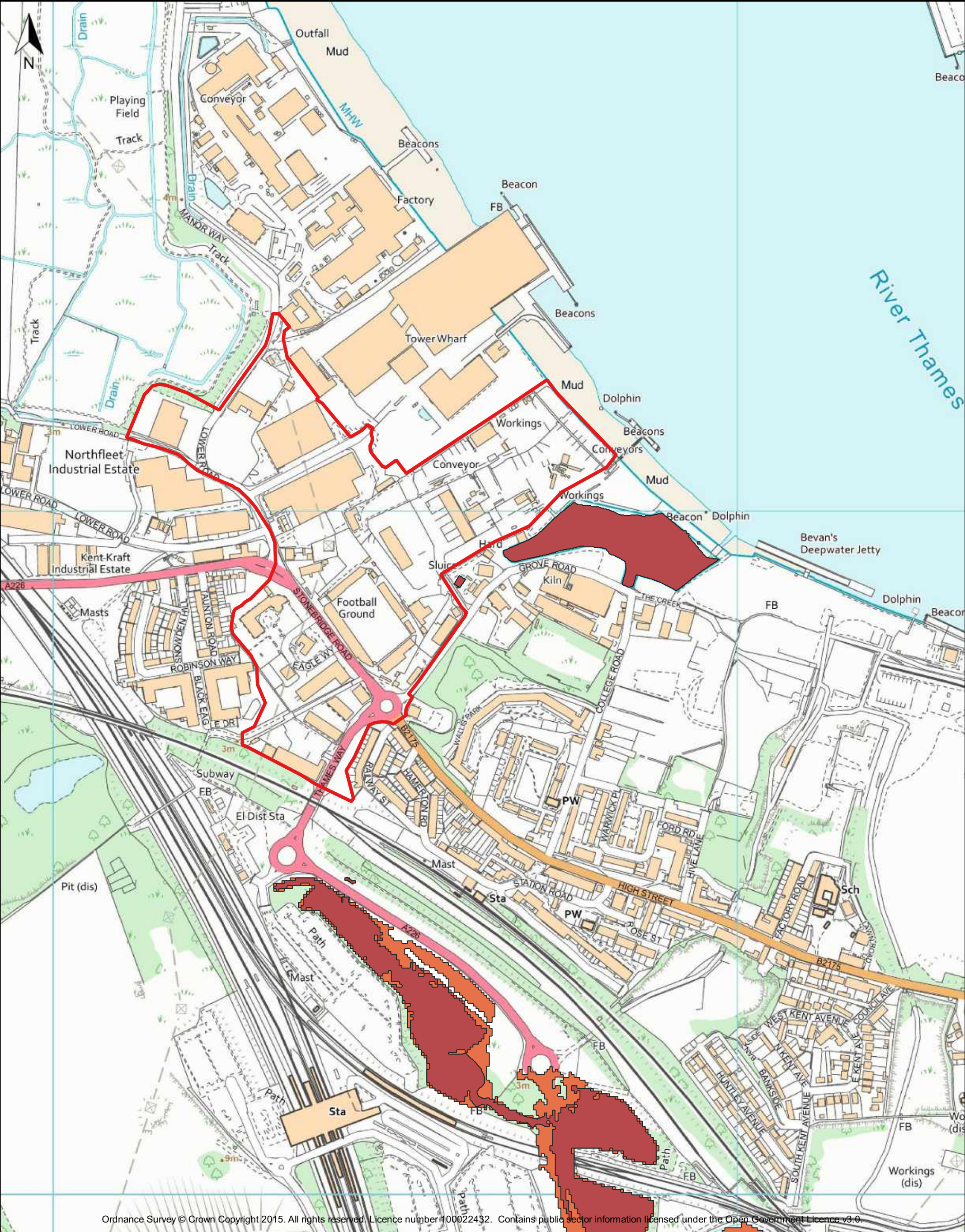
Appendix F: EA Flood Data



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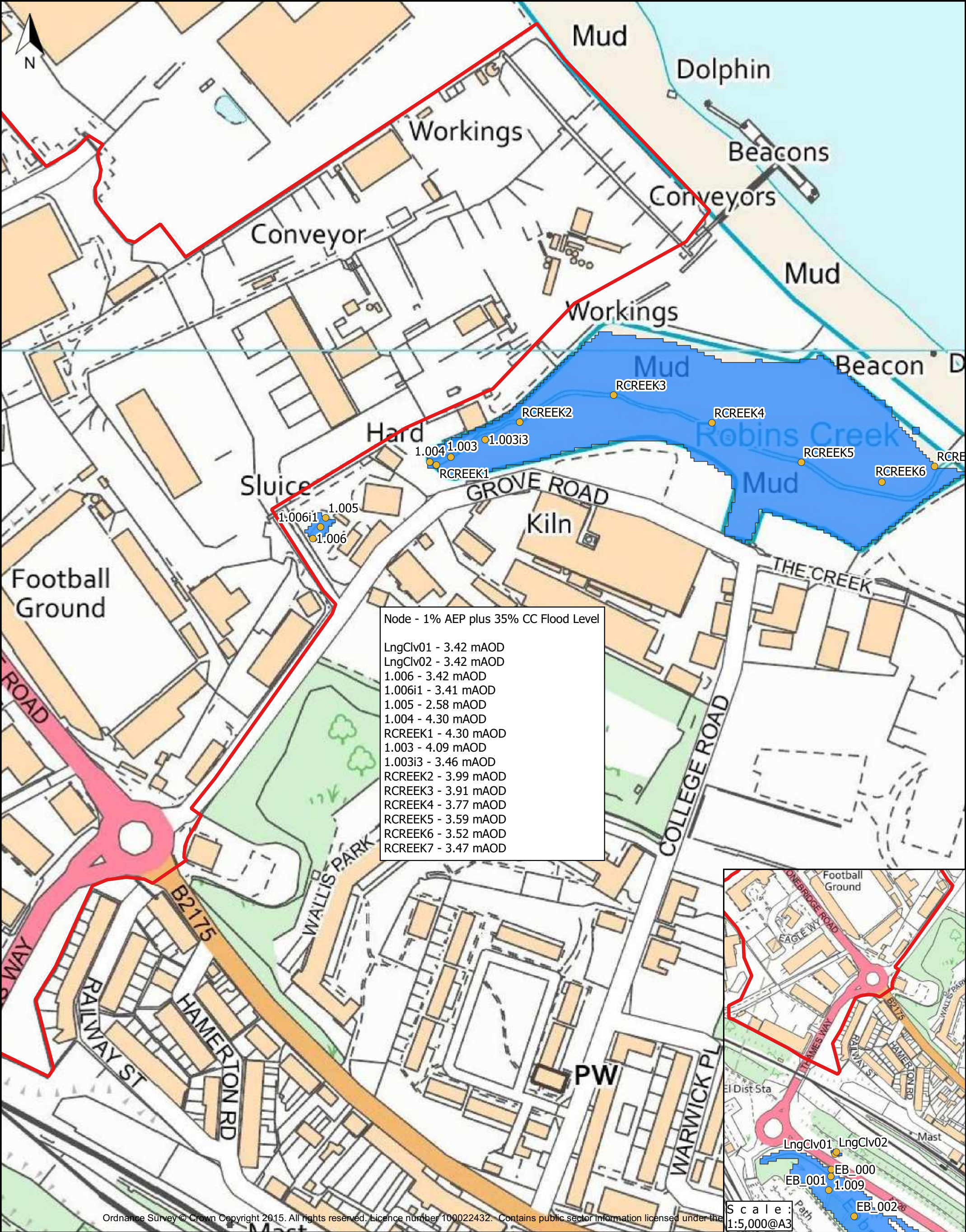
Scale:
1:5,000@A3

Key Red Line Boundary 1% AEP Flood Extent 1% AEP plus 70% Climate Change Flood Extent 0.1% AEP Flood Extent	Figure 1: EA's Fluvial Flood Extents	RMA ENVIRONMENTAL			
	Client: Northfleet Central 1 Ltd				
	Project: Northfleet Harbourside, Gravesham				
	Project No.: C2402				
		Drawn: RT	Checked: MS	Date: 27/09/2022	Scale: 1:5,000@A3



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Key Red Line Boundary 75% Blockage Scenario for Grove Road Culvert 75% Blockage Scenario for Long Culvert	Figure 2: Blockage Scenarios in the 20% AEP Event for the Culverts		RMA ENVIRONMENTAL			
	Client: Northfleet Central 1 Ltd					
	Project: Northfleet Harbourside, Gravesham		Drawn: RT	Checked: MS	Date: 27/09/2022	Scale: 1:5,000@A3
	Project No.: C2402					



Key

Red Line Boundary

1% AEP plus 35% Climate Change Flood Extent

Ebbsfleet Undefended Flood Nodes

Figure 3: EA's Fluvial Flood Levels

Client: Northfleet Central 1 Ltd

Project: Northfleet Harbourside, Gravesham

Project No.: C2402

RMA

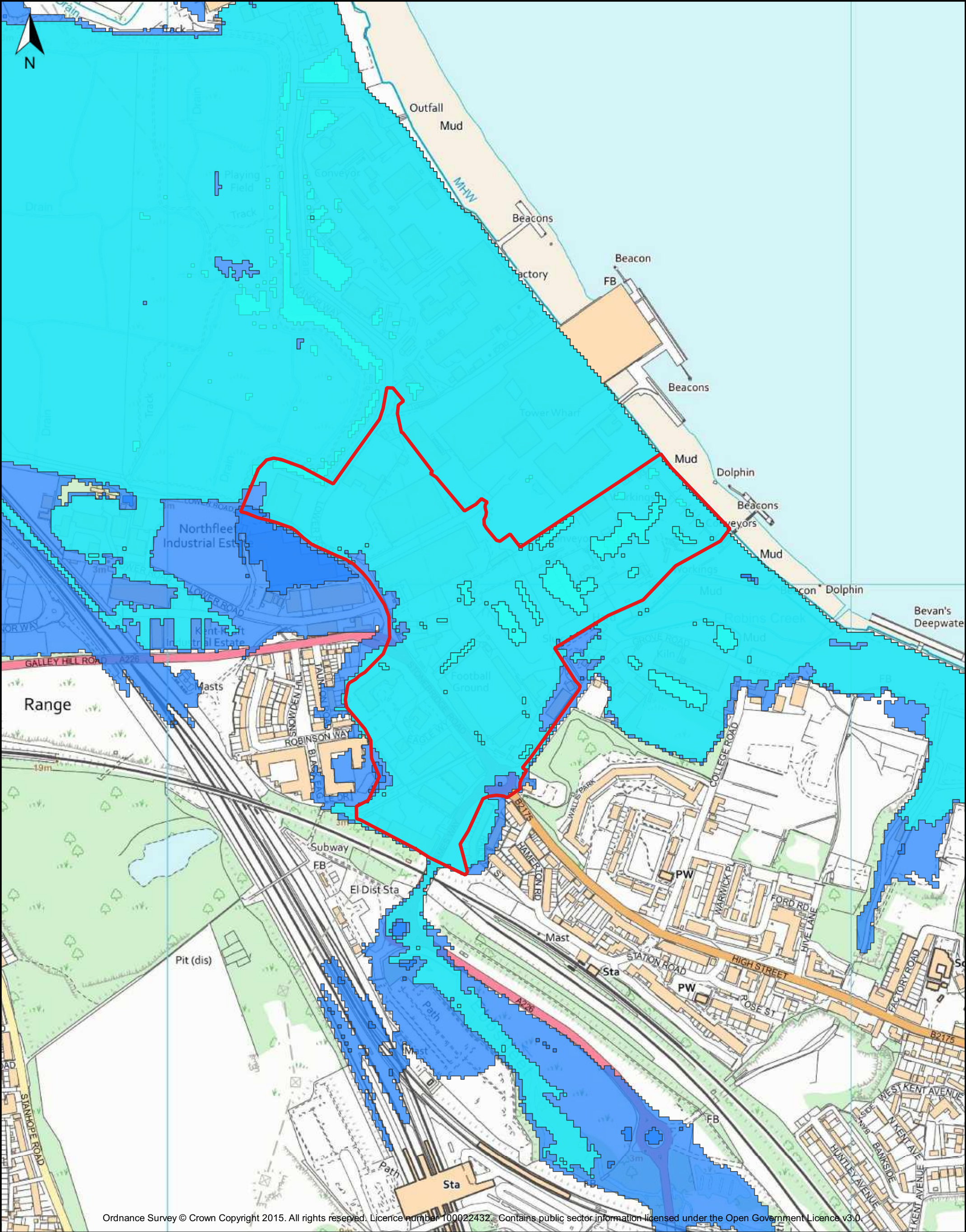
ENVIRONMENTAL

Drawn: RT

Checked: MS

Date: 27/09/2022

Scale: 1:2,000@A3



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- Key**
- Red Line Boundary
 - 0.5% AEP Breach Flood Extent in Current Scenario
 - 0.5% AEP Breach Flood Extent in the Year 2115

Figure 4:	EA's 0.5% AEP Tidal Breach Flood Extents
Client:	Northfleet Central 1 Ltd
Project:	Northfleet Harbourside, Gravesham
Project No.:	C2402



Drawn: RT	Checked: MS	Date: 27/09/2022	Scale: 1:5,000@A3
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	Red Line Boundary		4.5 - 4.6		5.1 - 5.2
Tidal Breach Flood Levels (mAOD)					
	Less than 4.2		4.6 - 4.7		5.2 - 5.3
	4.2 - 4.3		4.7 - 4.8		5.3 - 5.4
	4.3 - 4.4		4.8 - 4.9		Greater than 5.4
	4.4 - 4.5		4.9 - 5.0		
			5.0 - 5.1		

Figure 5:	EA's 0.5% AEP Tidal Breach Flood Levels in the Year 2005
Client:	Northfleet Central 1 Ltd
Project:	Northfleet Harbourside, Gravesham
Project No.:	C2402

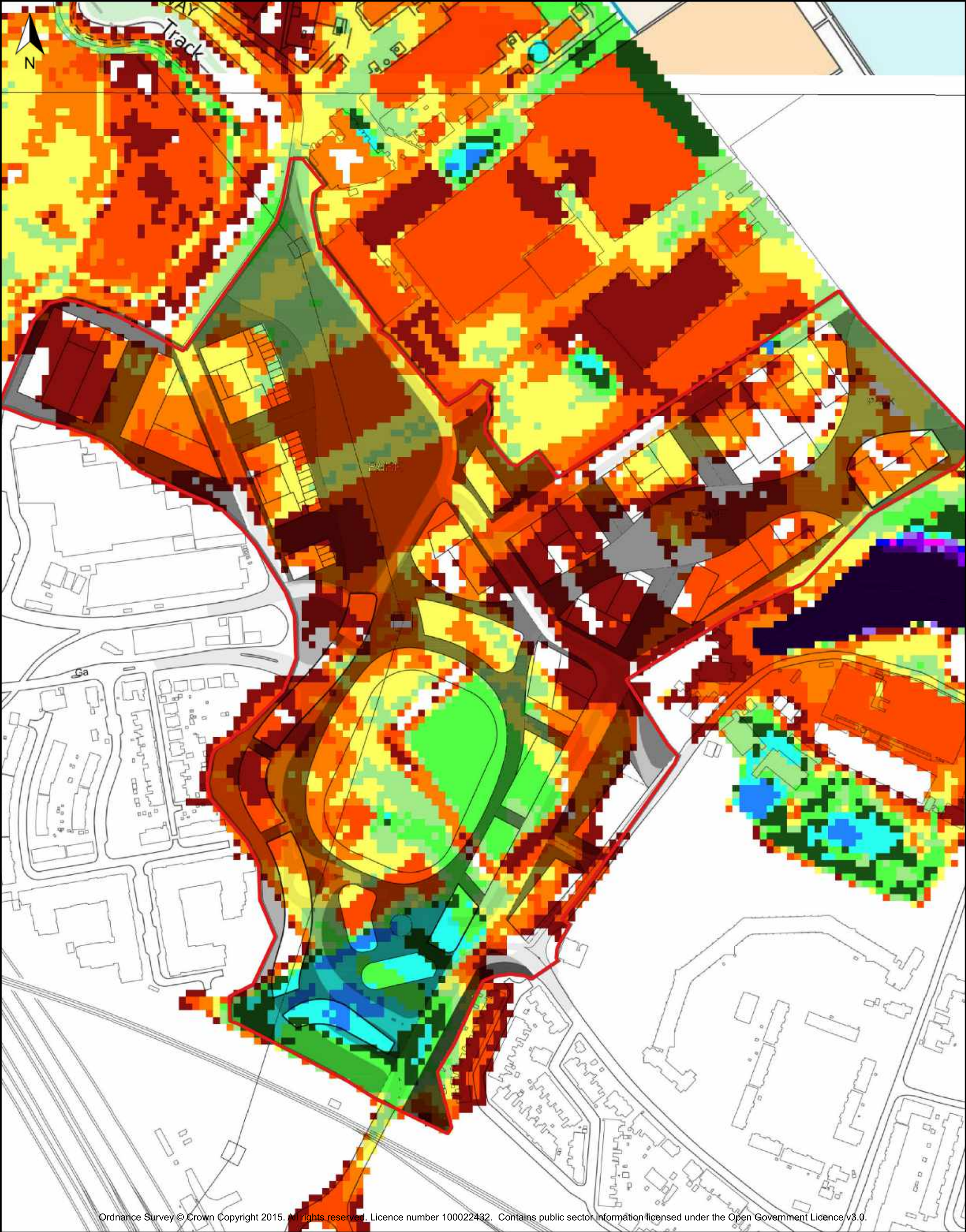


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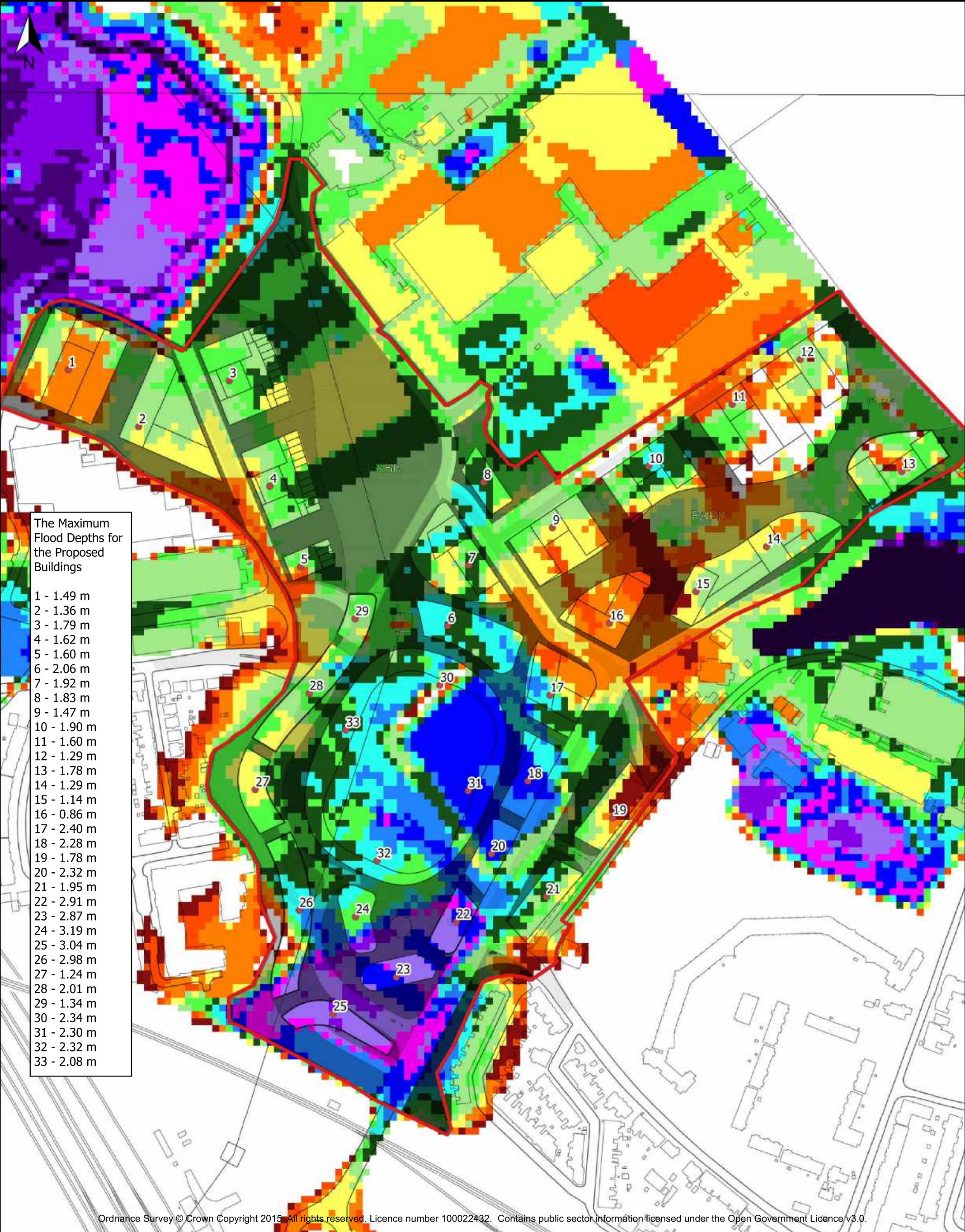
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Red Line Boundary Tidal Breach Flood Levels (mAOD) Less than 5.0 5.0 - 5.1 5.1 - 5.2 5.2 - 5.3	5.3 - 5.4 5.4 - 5.5 5.5 - 5.6 5.6 - 5.7 5.7 - 5.8 5.8 - 5.9 5.9 - 6.0 6.0 - 6.1 6.1 - 6.2 Greater than 6.2	Figure 6: EA's 0.5% AEP Tidal Breach Flood Levels in the Year 2115 Client: Northfleet Central 1 Ltd Project: Northfleet Harbourside, Gravesham Project No.: C2402	RMA ENVIRONMENTAL Drawn: RW Checked: MS Date: 10/04/2024 Scale: 1:2,500@A3
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Red Line Boundary Tidal Breach Flood Depths Less than 0.25 m 0.25 m - 0.50 m 0.50 m - 0.75 m 0.75 m - 1.00 m		1.00 m - 1.25 m 1.25 m - 1.50 m 1.50 m - 1.75 m 1.75 m - 2.00 m 2.00 m - 2.25 m 2.25 m - 2.50 m 2.50 m - 2.75 m 2.75 m - 3.00 m 3.00 m - 3.25 m 3.25 m - 3.50 m Greater than 3.50 m		Figure 7: EA's 0.5% AEP Tidal Breach Flood Depths in the 2005 Client: Northfleet Central 1 Ltd Project: Northfleet Harbourside, Gravesham Project No.: C2402		RMA ENVIRONMENTAL		Drawn: RW Checked: MS Date: 10/04/2024 Scale: 1:2,500@A3	
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	Red Line Boundary		1.00 m - 1.25 m		2.50 m - 2.75 m
	Building Numbers		1.25 m - 1.50 m		2.75 m - 3.00 m
Tidal Breach Flood Depths					
	Less than 0.25 m		1.50 m - 1.75 m		3.00 m - 3.25 m
	0.25 m - 0.50 m		1.75 m - 2.00 m		3.25 m - 3.50 m
	0.50 m - 0.75 m		2.00 m - 2.25 m		Over 3.50 m
	0.75 m - 1.00 m		2.25 m - 2.50 m		

Figure 8:	EA's 0.5% AEP Tidal Breach Flood Depths in the Year 2115
Client:	Northfleet Central 1 Ltd
Project:	Northfleet Harbourside, Gravesham
Project No.:	C2402



Drawn: RW	Checked: MS	Date: 10/04/2024	Scale: 1:2,500@A3
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Key Red Line Boundary Flood Hazard Ratings Danger for Most Danger for Some Danger for All	Figure 9: Flood Hazard Ratings during the Design Breach Flood Event		RMA ENVIRONMENTAL	
	Client: Northfleet Central 1 Ltd			
	Project: Northfleet Harbourside, Gravesham		Drawn: RW	Checked: MS
	Project No.: C2402		Date: 10/04/2024	Scale: 1:2,500@A3

Appendix G: River Wall Impact Assessment (Walsh; 2023)



RIVER WALL IMPACT ASSESSMENT NORTHFLEET HARBOURSIDE

March 2023

Document Reference: \\192.168.1.176\walsh\Projects\5848\Documents\Reports\River Wall Impact Assessment\5848-WAL-ZZ-XX-RP-C-6700.docx

Revision: 03



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RIVER WALL IMPACT ASSESSMENT

NORTHFLEET HARBOURSIDE

Walsh have prepared this report in accordance with the instruction of our client Landmarque Properties.

The report is for the sole and specific use of the client, and Walsh shall not be responsible for any use of the report or its contents for any purpose other than that for which it was prepared and provided. Should the Client require to pass copies of the report to other parties for information, then no professional liability or warranty shall be extended to other parties by Walsh in this connection without the explicit agreement thereto by Walsh.

Revision	Date	Notes	Prepared by	Checked by	Approved by
1	21/04/23	First Issue	FM	AS	AS
2	23/11/23	Updated to EA comments	FM	AS	AS
3	03/01/24	Updated to EA comments	FM	AS	AS

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1. Introduction

Walsh are appointed by Landmarque Properties to advise on river wall matters related to the development of the Northfleet Harbourside site in Kent. Given the site is riparian consideration is being given to the river wall with respect to flood risk, flood protection, maintenance and general longevity.

As part of the riparian works Walsh have been requested to undertake an assessment of the river wall and the impact it may have on the development and show that the proposals are sustainable and do not pose a unacceptable flood risk on the development or wider area. This report documents this study and we understand that this will form part of the sitewide flood risk assessment being undertaken by others.

2. Scope and Limitations

This note is prepared under the auspices of our appointment by Landmarque Properties.

The scope of the report as agreed with the wider team and EIA consultants is as follows;

- Desktop overview of the existing river wall
- Overview proposals for any river wall replacement of enhancement
- Commentary on flood risk and compliance
- Commentary on the impact of climate change and the need to raise defences.
- Assess the impact of the development on river wall and the flood defence maintenance and inspection.

3. Background

3.1. General

The proposed site at Grove Road in Northfleet, Kent is a mixed-used redevelopment consisting of residential units, retail, food and beverage, office spaces as well as a multi-use stadium with associated business and leisure facilities. The proposed extent of the development is shown in figure 1 below.

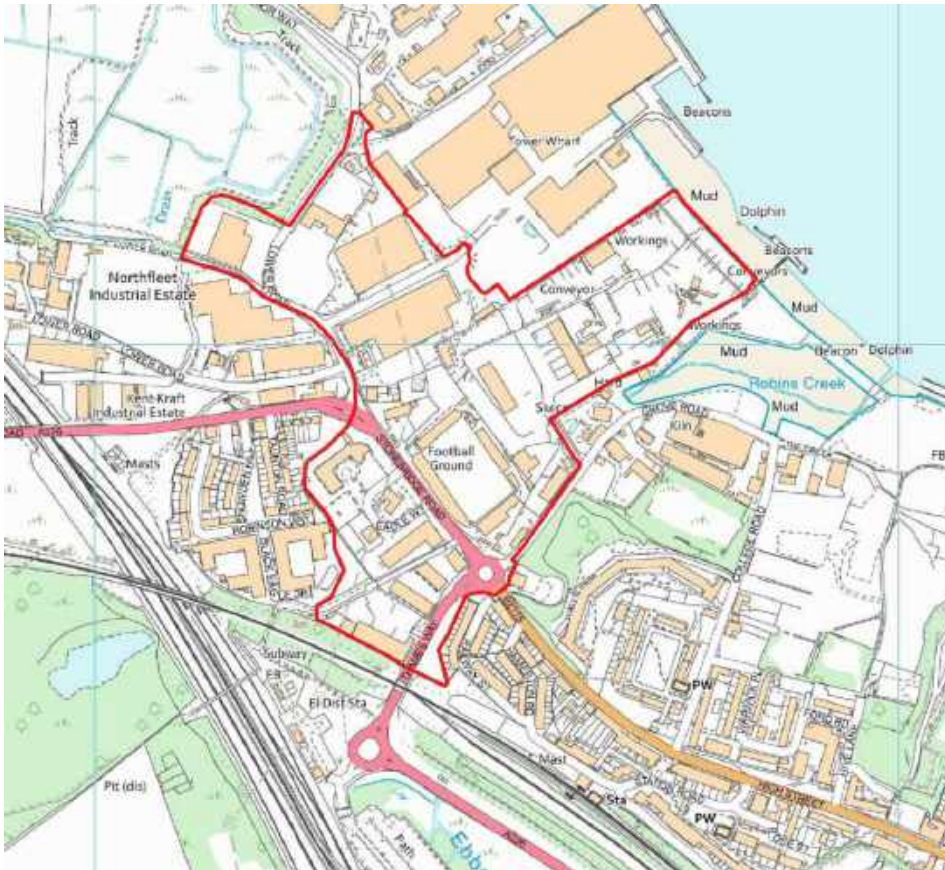


Figure 1: Proposed "red-line" planning boundary of development.

At the northeast boundary of the site there is an existing river wall which fronts the tidal River Thames estuary as shown in figure 2. The current river wall runs along the bank of the river Thames continuously from north west to south west. The south-eastern boundary of the site is formed by Robins Creek. Robins Creek is a basin area surrounded by river wall defences and forms the estuary of the River Ebbsfleet as it discharges into the Thames. Based on desktop information we believe that the tidal defence extends across the mouth of Robin's Creek and as such Robins Creek is not tidally influenced completely by the Thames however this does not fundamentally impact the assessment and proposals as the river wall forming Robins Creek is outside the scope of the application.

The section of river wall under consideration is shown in figure 3 below.



Figure 3 – Extent of river wall under consideration

3.2. River Levels

Table 1 below shows the relevant levels associated with the river and site adjacent to the river.

Table 1 - River Levels

Level Definition	Level (mAOD)
Mean Low Water Spring	-2.56
Riverbed Level at river wall	1.10
Mean High Water Spring	3.44
Highest Astronomical Tide	3.93
Site ground level by river (Based on LiDAR data)	Approx. 4.77
Current Defence Crest Level	6.70-6.90
Required Future Defence Level (as advised by EA)	8.00

3.3. Existing River Wall

Figure 4 below outlines the anticipated current river wall construction based on the investigations done into the levels of the area using EA data and LiDAR data. This is to be confirmed on site.

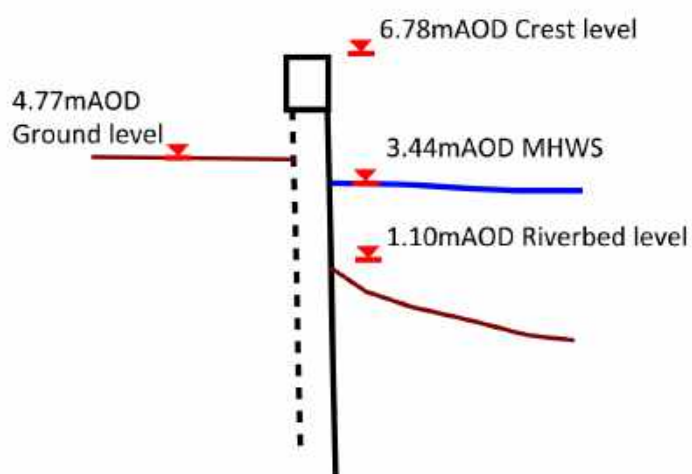


Figure 4 - Anticipated Existing River Wall construction

Figures 5 and Table 2 below outline the information taken from the EA's Asset Management Map. As shown the sections of the river wall along the site have crest levels of between 6.70m AOD and 6.90m AOD. This information also outlines that the condition of these sections of wall are 'Fair'. It is understood that the definition of this condition is 'Defects that could reduce performance of asset'. The condition ratings are not linked to design life however a rating of fair is likely to indicate that whilst there are no immediate concerns with the defences condition it is unlikely to have a residual life >20-30 years or have the ability to be raised significantly.

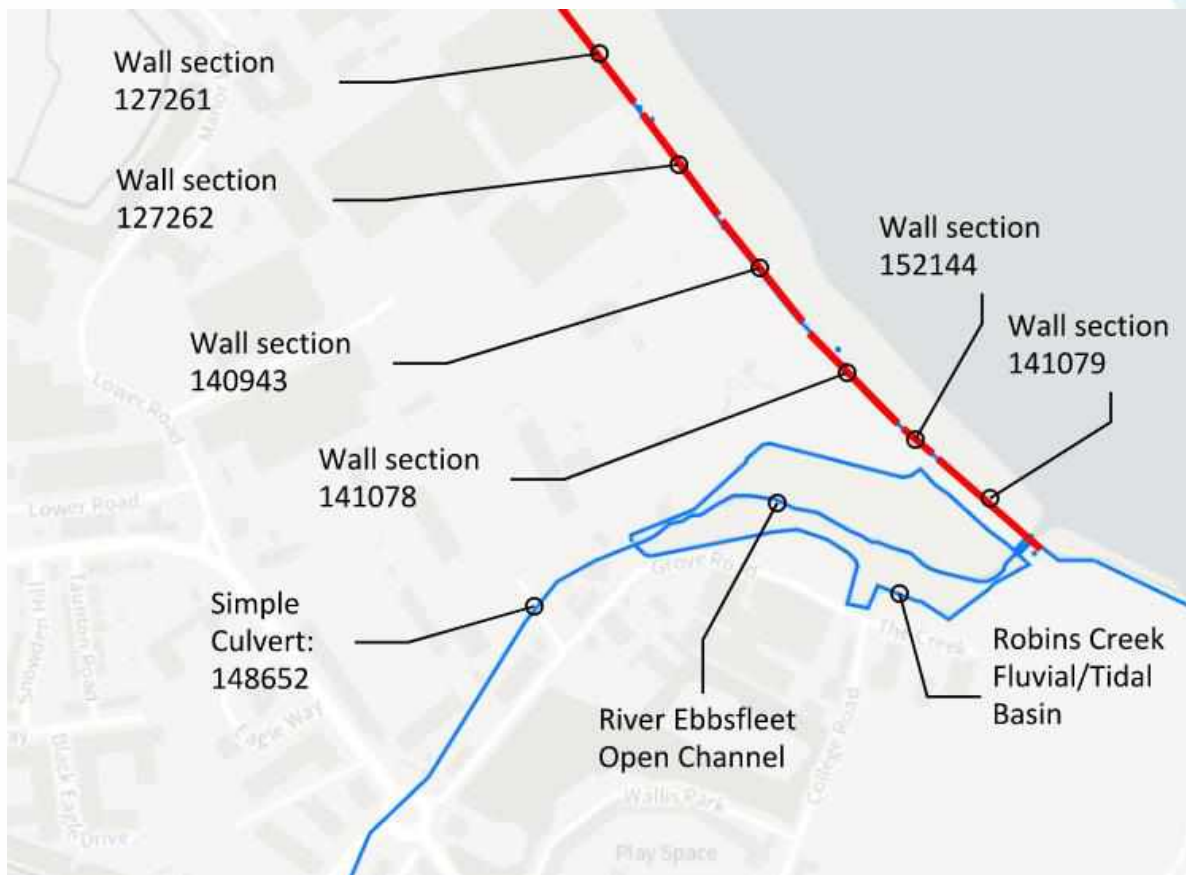


Figure 5 - Extract from EA Assets Management (AIMS) database

Table 2 - EA Asset Details (from AIMS database)

Asset Reference	Asset Type	Asset Condition	Defence Crest Level (mAOD)
127261	Wall	Fair	6.70
127262	Wall	Fair	6.85
140943	Wall	Fair	6.78
141078	Wall	Fair	6.80
152144	Wall	Fair	6.91
141079	Wall	Fair	6.86
Robins Creek Fluvial/Tidal Basin	Wall	Fair	5.66-5.27
Simple Culvert 148652	Simple Culvert	Not Known	N/A

4. Proposed Enhancements

4.1. General

Through consultation with the EA it has established that the development proposals will include a 16m “set back”. It has also been noted by the EA that the development will need to include a new tidal defense structure or mechanism with a defense level of 8mAOD to account for climate change impacts and see that the development is sustainable from a flood defense perspective for the next 100 years.

These proposals have been incorporated into the landscape strategy (see Appendix A) although the actual details of the riparian public realm and details are not the subject of the proposed outline planning application and will be a reserved matter. In this regard the assessment within this report is focused on seeing that the strategy can be delivered and maintained and further detail will form part of subsequent submissions.

4.2. New Tidal Defence

To demonstrate that the proposals are achievable and sustainable we have developed a number of options and sections that could be implemented for the new river wall and they all have the following common key design features;

- Riparian area 16m from waterfront to be free from development.
- Top of defence level set at 8.00mAOD,
- Edges to tie into defences on either end of the wall to ensure continuous defence,
- Access provided for maintenance vehicles,
- 100-year design life,
- Existing river wall considered sacrificial from a flood defence perspective.
- Typically, 6m-8m wide service area behind the new defence line to enable emergency and maintenance works.

Given that the detailed design will focus on the “terracing” of the riparian land we have outlined below several options that will form a “design code” for the development of the detailed design.

As noted above, the existing river wall will be considered “sacrificial” from a flood defence perspective it will still be subject to detailed assessment to see that it has sufficient residual life to see that it is maintainable and does not pose a risk of collapse which could impact the river and shipping. The parameters of this assessment will be the subject of further discussion with the EA and PLA. It should be noted that any maintenance access in the new tidal defence would not be reliant on proposed “sacrificial” elements.

Given that the river wall is believed to be a cantilevered sheet pile wall, lowering the wall will reduce the stress and thus increase its residual life. In this regard the lowering of the existing wall in some way is likely to form a fundamental part of the proposals as this not only has structural benefits but it is in line with the

EA desire to make the river more accessible. Should the need arise additional tie rods will be installed to enhance the residual design life.

It should be noted that whilst three options are proposed it is likely the detailed design will combine all three options as a “hybrid” approach so the proposal should not be taken literally and they are described to set out the principles of the riparian development.

4.2.1. Option 1 – Single Terrace.

The first option of a single terrace utilises the new defence wall to form a single terrace.

The level of the terrace will be reviewed but is likely to be at least 4.5m at the river slope upwards as one goes inland. This will set it at least 500mm above HAT.

The terrace will be landscaped but access to both the set back defence wall and the existing river wall will be maintained in line with the proposals set out in section 5.

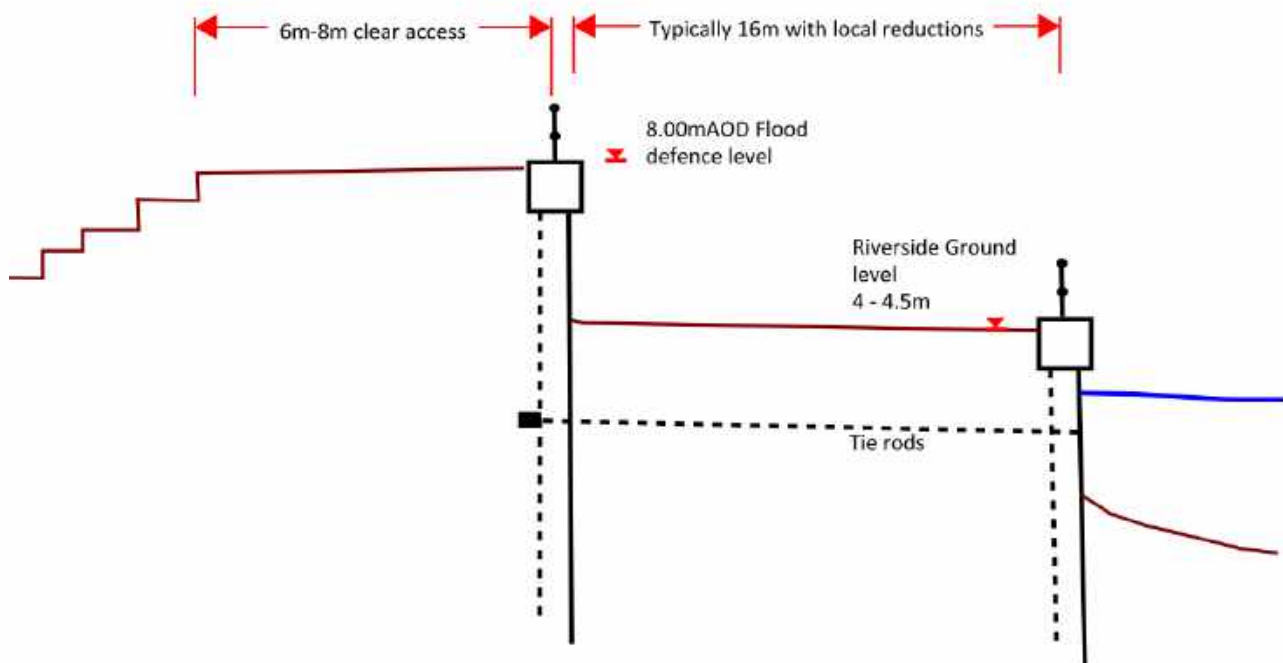


Figure 6 - Option 1 Single Terrace

4.2.2. Option 2 – Double Terrace.

The second proposed option is for a double terraced arrangement. This will consist of two levels staggering down from the proposed flood defence level to the existing ground level. This will be achieved with the use of an addition gravity retaining wall.

The level of the terraces will be reviewed but consideration could be given to a riparian terrace slightly lower than that shown in option 1. A Terrace set 4-4.5mAOD would be slightly less accessible than option 1 due to the slightly increased risk of tidal influence (albeit at 4mAOD it would still be above HAT and therefore still have a low risk of flooding) but would make the river more visible.

The upper terrace will be set above 4.5mAOD and thus at least 500mm above HAT and therefore have a very low risk of flooding from tidal waters and be very accessible.

The terrace will be landscaped and the widths of each level will accommodate the access for major maintenance at the top level and emergency and periodic access at the bottom level. This will see that the appropriate level of maintenance, as set out in the proposals set out in section 5, are provided.

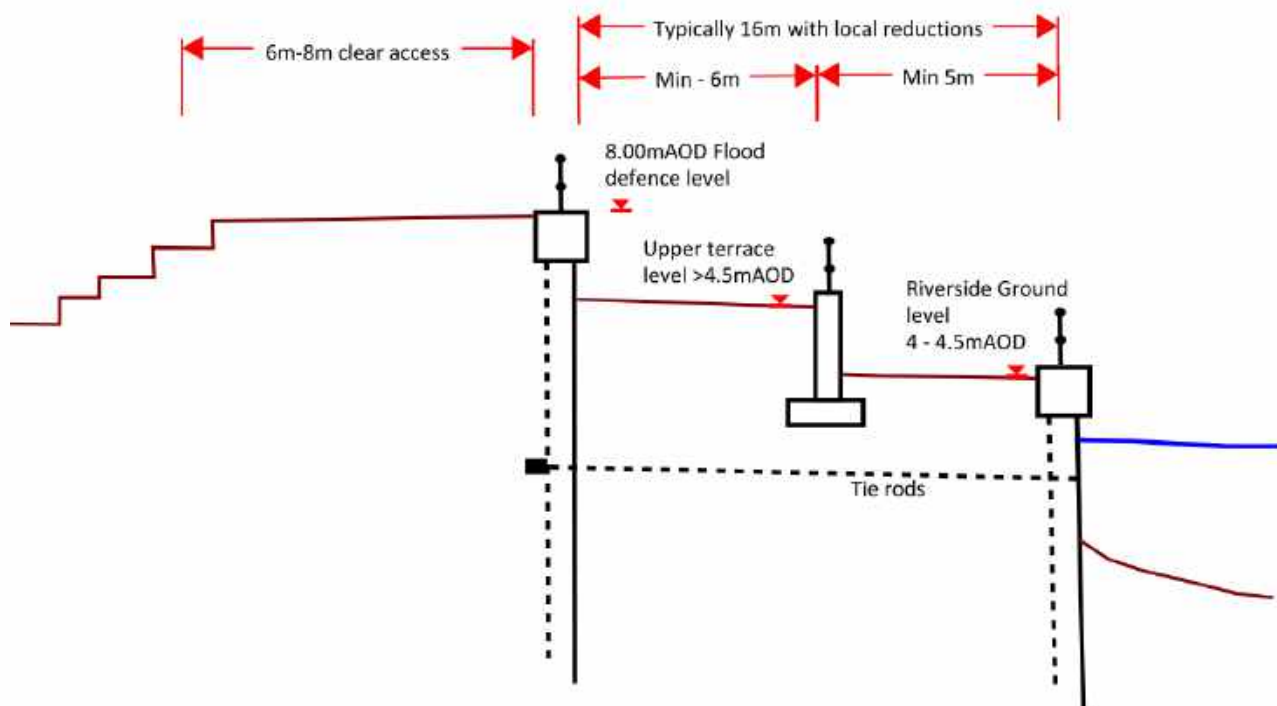


Figure 7 - Option 2 Double Terrace

4. 2. 3. Option 3 – Double Terrace with additional tidal terrace.

This enhanced option is similar to option 2 however it gives provision for a tidal terrace at the lowest level. A tidal terrace is set in the inter-tidal zone between MHWN and MHWS and thus regularly floods. The terrace would create an inter-tidal habitat planted with marine and aquatic flora such as common reeds (*phragmites australis*) which provides significant positive biodiversity benefits.

The tidal terrace would typically not be publicly accessible although if safety measures are incorporated it can be somewhat accessible at low tide.

The tidal terrace would be formed by cutting the existing wall down to below the MHWS level and installing an additional gravity retaining wall.

The level of the upper terraces will be reviewed but similar consideration to the lower terrace of Option 2 would be followed.

The upper terrace will be set above 4.5mAOD and thus at least 500mm above HAT and therefore have a very low risk of flooding from tidal waters and be very accessible.

The terraces will be landscaped and the widths of each level will accommodate the access for major maintenance at the top level and emergency and periodic access at the bottom level. This will see that the appropriate level of maintenance, as set out in the proposals set out in section 5, are provided.

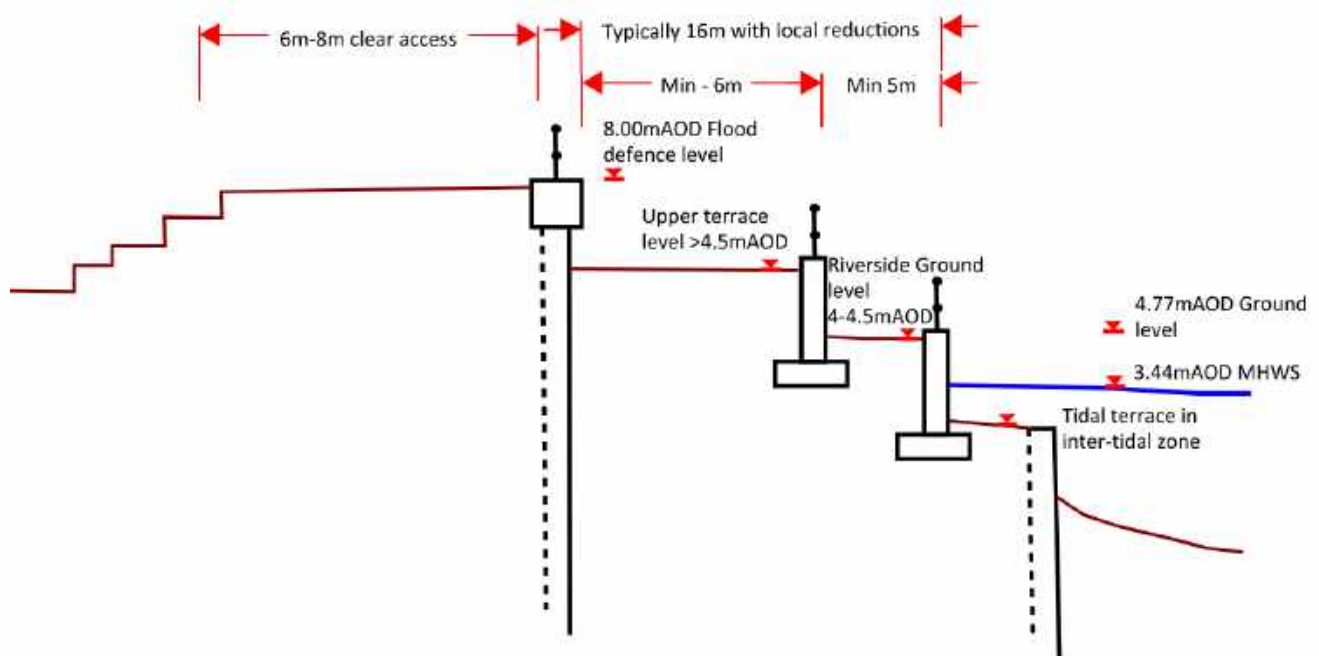


Figure 8 – Option 3 Double Terrace w/ tidal terrace

4.3. Links to Adjoining Tidal Defence

For each of the river wall options put forward consideration has been given to the connection to the tidal defence at either end of the wall. It is anticipated that these connection points will provide a wall at the existing flood defence level (6.85mAOD at either end) on adjoining sites although the proposed site will provide the tidal defence up to the 8mAOD level. This will facilitate the upgrading of the adjoining defences to be brought forward as the adjoining sites are developed or when climate change requirements dictate otherwise.

4.4. General Access to River

With all the river wall options access needs to be provided for inspections and maintenance. As per Figure 7 below it is proposed that the main vehicular access is provided from the access road in the north of the site with further pedestrian access to be from the centre landscaped areas further south.

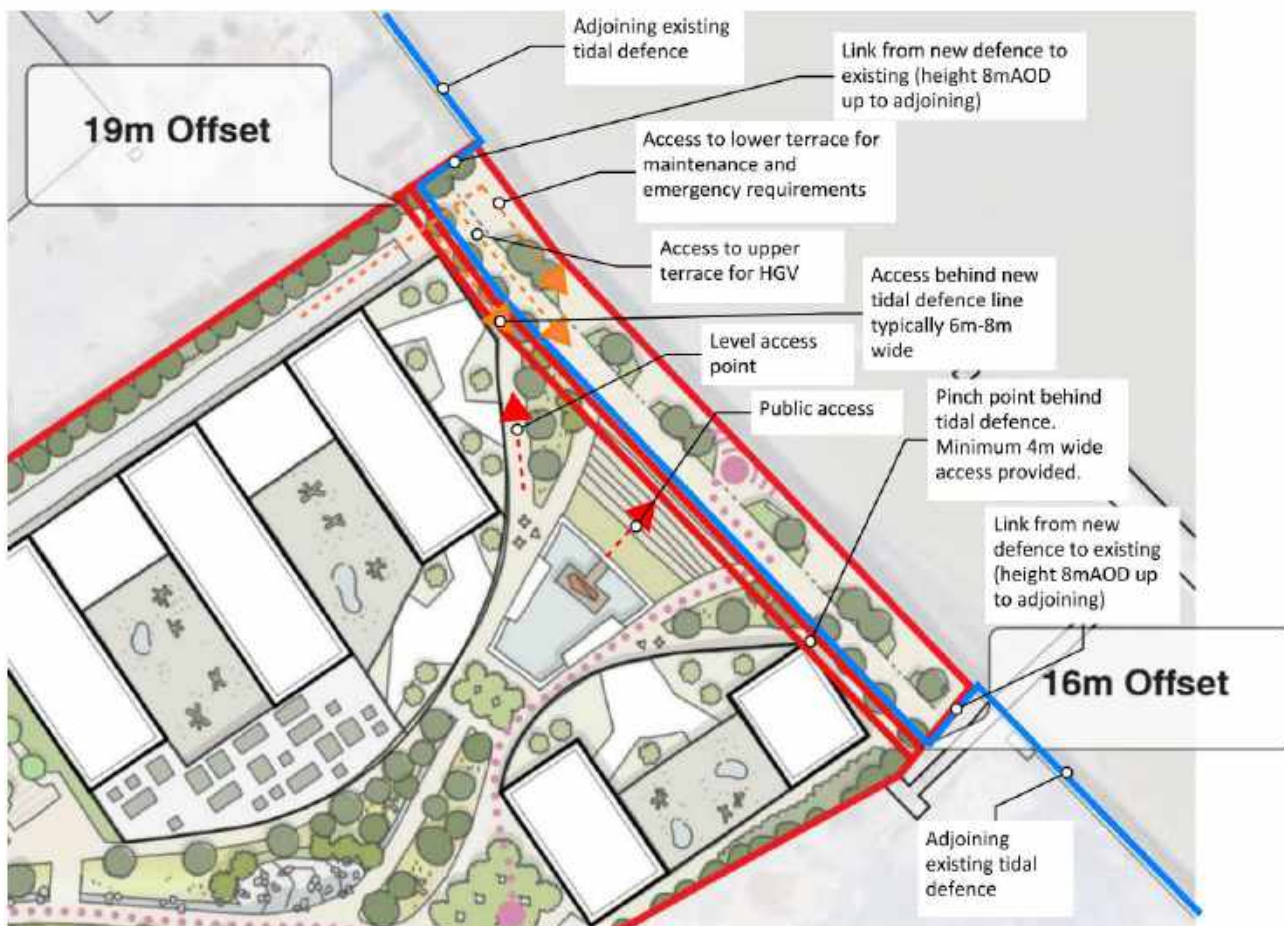


Figure 9 - Proposed access arrangements

5. Inspection and Maintenance

Consideration has been given to the access and maintenance strategy for each of the river wall options post development.

To demonstrate that the river walls can be adequately maintained a review has been undertaken to demonstrate suitable plant can be maneuvered into place to enable safe inspection and maintenance as required.

There are several ways and the requirements for access can be categorised as follows and we have dealt with these separately.

1. Regular Inspection
2. Detailed inspections and Minor Maintenance
3. Major Maintenance and repair
4. Environmental Enhancements
5. Emergency Access

It should be noted all paving materials proposed for access and tracked paths should be designed to support the proposed vehicles, such that the vehicle access described can be realised.

Below we have provided the key principles that will be incorporated into the design. It should be noted that these access requirements are purely for the river walls and flood defences. Further access requirements will be required for pedestrians, landscape maintenance and public emergencies. These will form part of the landscape design and access statement although they are likely to be similar.

5.1. Regular Inspections

Visual inspections would be possible from the riverside walk and from the river. Technology such as drones could also be used to provide a visual inspection. Such inspections would need to be undertaken regularly, say every 2 years. These types of inspection can be do for all the design options outlined.

Element	Requirement
Frequency of access	Every 2 years
Access requirements to “drop off zone” adjacent to riverside area	Standard highway access for small vehicles/vans and pedestrians
Access along riparian terracing and paths	Small vehicles/vans and pedestrians
Min width along riverside	3.5m
Max gradient	5% (8% for vehicle only ramps)
Loading/surfacing	Traffic Category 3 to BS7533:101

Table 3: Summary of Access Requirements for Regular Maintenance

5.2. Detailed Inspections and Minor Maintenance

A more detailed inspection will be required every five to six years. This may also include minor maintenance.

Access for a detailed inspection the river wall will generally be via the river itself at low tide but could also be via the use of specialist access equipment and plant which is readily available. Such equipment would facilitate closer “hands on” inspection and maintenance which may be required during detailed inspections.

Access for such equipment and associated transport would be via the site access road at the north where it could be dropped close to the riverside path. From the drop off point it would self-propel along the riverside walkway. Larger plant may be facilitated by the use of tracking mats and similar equipment.

Such equipment could also be used to undertake minor maintenance and testing if needed.

Element	Requirement
Frequency of access	Every 5 years
Access requirements to “drop off zone” adjacent to riverside area	Standard highway access for large vans and small (7.5T lorries)
Access along riparian terracing and paths	Unobstructed access for maintenance vehicles (MEWP’s and dumpers etc) and pedestrians. Ability for larger plant to access areas with tracking mats etc.
Min width	3.5m
Max gradient	5% (8% for vehicle only ramps)
Loading/surfacing	Traffic Category 4 to BS7533:101

Table 4: Summary of Access Requirements for Detailed Inspections and Minor Maintenance

5.3. Major Maintenance and Repair

Major maintenance and repairs may be required and it is likely that planned major maintenance will be required every 10-15 years.

For such tasks, a lorry up to 30T could access via the site highways and materials distributed along the river edge with “dumpers” and forklift type equipment. It is for these sorts of vehicles that the minimum width of 8m should be provided for the upper terrace of each design option.

Element	Requirement
Frequency of access	Every 5 years
Access requirements to “drop off zone” adjacent to riverside area	Full access for all road legal vehicles including “low loaders”
Access along riparian terracing and paths	Access along “upper terrace” for large plant and equipment – given that this work is likely to require some degree of planning some preparatory works (moving landscape features and the like) would be acceptable.
Min width	Typically 6m-8m (incl working room) with min 4m (only at “pinch point” as noted in figure 9)
Max gradient	5% (6% for vehicle only ramps)
Loading/surfacing	Traffic Category 4 to BS7533:101

Table 5: Summary of Access Requirements for Major Maintenance and Repair

5. 4. Environmental Enhancements and Climate Change

As policy changes throughout the life of the wall there may be a need for enhancements and/or upgrades, however the requirement for such work has been mitigated by the proposal to upgrade the flood defence level to 8.00mAOD.

Some enhancement may be required to the river edge walls as the accessibility of these areas may reduce as tide levels rise.

Other environmental enhancements could include set-backs, fenders, fish enhancements and/or safety chains.

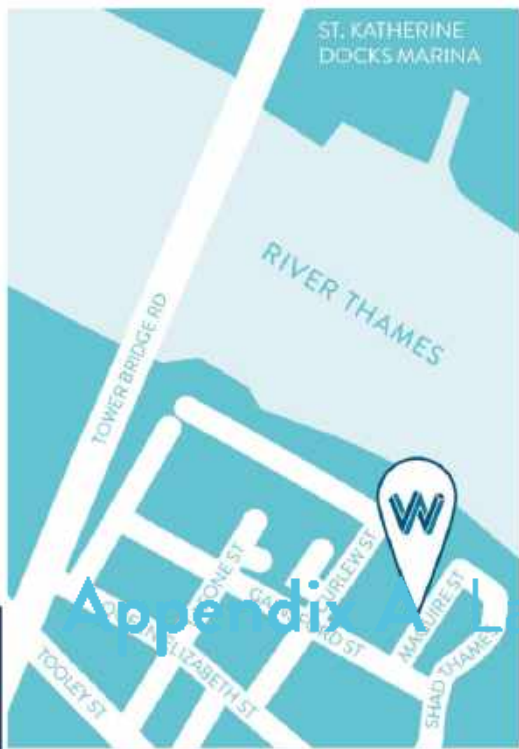
All of the above could be undertaken in the same way as a major maintenance would be and as such there are no separate requirements.

5.5. Emergency Access

It is noted that emergency access will be facilitated via the site access road and along the walls at whichever level that is required with minimum width of 4m always provided at terrace levels.

Element	Requirement
Frequency of access	Ad hoc
Access requirements to “drop off zone” adjacent to riverside area	Full access in accordance with ADB and BS9999
Access along riparian terracing and paths	Full access in accordance with ADB and BS9999
Min width	As ADB and BS9999
Max gradient	5% (6% for vehicle only ramps)
Loading/surfacing	Traffic Category 4 to BS7533:101

Table 6: Summary of Access Requirements for Emergency Access



Appendix Landscape Strategy

Contact

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e. contact@walsh.co.uk

www.walsh.co.uk



NORTHFLEET HARBOURSIDE

River edge retaining wall review



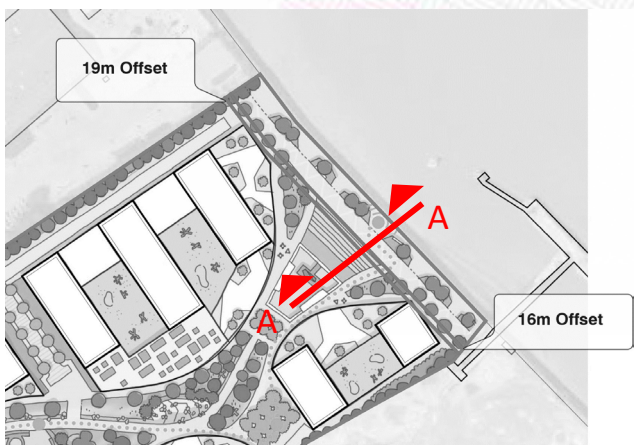
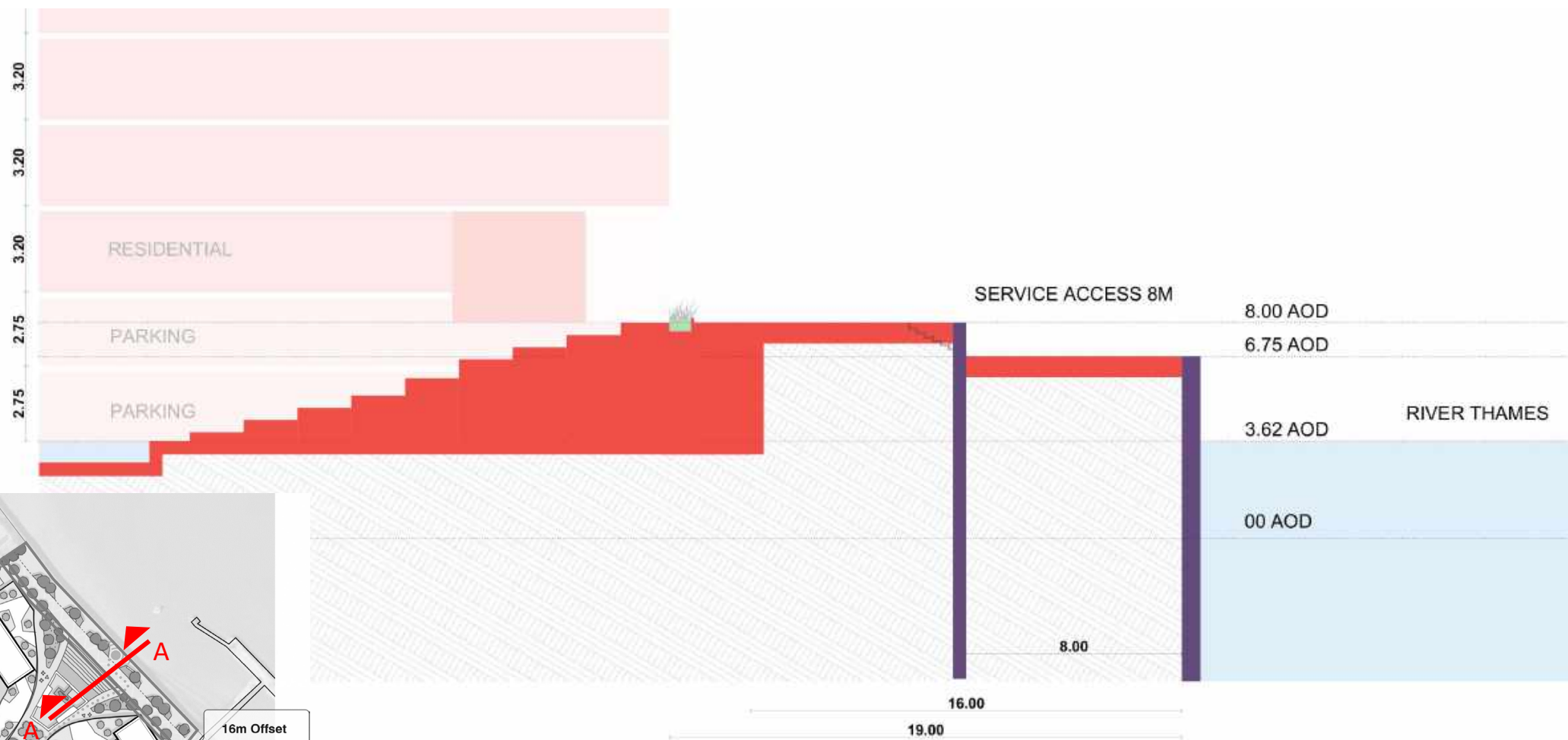
Constraints

- Distance of built form from existing retaining wall must be -16m
- Existing proposed built form ground FFL- 3.62AOD
- Top of existing retaining wall - 6.75 AOD
- Loss of views due to level difference between FFL and Top of retaining wall

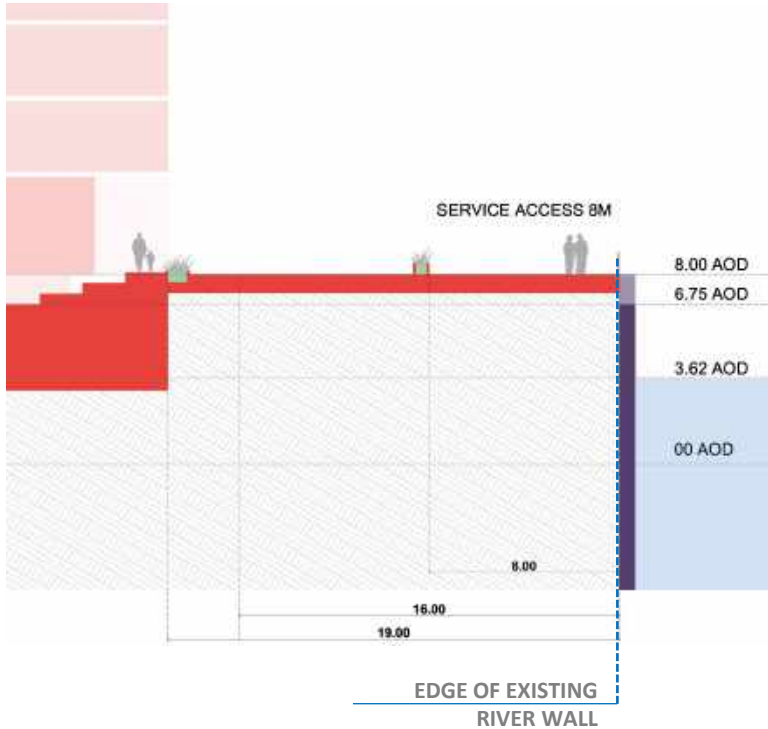
Requirements

- Top of proposed retaining wall – 8.00 AOD
- Finished ground level of public realm adjacent to wall- above 6.75 AOD
- Width of mandatory service access- 8 m

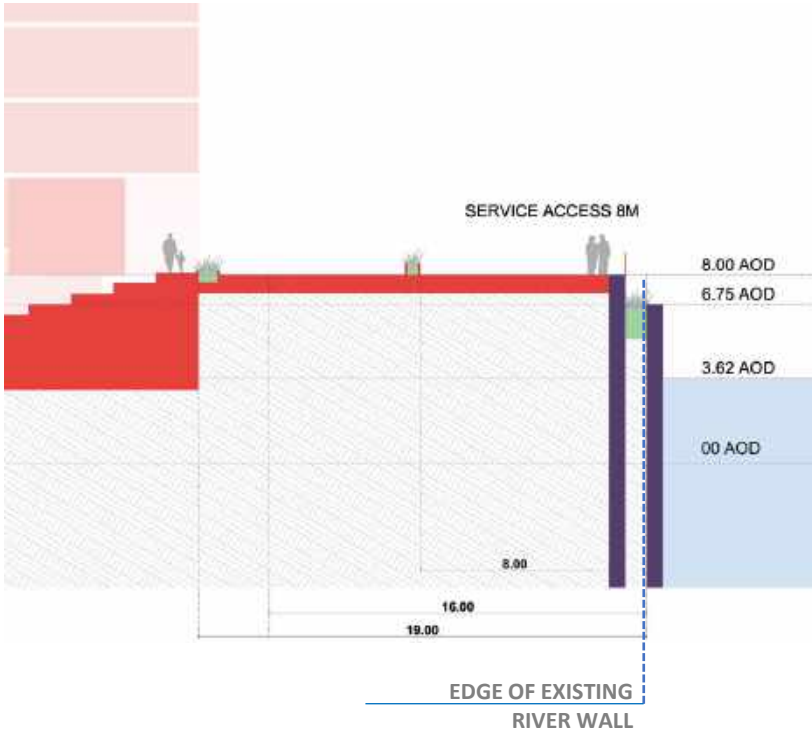
TYPICAL SECTION AA (AS PER EXISTING DESIGN)
Through Thames View promenade



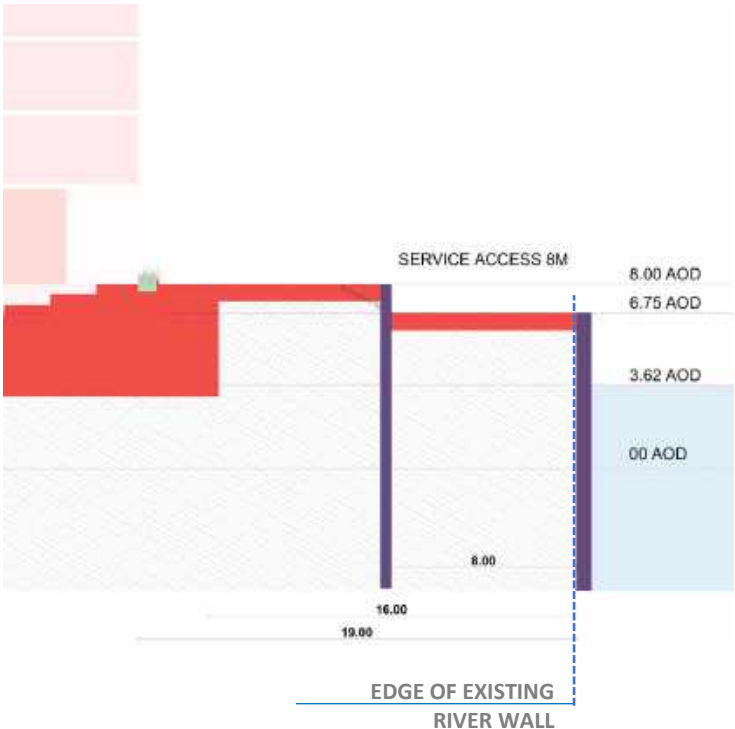
ALTERNATE RETAINING WALL CONDITIONS
Along the Thames View promenade



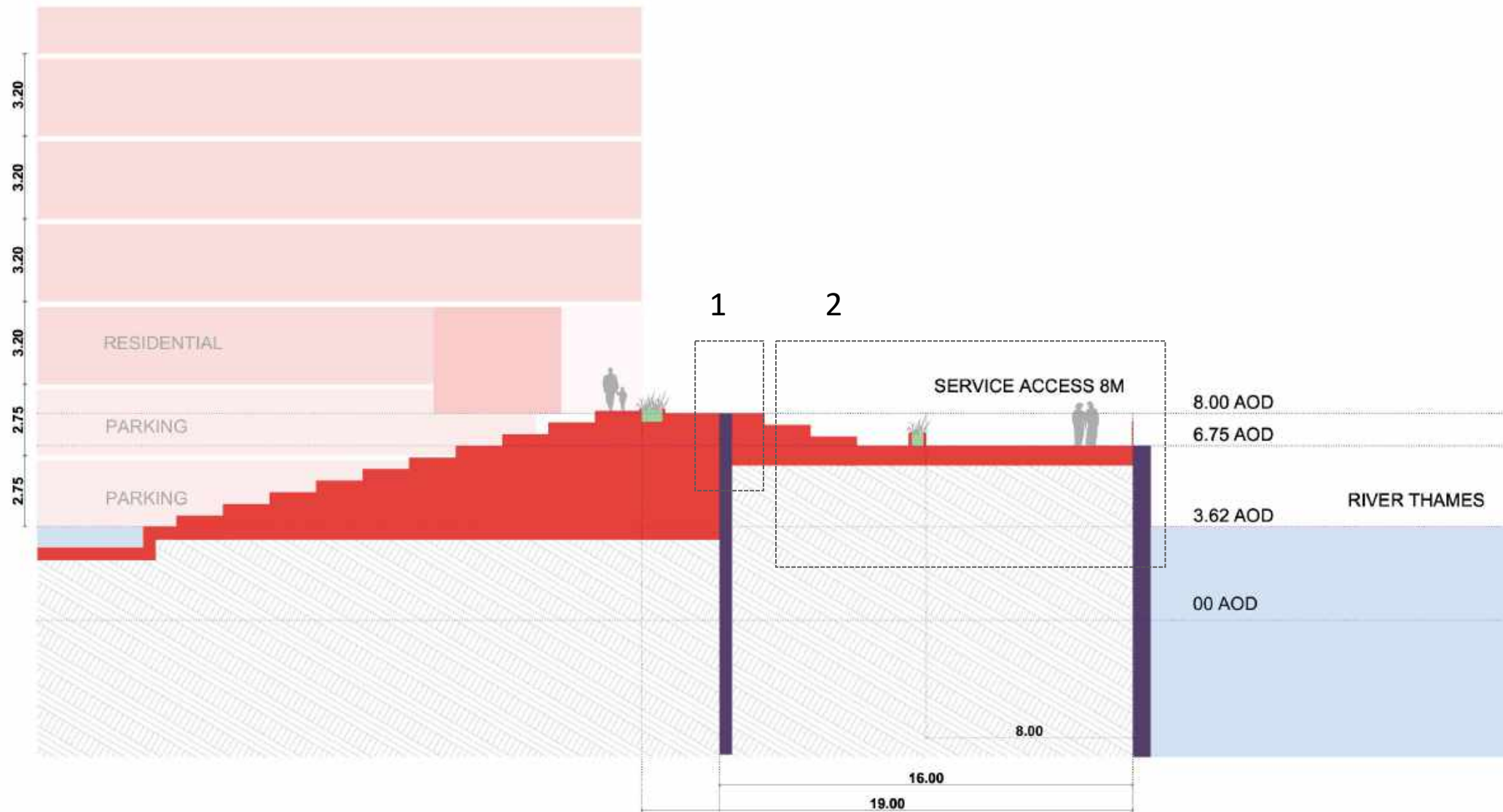
OPTION 1



OPTION 2



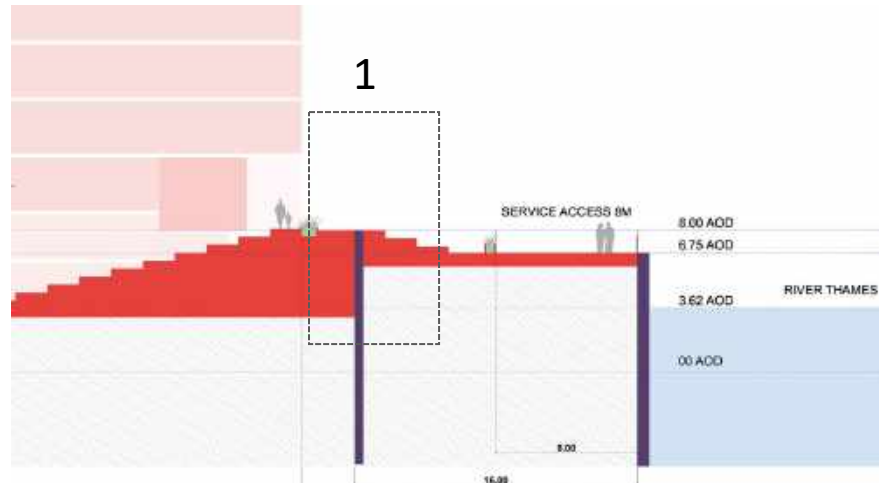
OPTION 3



PROPOSED CONCEPTS

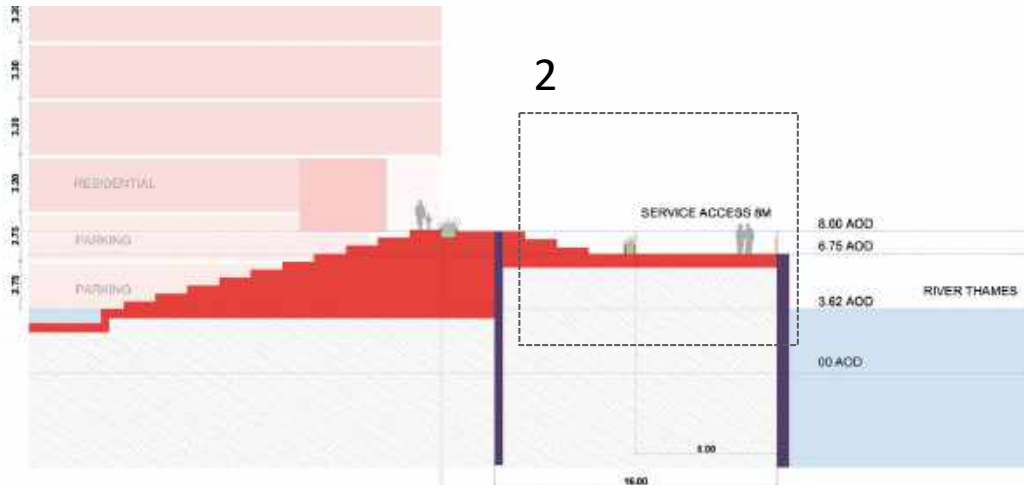
(Thames View promenade)

CONCEPT 1 (8.00 AOD RETAINING WALL)



1 _ MORE THAN JUST A RIVER RETAINING WALL !

CONCEPT 2 (THAMES VIEW PROMENADE)

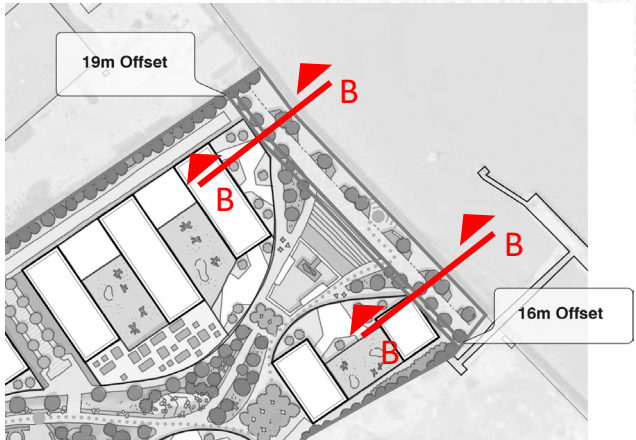
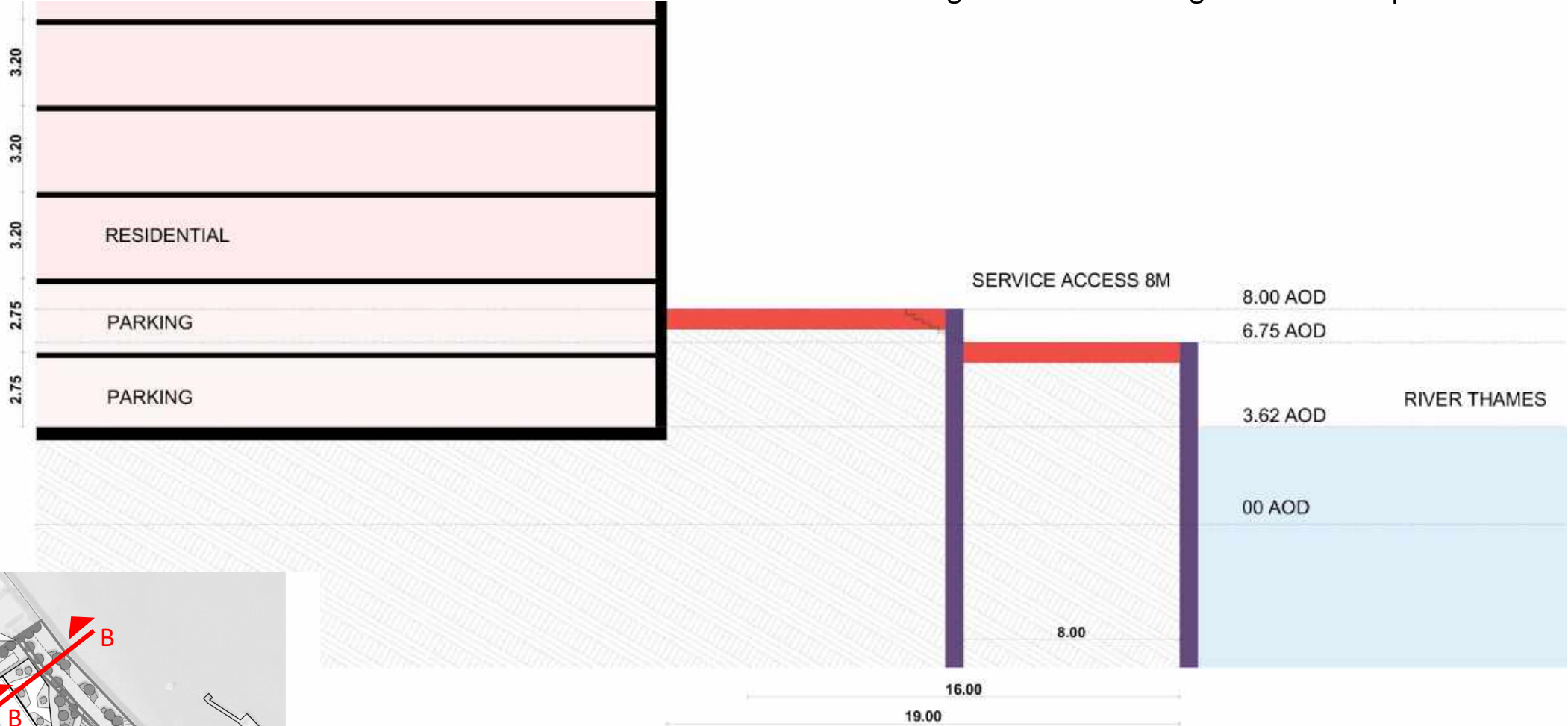


CONCEPT 2 (THAMES VIEW PROMENADE)

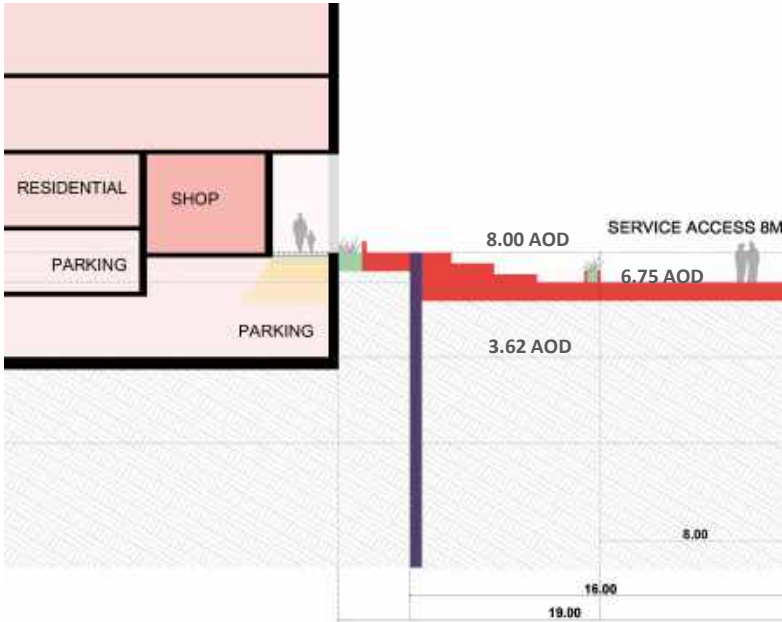
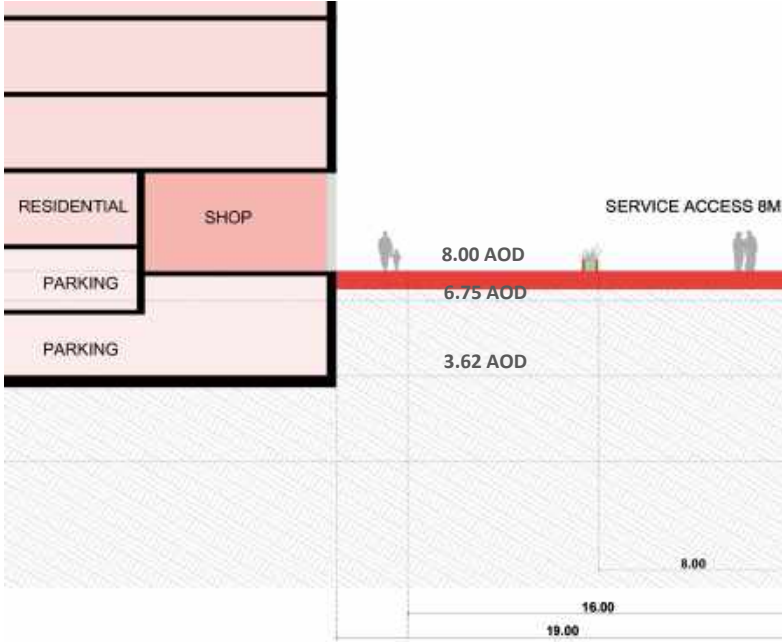
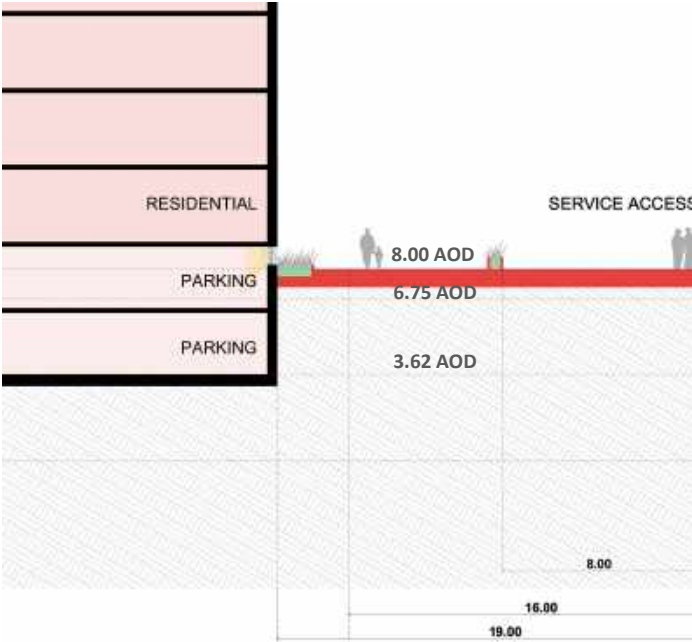


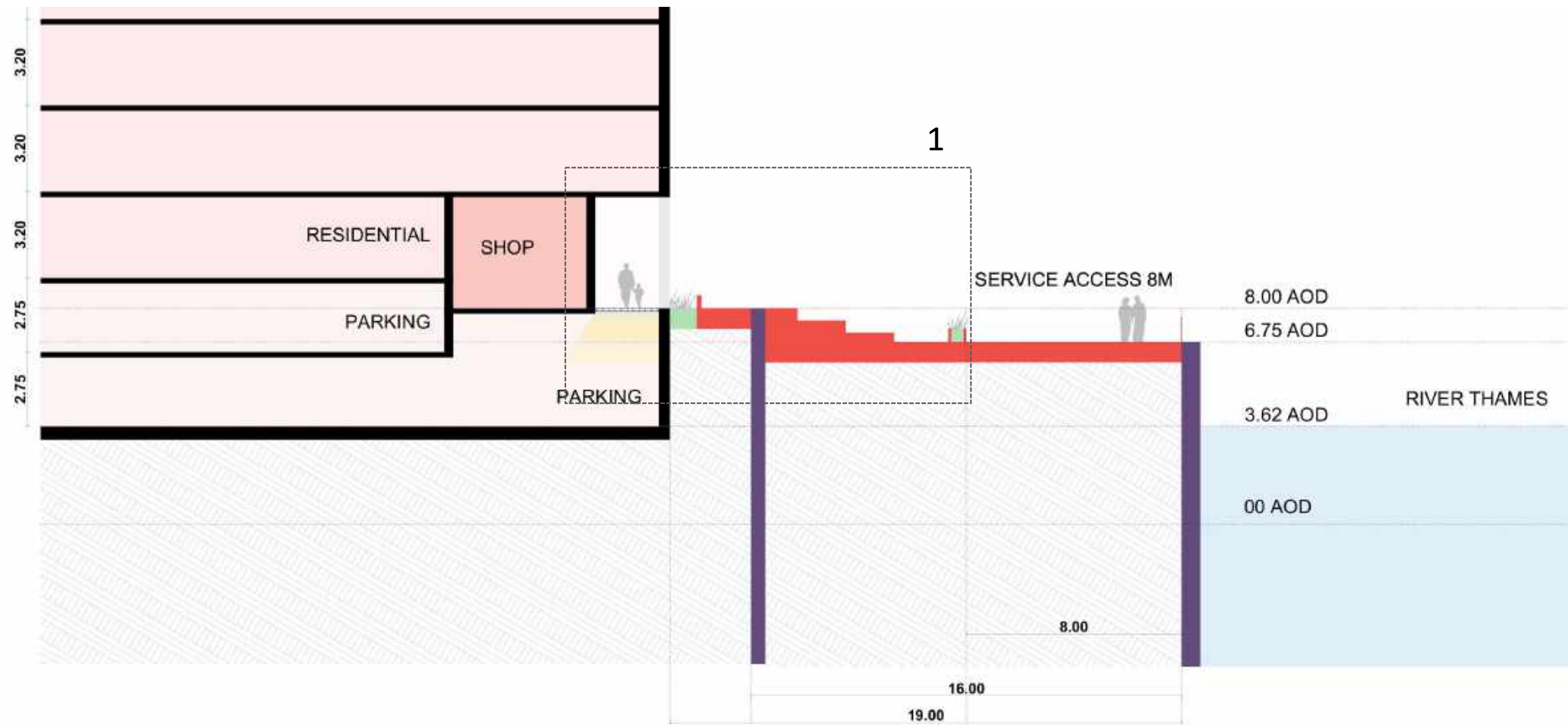
2 _ ACTIVATED RIVERFRONT EDGE

TYPICAL SECTION BB (AS PER EXISTING DESIGN)
Through built forms along Thames View promenade



ALTERNATE BUILDING INTERFACE CONDITIONS
Along the Thames View promenade

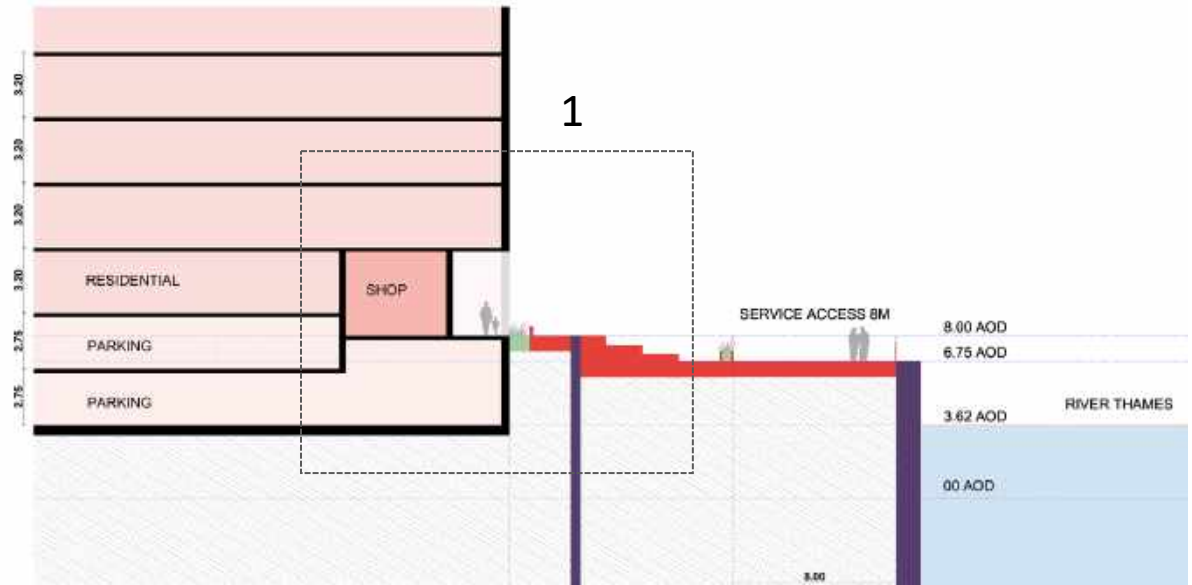




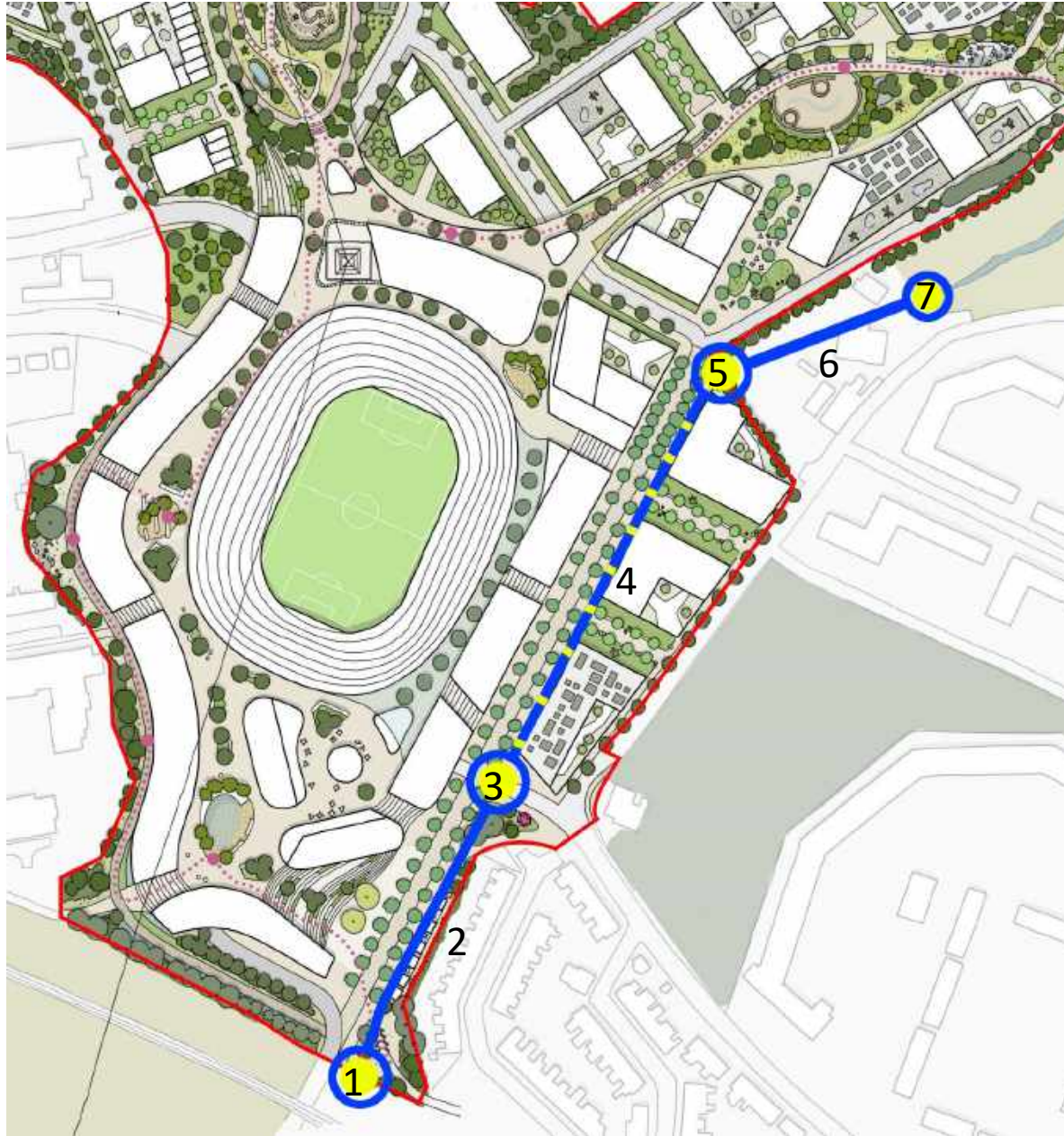
PROPOSED CONCEPTS

(Built form interface with Thames View promenade)

CONCEPT 1 (Built form interface with Thames View promenade)



1 _ BUILDING INTERFACE



CULVERTED ROBINS CREEK/RIVER EBBSFLEET ZONES

1. Connection into EDC land
2. Potential section of daylighting – within park area
3. Culverting required under Stonebridge Road
4. Potential section of daylighting – within Boulevard
5. Connection into third-party land
6. Existing culvert in third-party land
7. Existing outflow into Northfleet Harbour

DAYLIGHTING DESIGN IDEAS – Large options

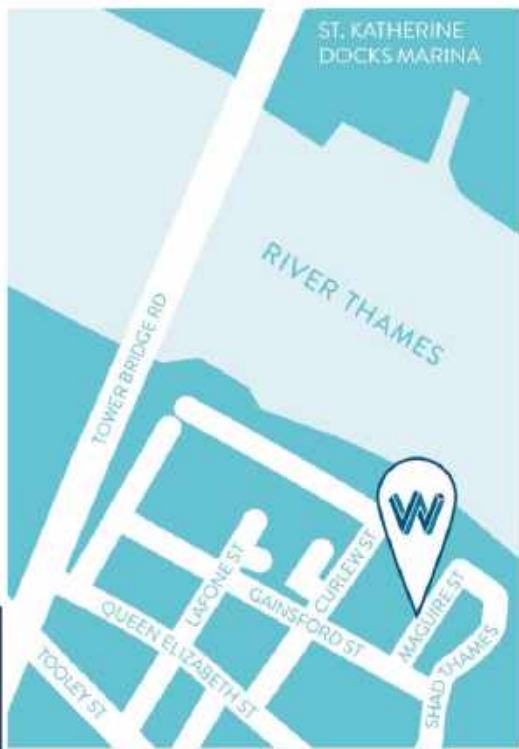


DAYLIGHTING DESIGN IDEAS – Medium options



DAYLIGHTING DESIGN IDEAS – Small options





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ISO 9001

QUALITY
MANAGEMENT



ISO 14001

ENVIRONMENTAL
MANAGEMENT

Appendix H: Northfleet Flood Modelling Technical Note (JBA; 2023)

TECHNICAL NOTE

JBA Project Code	2022s1459
Contract	Northfleet Flood Modelling
Client	RMA Environmental Ltd
Date	05/02/2023
Author	Paul Redbourne BSc, PGCert, MCIWEM, C.WEM
Reviewer / Sign-off	Jenni Essex BSc MSc PhD CEnv MCIWEM C.WEM
Subject	Northfleet Flood Modelling Technical Note - REVD

1 Introduction

1.1 Terms of reference

JBA Consulting (JBA) was commissioned by RMA Environmental Ltd to undertake a hydraulic modelling study of the River Ebbsfleet in Northfleet, Gravesham. A mixed-use development is being proposed consisting of residential units, businesses, and replacement of the Ebbsfleet football stadium. During pre-application consultation, the Environment Agency raised concerns with the current understanding of fluvial flood risk in the study area. It was recommended that a new flood modelling exercise was undertaken to provide an improved understanding of flood risk for the proposed development.

This technical note has been produced to provide a summary of the flood modelling works that have been completed as well as providing an analysis of the model results. The document also includes discussion on the assumptions and uncertainties that are present within the model.

1.2 Study area

The modelled study area covers the reach of the River Ebbsfleet from Springhead, located immediately to the north of Watling Street, to the confluence with the River Thames at Robins Creek. The location of the proposed site boundary, the model domain and the river network are shown in Figure 1-1.



Figure 1-1: Modelled study area

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2 Model review

The existing hydraulic model of the River Ebbsfleet is a 1D-2D linked ISIS-TUFLOW model developed by Capita URS in 2015. The purpose of that study was to provide updated flood risk mapping for the River Ebbsfleet. This followed on from the original River Ebbsfleet flood model, developed in 2005, which consisted of a 1D-only approach using extended cross-sections to represent the floodplain.

As part of the study for the Northfleet mixed use development, a review of the 2015 hydraulic model was completed. A summary of the findings and recommendations are provided below:

- A 1D-2D linked approach is considered appropriate but the hydraulic modelling software versions are now outdated and any new modelling should be updated to utilise latest available software.
- The downstream boundary used a tide series to represent the potential tide locking mechanism present on the River Thames. Although appropriate, this has used the Highest Astronomical Tide (HAT), rather than the Mean High-Water Spring (MHWS) tide curve which is considered standard practice.
- The model included a simulation for climate change with a 20% uplift applied to the 1% annual exceedance probability (AEP) event. This was appropriate at the time of the previous study, but climate change guidance has since been updated and new uplifts should be applied.
- The HAT tidal boundary was not updated to include an uplift for climate change in the fluvial 1% AEP event plus climate change scenario. When simulating a climate change scenario, climate change should be applied to both the fluvial and tidal boundary conditions.
- New LIDAR data covering the modelled study area was flown in 2018/2019 and therefore it is recommended that this is incorporated into the new River Ebbsfleet model.
- Analysis of the 1D model schematisation identified that improvements could be made to the 1D conveyance plots through the addition of panel markers at river channel sections and embankment markers at structures.
- The representation of structures could be improved, particularly the long culvert that runs through the proposed development site. It is recommended that all structures are updated to more closely align with the river channel survey data that was collected by Maltby Land Surveys Ltd in 2013.
- The 2015 model includes sections originally derived from LIDAR as part of the 2005 study. Analysis of the 2013 river channel survey data showed that these sections are not required and should be removed.
- The 2015 study included a new hydrological assessment. This is now outdated, and a new hydrological assessment is recommended that makes use of best available data, methods, guidance, and software.
- The 2015 modelling study and the Environment Agency pre-application consultation comments highlighted the potential influence of groundwater within the catchment, and that this should be investigated further during this study.

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3 Baseline modelling

3.1 General schematisation

The new hydraulic model of the River Ebbsfleet is a 1D-2D linked Flood Modeller - TUFLOW model. Flood Modeller version 5.1 and TUFLOW version 2023-03-AA have been used for the final design event simulations. A more recent version of the Flood Modeller software has been released since the commission of this study, but the use of v5.1 is considered acceptable and, importantly, represents a significant improvement to the previous modelling completed in 2015. More recent versions of the TUFLOW executable are also available but there is a known bug issue with water level lines that incorrectly projects in-channel results and therefore the 2023-03-AA version has been adopted.

The model has adopted a 4m grid resolution for the 2D domain. This is the same resolution as the existing model and is considered to provide an acceptable balance between the representation of floodplain features and managing acceptable run times. Given the 4m resolution, a 2D timestep of 2s has been adopted, along with a 1D timestep of 1s, which aligns with industry best practice.

3.2 1D domain

The 1D open channel and structure geometry has been reviewed and updated to improve the 1D model performance, the representation of channel and structure geometry, and in-channel conveyance. The 2015 model schematisation was reviewed against the 2013 river channel survey data collected specifically for that study. Where required the 1D open channel and structure geometry has been updated to be more representative of the surveyed cross-sections. The 2013 river channel survey is provided in Appendix B.

The river channel Manning's n roughness coefficients have been retained from the previous Environment Agency flood modelling. This has been reviewed on a section by section basis and updated at any locations that were identified as erroneous but generally the 1D roughness has not had any significant updates.

The existing 2015 model contained sections derived from LiDAR data and site measurements based on the 2005 model, which were applied alongside cross-sections based on the 2013 survey. Upstream of the outfall to Robins Creek any sections based on the 2005 model have been removed and the channel geometry has been defined based on the 2013 river channel survey data only.

The representation of the wetland area upstream of the A226 Thames Way Road (between model nodes 1.024 and 1.019) has been improved as the 2015 model was inconsistent in its approach. This wetland reach is now represented with more consistent channel widths within the 1D domain. Within this wetland area some of the surveyed cross-sections were extended based on more recent LiDAR data from the 1m EA 2022 composite DTM. In addition, two cross-sections (1.020_u2, 1.020_u1) based on the 1m EA 2022 composite DTM, with modifications to represent extrapolated channel bed levels, were included to account for a notable change in width that would otherwise not have been accounted for in the surveyed sections. These open channel sections have adopted a high roughness value of 0.065 to account for the dense vegetation identified here through the river channel survey site photographs.

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New initial conditions have been developed for the model. For the baseline scenario, a steady state simulation was completed to derive new initial conditions following the updates that have been applied to the model. The steady state results have been imported in the .DAT file for the baseline scenario. For the post-development and managed realignment scenarios, separate steady state simulations have been completed and their respective .zzs outputs have been used to specify the initial conditions for these scenarios.

Other updates to the model 1D domain have included:

- the addition or alteration of panel/embankment markers to improve 1D conveyance,
- updates to the top of bank deactivation locations to improve the 1D-2D linkage interaction,
- corrections to chainages and skew angles to better match the 2013 survey data, and
- the addition of interpolate sections to provide a more stable and reliable set of model outputs.

Table 3-1 outlines the structures included within the model. It should be noted that the Springhead Park Bridge which would be located at approximately 1.022 and the railway bridge located just downstream of model node 1.016 were not included within the 2013 survey and therefore could not be represented. These omissions are discussed further within the model assumptions and limitations in Section 6.

Pipe crossings which were considered unlikely to have a significant impact on flow within the channel and have also not been represented within the 1D model.

Table 3-1 Model structures

Structure ID / Comments	Photograph
1.029_Bu Modelled as a USBPR bridge unit. US Invert level = 3.17mAOD Soffit level = 5.11mAOD Overtopping modelled in the 1D domain with a separate spill unit.	

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1.024_Bu

Modelled as a USBPR bridge unit.
US Invert level = 1.321mAOD
Soffit level = 4.725mAOD
Overtopping modelled in the 2D domain with a separate bridge 2D zshape to represent the bridge deck elevation.



1.019C1_1 & 1.019C2_1

Modelled as twin rectangular conduit units.
Left opening
US Invert level = 1.34mAOD
Soffit level = 2.57mAOD
Right opening
US Invert level = 1.34mAOD
Soffit level = 2.57mAOD
A roughness of 0.015 has been used.
Overtopping modelled in the 2D domain with the base LIDAR used to set to the bridge deck elevation.
An orifice unit has been used to represent the circular flood relief culvert present at this structure.



1.018C1_1 & 1.018C2_1

Modelled as twin rectangular conduit units.
Left opening
US Invert level = 1.27mAOD
Soffit level = 2.54mAOD
Right opening
US Invert level = 1.23mAOD
Soffit level = 2.54mAOD
A roughness of 0.015 has been used.
Overtopping modelled in the 2D domain with the base LIDAR used to set to the bridge deck elevation and separate 2D Z-Shape lines used to set overtopping levels based on 2013 survey.



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1.015C2_1 & 1.015C3_1 Modelled as twin rectangular conduit units. Left opening US Invert level = 1.27mAOD Soffit level = 2.54mAOD Right opening US Invert level = 1.23mAOD Soffit level = 2.54mAOD A roughness of 0.015 has been used. Overtopping modelled in the 2D domain with the base LIDAR used to set to the bridge deck elevation and separate 2D Z-Shape lines used to set overtopping levels based on 2013 survey.	
1.012Bu & 1.012Su Modelled as a USBPR bridge unit. US Invert level = 1.439mAOD Soffit level = 2.830mAOD Overtopping modelled in the 1D domain with a spill unit used to represent the bridge deck elevations. A weir coefficient of 1.2 was applied.	
1.009Bu, 1.009_Su, 1.009C1_u, 1.009C3_u, Modelled as a USBPR bridge unit with two high level flood relief culverts modelled as orifice units. Weir located close to (within) the downstream portion of the culvert represented by a spill unit. Left opening (orifice unit) US Invert level = 2.280mAOD Soffit level = 3.180mAOD Central opening (USBPR unit) US Invert level = 1.151mAOD Soffit level = 2.830mAOD Right opening (orifice unit) US Invert level = 2.180mAOD Soffit level = 3.080mAOD Overtopping modelled in the 2D domain with the base LIDAR used to set to the bridge	Upstream face  Downstream face

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deck elevation and separate 2D Z-Shape lines used to set overtopping levels based on 2013 survey.

Orifice mode has been enabled on this bridge unit. This approach is considered acceptable given the high depths of water being impounded behind the A226 road embankment.



LngClv2, to LngClv3

Modelled as consecutive circular conduit units with invert levels and diameters based on the 2013 survey long section which appears to be based on cover lifting undertaken as part of that survey. This is considered an improvement over the representation in the 2015 model which assumed a constant gradient within the culvert.

Replicates were included throughout the conduit sections, at approximately 50m intervals, to aid model stability.

LngClv2

US Invert level = 0.750mAOD

Soffit level = 2.460mAOD

LngClv2b

US Invert level = 0.980mAOD

Soffit level = 2.430mAOD

LngClv2d

US Invert level = 0.630mAOD

Soffit level = 2.400mAOD

LngClv2f

US Invert level = 0.660mAOD

Soffit level = 2.236mAOD

LngClv3

US Invert level = 0.710mAOD

Soffit level = 2.210mAOD

Overtopping modelled in the 2D domain with the base LIDAR used to set to the bridge deck elevation and separate 2D Z-Shape lines used to set overtopping levels based



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on 2013 survey. 1.005C_1, 1.005C_2 (and associated spill unit) The main barrel of the culvert has been approximately represented with two irregular conduit units based on measurements from the 2013 survey. The complex outflow arrangement to Robins Creek could not be represented based on the available survey data and a spill unit has been used to drop water levels into Robins Creek. The main barrel of the culvert represents the smallest opening area in the outflow structure and has been represented within the conduit units. Overtopping modelled in the 2D domain with the base LIDAR used to set to the bridge deck elevation and separate 2D Z-Shape lines used to set overtopping levels based on 2013 survey.	Upstream face  Downstream face  
OUT1 to CHAMB2 Tidal outfall structure unchanged, tidal flood wall across Robins Creek represented as per the 2015 model.	Upstream face

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Consideration was given to re-schematising the representation of Robins Creek and the tidal outfall structure. However, a review of the hydraulic model found that the approach taken was broadly acceptable and there was little benefit to altering this reach of the model.



Intermediate chamber



Downstream face



3.3 Boundary conditions

3.3.1 Model inflows

The review of the 2015 River Ebbsfleet flood modelling identified that a new hydrological assessment should be completed to make best use of the latest available software, guidance, and methods, and to utilise any available hydrometric data.

The previous modelling adopted a joint fluvial / groundwater approach due to the chalk geology of the upper catchment. The Environment Agency highlighted as part of the pre-application consultation that there is an uncertainty with the application of groundwater inputs, and these should be considered further as part of any new assessment.

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The previous study included a detailed groundwater analysis which was undertaken to derive a suitable baseflow boundary for application to the hydraulic model. A groundwater level of 4.3mAOD was found to have an annual probability of 0.025 and represents the upper 95% confidence interval. The 4.3mAOD groundwater level was applied to the model as a time invariant level using a head-time boundary (HTBDY) and a Bernoulli loss unit. Consideration was given to applying a groundwater level and Bernoulli loss unit as per the previous study, updating the analysis to use the latest data. However, findings from the current study concluded that this is not recommended, and instead a fluvial only approach has been adopted. The FEH Calculation Record provided in Appendix A provides a detailed breakdown of the limitations; a summary is provided below.

- There is no clear justification within the 2015 report for the approach used to generate the groundwater input and how this benefits the study.
- There is uncertainty regarding the location of the borehole used in the previous study. Regardless of this the location of the borehole is not at the location where the groundwater level is applied to the model and converted to flow (upstream model extent). This means that there cannot be confidence that the level being applied to the model is representative of the actual groundwater level at the upstream model extent.
- There are large variations in peak levels at the boreholes, both between the two assessed for this study, and the values for the borehole used in the previous study. This is likely to be dependent on hydraulic connectivity, which may also be influenced by Sawyer's Lake.
- There will be uncertainty in the way in which the Bernoulli loss unit converts level to flow. This will not account for the spatial variation in groundwater level, so flow is very dependent on which borehole is used for the analysis.
- An arbitrary choice of design event to use for groundwater input appears to have been made. The input flow does not change with design event / return period.
- It is believed that there is no information on groundwater flow for this area and there is no river flow data against which to compare the groundwater response. This means that the flow generated from groundwater level is highly uncertain as there is no data to verify it against.
- This type of analysis is not something that is generally undertaken for fluvial modelling studies and there are many other catchments like this in terms of groundwater dominance for which this type of analysis has not been carried out. If groundwater analysis had not been applied in the past it is highly unlikely that it would be requested for this catchment now.

It was concluded that adoption of standard FEH methods (FEH Statistical and ReFH2) was appropriate for this study. Both approaches have been assessed to calculate peak flow estimates with the recommendation to adopt the ReFH2 peak flow estimates and hydrographs for the final design event simulations. Analysis has shown that for the 1% AEP event, the Statistical and ReFH2 peak flow estimates are very similar whereas ReFH2 has much smaller flows for the more frequent design events and higher flows for the larger, less frequent design events. Given the uncertainty surrounding this catchment due to the lack of hydrometric data, and the focus of the study on the more extreme events (1% and 0.1% AEP), it was decided to adopt a more conservative

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approach and use the higher flows produced by the ReFH2 method. The full analysis and justification of the hydrological assessment can be found in Appendix A.

Climate change has been applied to the 1% AEP event with uplifts of 27%, 37%, and 62% applied. These have been taken from the Environment Agency peak river flow map for the Medway Management Catchment for the central, higher, and upper 2080's climate change projections.

3.3.2 Storm duration testing

Storm duration testing has been completed to determine the critical storm duration, resulting in the largest flood extent and highest water levels throughout the modelled study area. Storm durations of 15-hour, 23-hour, and 31-hour were used for this testing. Figure 3-1 shows the TUFLOW MaxMax output, identifying which duration resulted in the highest water levels throughout the model extent.

The 31-hour duration produced the largest flood extent and the highest water levels and therefore this has been adopted for the final design event simulations. For the storm duration testing, the application of the tidal boundary has been included as the potential for tide locking is critical for understanding the flood mechanism impacting the study area.

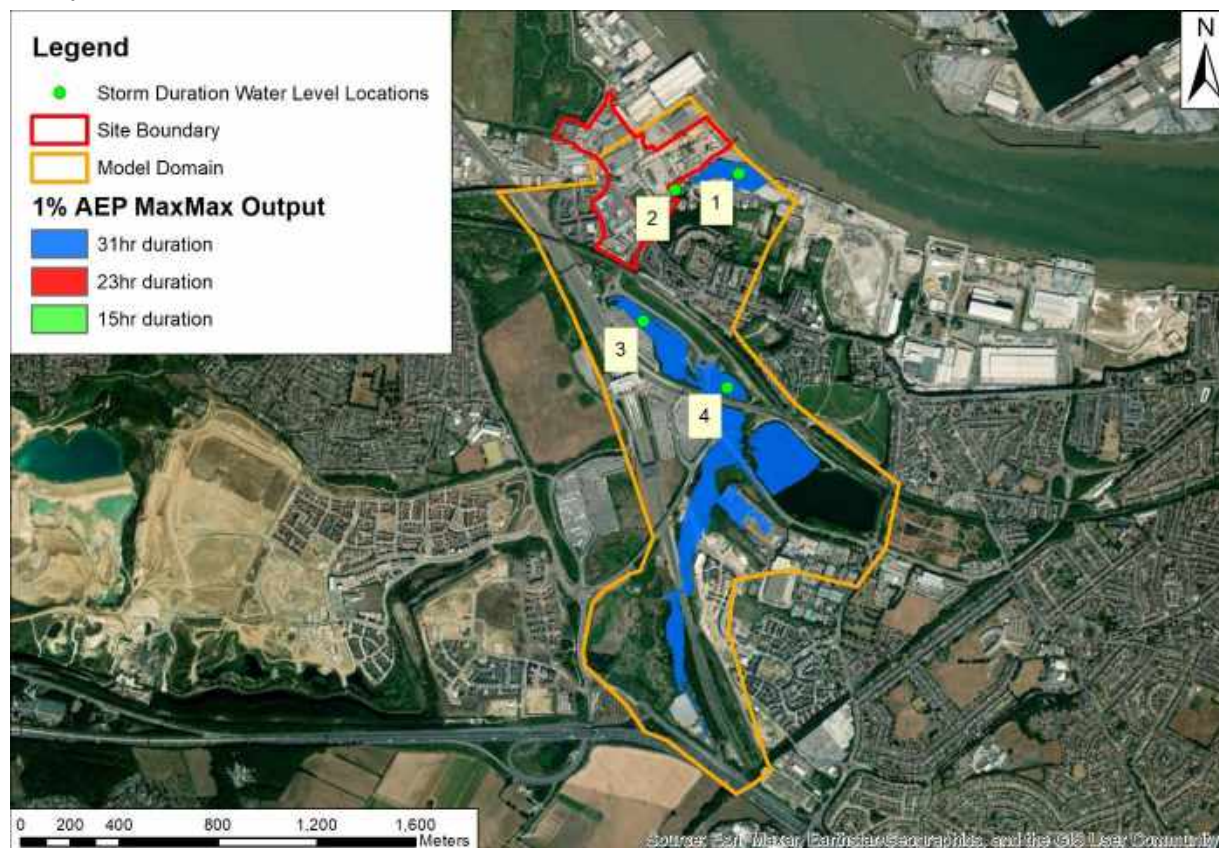


Figure 3-1: Maximum water level storm duration testing

The Environment Agency model review questioned whether a longer duration than the 31-hour should have been tested. The FEH Calculation Record found in Appendix A has

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been updated to summarise the limitations associated with using longer storm durations as they become less representative of real storm events. To provide further justification that the testing of longer storm durations is not required, the storm duration testing results have been presented and discussed with the Environment Agency which showed only negligible differences in maximum water level between the 23-hour and 31-hour results. The maximum water levels from the three different storm durations have been extracted at the four locations presented in Figure 3-1 and are shown in Table 3-2.

The difference in the maximum water level between the 23-hour and 31-hour storm duration outputs is very small (up to 6mm) in the downstream portion of the model extent where the primary interest of this study focuses on. Given the negligible differences in modelled water levels, the Environment Agency have agreed that no further storm duration testing is required.

Table 3-2: Storm duration testing maximum water levels (mAOD)

Location	15-hour	23-hour	31-hour
1	2.405	2.421	2.422
2	3.516	3.552	3.558
3	3.853	3.894	3.898
4	3.874	3.932	3.934

3.3.3 Tidal boundary conditions

The existing 1D HT tidal downstream boundary (HAT) was replaced with a MHWS curve for Tilbury from the ADMIRALTY TotalTide software, which was smoothed and adjusted from Chart Datum to Ordnance Datum (-3.12) as per industry standard practice.

When applied to the model, the timing of the MHWS curve was adjusted by 58.75 hours so that the tidal peak aligned with the peak of the main fluvial inflow (EBB04) at 27 hours. Over the first tidal cycle water levels have also been adjusted so that they ramp up from the initial water level at the downstream end of the model (-2.62m AOD) into the tidal cycle to aid model stability at the start of the simulations.

To account for the impact of sea level rise during climate change scenarios, the MHWS levels were uplifted by 1.078m (Higher Central allowance) based on the Environment Agency's guidance on Flood risk assessments: climate change allowances. Table 3-3 shows the peak tide levels applied at the downstream boundary for the present day and climate change simulations.

Table 3-3 MHWS peak water levels

MHWS peak water level (mAOD)	MHWS peak water level (mAOD) with Higher Central allowance
3.280	4.358

3.4 2D domain

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3.4.1 Topography

Review of the 2015 model indicated new LiDAR of the study area was flown 2018-2019. The base model topography was therefore updated based on the Environment Agency 2022 1m LiDAR DTM Composite which included this updated LiDAR dataset.

3.4.2 2D roughness

Consideration was given to updating the representation of the 2D roughness coefficients. However, a review of the 2015 model found that the 2D roughness representation, based on OS Master Map, was suitable for the purposes of the current study and was therefore maintained unaltered.

3.4.3 1D-2D linkage

The 1D-2D linkages across the model were updated to align with the updates to open channel cross-sections and deactivation markers in the 1D domain. Bank heights across the 1D-2D linkages are defined from the base model LiDAR topography.

3.5 Baseline model results

The updated baseline scenario has been simulated for a range of design events including the 3.33%, 1%, and 0.1% AEP present day events and the 1% AEP event plus climate change with uplifts of 27%, 37%, and 62% to represent the Medway Management Catchment peak river flow allowances.

This section of the report shows the modelled flood depth outputs for the 3.33%, 1%, 1% +27% climate change, and 0.1% AEP events. These are shown in Figure 3-2 to Figure 3-5, with the additional design events provided as part of the packaged model deliverables contained in Appendix D. The new flood modelling indicates that there is currently no fluvial flood risk to the site in any design event. The reason there is no flooding to the site is due to the location of the raised road embankments located upstream of the long culvert. Water is stored upstream of the A226 road embankment and is prevented from flowing northwards to the site.

The primary flood mechanism impacting the River Ebbsfleet through the modelled study reach is a volume driven system. The watercourse outfalls into the River Thames and due to the application MHWS tide curve, tide locking occurs preventing a free discharge of the watercourse. The majority of the flood water is contained behind the raised road embankments situated throughout the study area but in some locations

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flooding does occur to areas of built development.



Figure 3-2: 3.33% AEP event baseline flood depth

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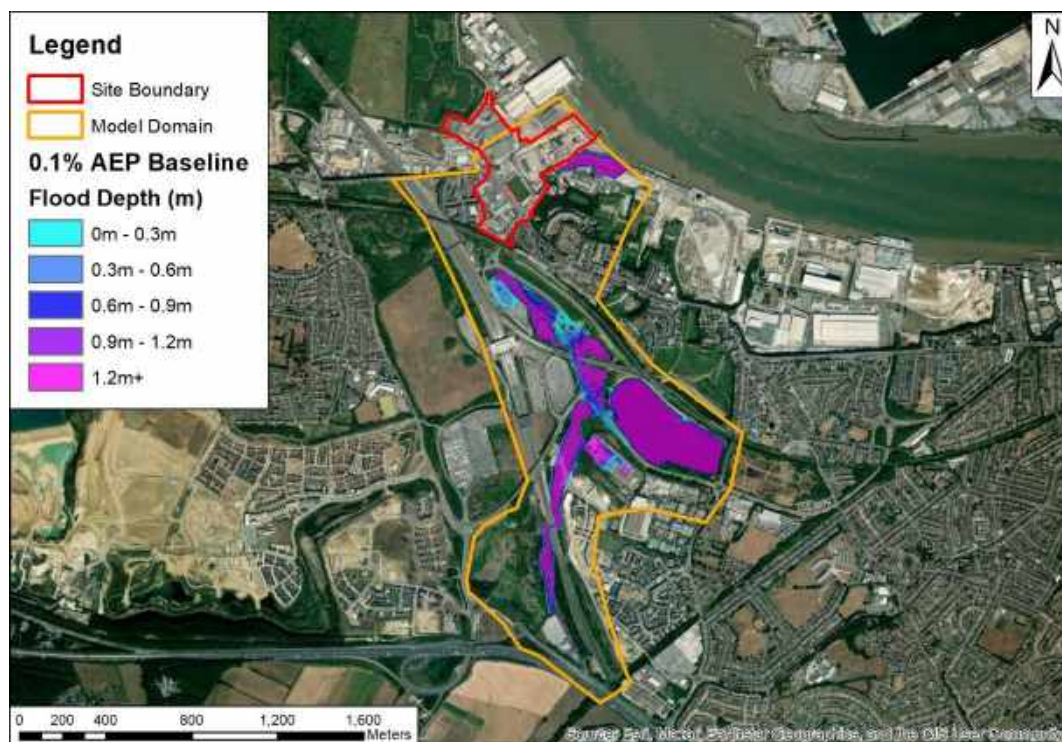


Figure 3-5: 0.1% AEP event baseline flood depth

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4 Culvert daylighting

The Environment Agency response during the pre-application consultation noted that the development is an opportunity to de-culvert and naturalise the river channel, providing environmental enhancement to the site. Therefore, an outline design of daylighting the existing culvert has been developed and this has been tested within the hydraulic model to understand the potential fluvial flood risk constraints.

HLM Architects has produced a concept design showing the location of the proposed daylighted reach along with indicative channel cross-sections so that the channel could be tested within the hydraulic model. The location of the proposed daylighted reach is between Grove Road and the new football stadium, and will consist of an approximate length of 140m. The location of the daylighted reach is shown in Figure 4-1 and is also included in Appendix E along with the channel cross-section profiles.

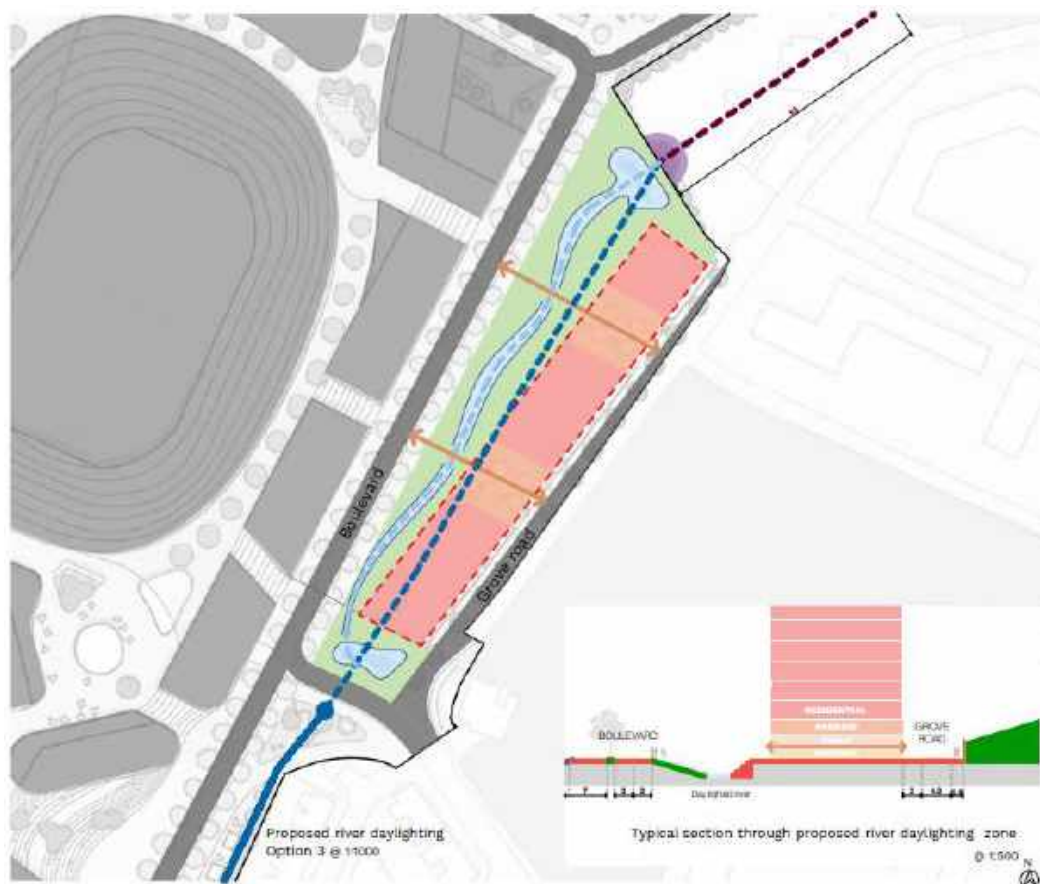


Figure 4-1: Daylighted reach (HLM Architects)

To represent the daylighted reach as accurately as possible, a 1D-2D linked approach has been adopted with the long culvert cut down and new open channel river sections added into Flood Modeller. In the event of the channel capacity being exceeded, the 1D reach has been linked to TUFLOW to allow spilling into the floodplain with HX boundary conditions applied along the right and left bank locations and along the upstream and downstream faces at the entry and exit of the daylighted reach. Figure 4-2 shows the

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location of the open channel sections and section C-C has been shown in Figure 4-3 for reference.



Figure 4-2: Daylighted channel section locations (HLM Architects)

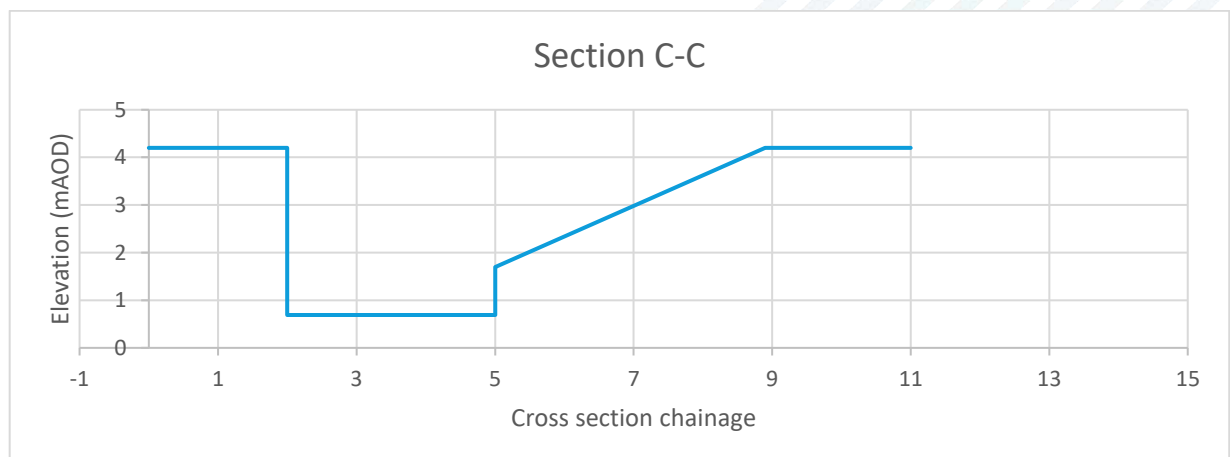


Figure 4-3: Section C-C cross section

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For the representation of the open channel sections in the 1D domain, each channel section has been represented using a Flood Modeller river channel section unit. A consistent approach to the Manning's n roughness coefficients has been adopted with a bed roughness of 0.035 and a bank roughness of 0.05. The exact bed and bank material will need to be confirmed but these values were chosen to reflect a more naturalised river channel as requested by the Environment Agency.

For the 2D domain, the watercourse has been positioned approximately aligned with the PDF design drawing shown in Figure 4-1. The exact location is not considered as important as correctly representing the channel capacity and the top of bank spilling elevations. Figure 4-4 shows the location of the channel as represented within TUFLOW with the node references provided and the bank elevations included. The bank elevations have been specified using a 2D z-line with the elevations matching the top of bank heights specified in the Flood Modeller 1D domain.

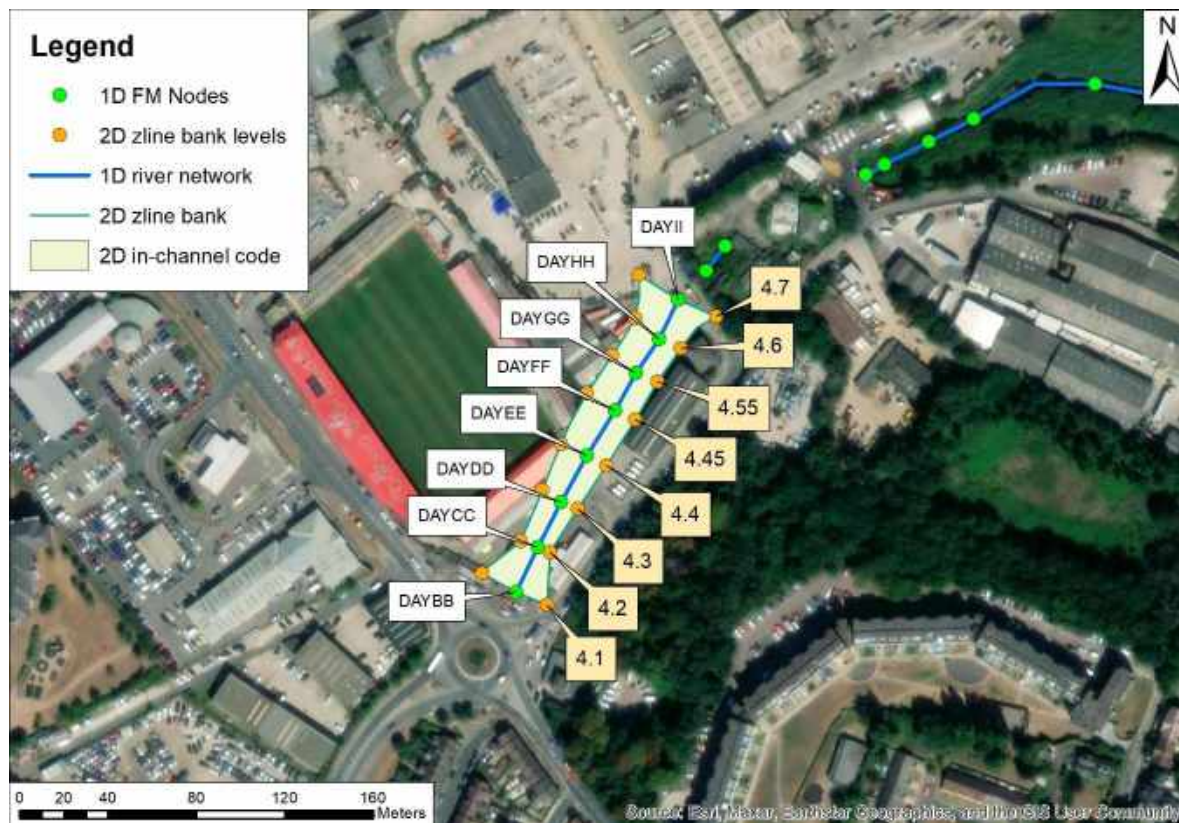


Figure 4-4: Daylighted channel TUFLOW schematisation

Analysis of the model outputs has shown that no spilling will occur from the proposed daylighted channel in any of the design event simulations. This is shown in Figure 4-5 which shows the maximum flood depth outputs for the 1% AEP plus climate change (27%) event. All floodwater is contained within channel for all design event simulations. The full suite of events has been provided as part of the packaged model deliverables and can be found in Appendix D.

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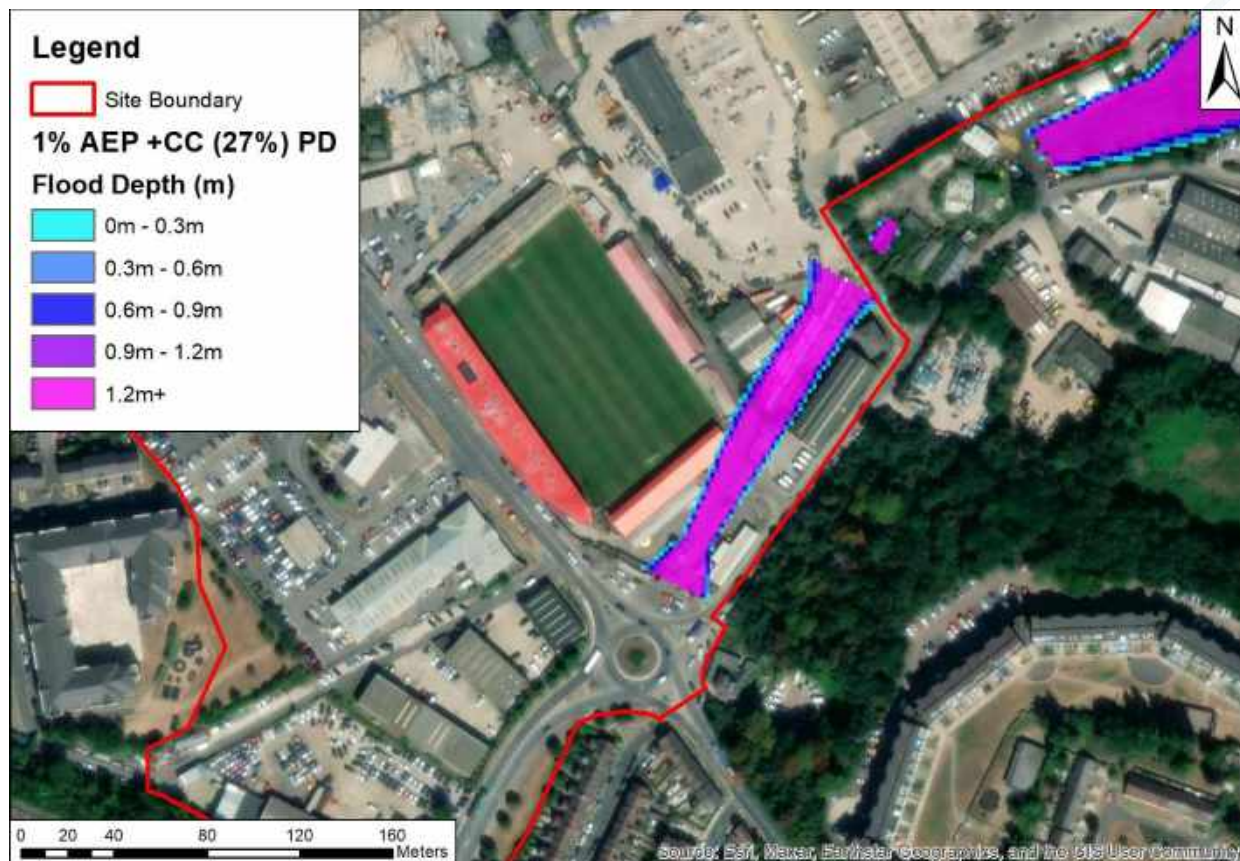


Figure 4-5: Daylighted 0.1% AEP event flood depth

To further demonstrate that spilling will not occur in any of the modelled design events, the maximum water level from the daylighted reach at section B-B has been tabulated and is shown in Table 4-1. This location has been chosen for comparison as it has the lowest top of bank elevations and is therefore most susceptible to out of bank flooding. The bank heights at this location have been set to 4.1mAOD which is well above the maximum modelled water levels shown in Table 4-1.

Table 4-1: Table of maximum water levels within daylighted reach

Design Event AEP	Maximum Water Level (mAOD)
3.33%	3.77
1%	3.90
1% plus climate change (27%)	3.86
1% plus climate change (37%)	3.86
1% plus climate change (62%)	3.87
0.1%	3.82

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5 Robins Creek managed realignment

The 2015 flood modelling included a scenario called 'managed realignment'. This removed the tidal wall separating Robins Creek from the River Thames to allow tidal ingress and installation of a tide flap on the long culvert to prevent the tide backing-up the structure. The Environment Agency requested that this scenario was tested as part of the current modelling study to understand any potential implications for the daylighted reach of channel.

The approach taken in the 2015 study has been reviewed and found to be suitable. This approach has been retained for the current study with the Robins Creek channel sections removed, the tidal wall and outlet structure to the River Thames removed, and two orifice units added at the downstream extent of the culvert that outfalls into Robins Creek. One of the orifice units is flapped representing the flapped outfall that would need to be constructed to prevent the ingress of the tide upstream and the other orifice unit was incorporated to aid with model stability and allow a small amount of backflow.

For the managed realignment scenario, the tidal boundary conditions have been updated so that the tide series starts at 1.3mAOD and continues at this level until it aligns with the natural tide cycle. This has been done to help model stability at the start of the model simulation.

The managed realignment results in an increase in water levels through the daylighted reach but, importantly, it does not result in any out of bank flooding in any design event or climate change scenario. Table 5-1 shows the maximum water levels at daylighted section B-B for the managed realignment scenario. This can be directly compared to Table 4-1 and, although the water levels increase, they are not sufficient to cause out of bank flooding.

Table 5-1: Table of maximum water levels within daylighted reach in managed realignment scenario

Design Event AEP	Maximum Water Level (mAOD)
3.33%	3.92
1%	3.93
1% plus climate change (27%)	4.05
1% plus climate change (37%)	4.06
1% plus climate change (62%)	4.08
0.1%	3.97

The modelled flood depth map for the 1% AEP plus climate change (27%) event for the managed realignment scenario is shown in Figure 5-1 which indicates that there is no out of bank flooding in this model scenario.

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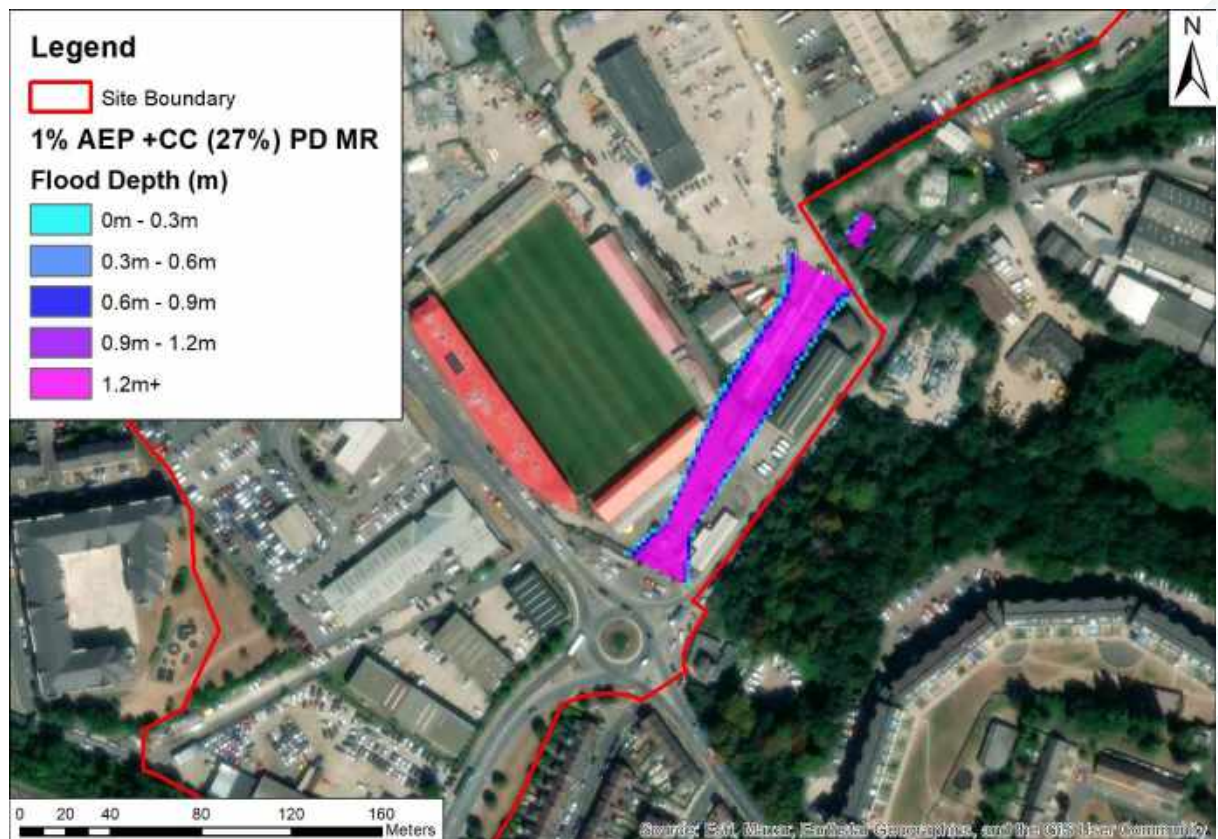


Figure 5-1: 0.1% AEP event daylighted managed realignment scenario flood depth

6 Sensitivity testing

The Environment Agency interim review of the hydraulic modelling noted that the REVA flood modelling deliverable did not include any sensitivity testing; this has been undertaken for the revised REVB submission. It was decided to complete the sensitivity testing on the daylighted reach model scenario to understand how the model parameterisation could affect the assessment of flood risk for the proposed scheme. Sensitivity testing of the Manning's n roughness and downstream boundary conditions has been completed. It was decided not to complete a +/-20% test of the model inflows due to the number of climate change scenarios that have been completed.

The sensitivity testing has been completed on the 1% AEP plus climate change (27%) event as this is considered most important for the flood risk assessment. This section of the report provides a detailed summary of the sensitivity testing findings.

6.1 Manning's n roughness

For the Manning's n roughness sensitivity testing, a 20% increase and decrease has been applied to both the 1D and 2D domains. Due to stability issues during these simulations, the roughness has not been applied to the culvert units in Flood Modeller, only the open channel and bridge units. Figure 6-1 shows the water level comparison between the post-development daylighted scenario with the baseline roughness against the sensitivity test with roughness increased by 20%.

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It was decided to present this using a water level comparison output as the flood extents are almost identical due to the presence of the impounding road embankments located throughout the study area. The comparison output shows no change in water levels for the majority of the modelled study area except for minor fluctuations at the upstream extent of the model and in the area upstream of the Thames Way road embankment. The increase in roughness does very little to the modelled water levels in the lower part of the model as the flood mechanism is volume driven due to the presence of tide locking.

Within the proposed daylighted channel reach, the maximum 1D water levels at section B-B have reduced by 4mm with an increase in roughness, indicating that the roughness coefficients are having very little influence on the model results.

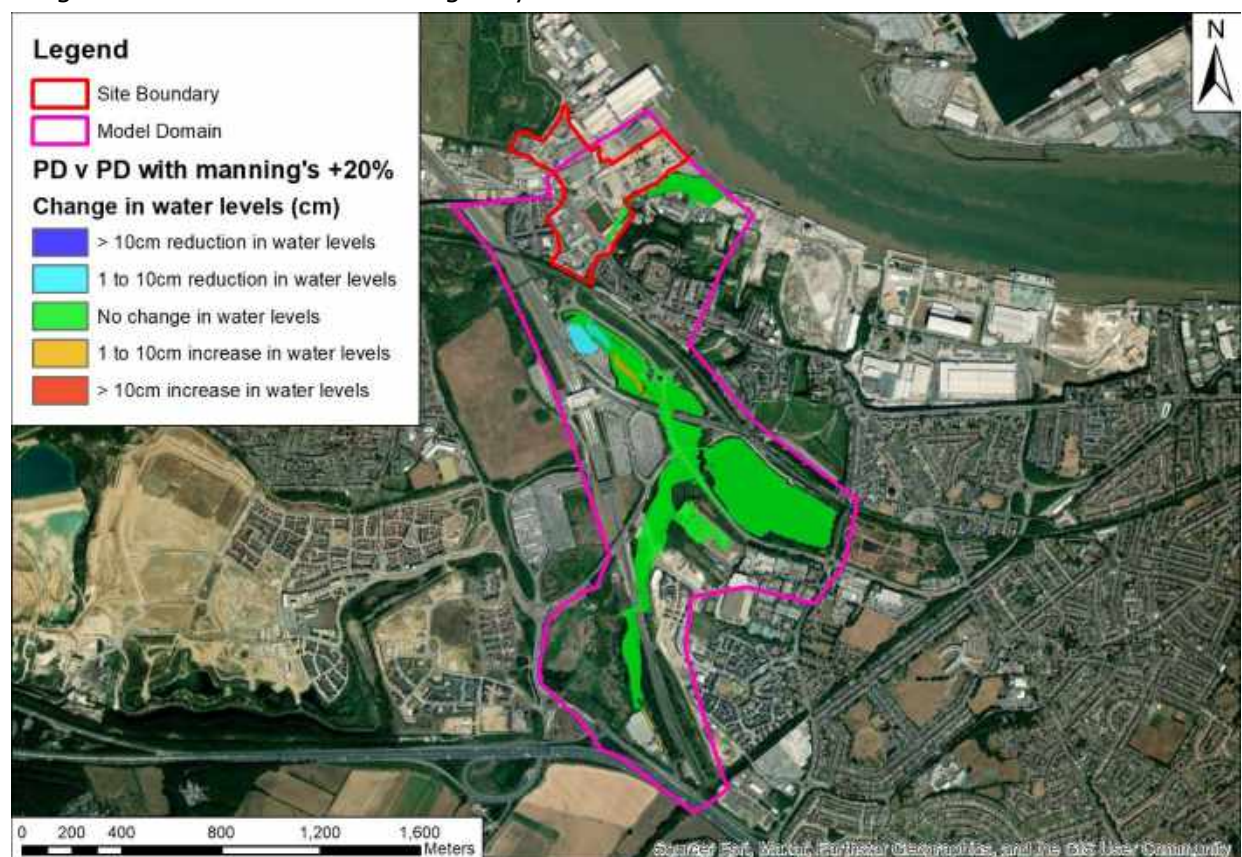


Figure 6-1: Manning's n roughness 20% increase level comparison

Figure 6-2 shows the water level comparison output between the proposed daylighted scenario with the use of the baseline roughness against the 20% reduced roughness sensitivity test. The mapped output, somewhat surprisingly, indicates an increase in water levels through the middle part of the model due to a reduction in Manning's roughness. Analysis of the 1D results upstream of the Thames Way Road embankment shows many oscillations in the stage which indicates the reduced roughness is leading to an unstable water surface through this reach. These oscillations in the 1D results are leading to oscillations in the 2D water levels which is the reason for the results presented in Figure 6-2.

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Through the proposed daylighted reach, the modelled water levels are almost identical. The reduced roughness sensitivity test results in an increase of 1mm in water level at the B-B section, indicating that this part of the model is not considered sensitive to Manning's n roughness.

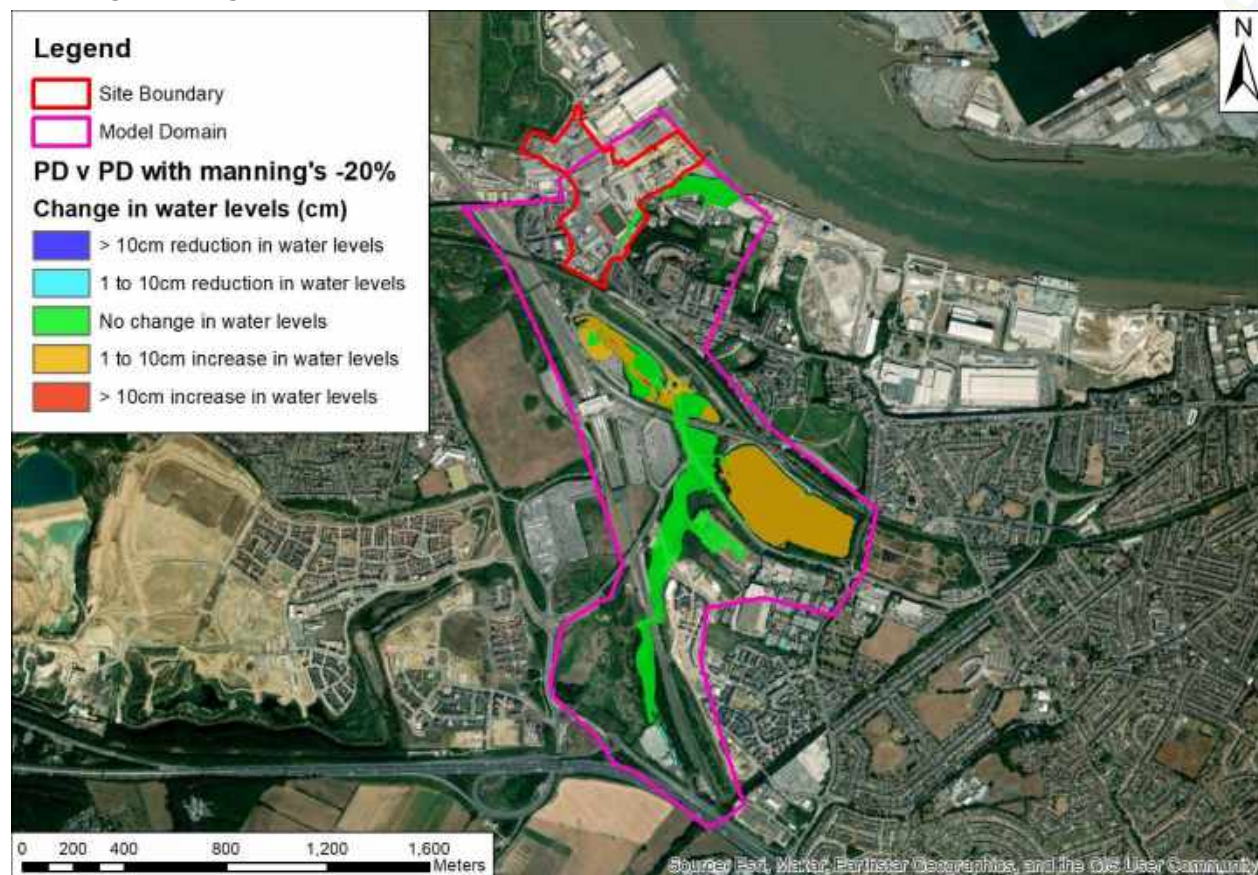


Figure 6-2: Manning's n roughness 20% decrease level comparison

The sensitivity testing of the Manning's n roughness indicates that this is having very little impact on the modelled flood risk throughout the study area. Due to the tide locking flood mechanism, the channel conveyance and roughness coefficients are having less of an impact. Through the proposed daylighted reach, the change in roughness results in minimal change to water levels (+/-4mm) meaning that this parameter has no significant bearing on the assessment of flood risk for the proposed development.

6.2 Downstream boundary conditions

The baseline model has used MHWS tide curve to represent potential tide locking during the fluvial design events. For the climate change simulations, the MHWS tide boundary condition has been uplifted to represent sea level rise for 100-years of climate change. To help understand the potential impact this boundary is having on the model results, a sensitivity test has been completed whereby the Head-Time (HT) boundary has been amended.

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There is no standardised approach for sensitivity testing the downstream boundary especially when there is fluvial-tidal interaction. It was decided to use the confidence intervals specified within the Coastal Flood Boundary (CFB) dataset for the Thames Estuary Node_3.23. The MHWS does not include confidence intervals, so it was decided to use the 0.5% AEP tidal event confidence intervals. This resulted in an increase of 0.33m and a decrease of 0.27m.

Figure 6-3 shows the modelled water level comparison output with the downstream boundary condition increased by 0.33m. This results in an increase in water level through Robins Creek of greater than 10cm. Through the proposed daylighted reach, the water levels increase by 2cm. This moderate change is not sufficient to change the out of bank flood risk.

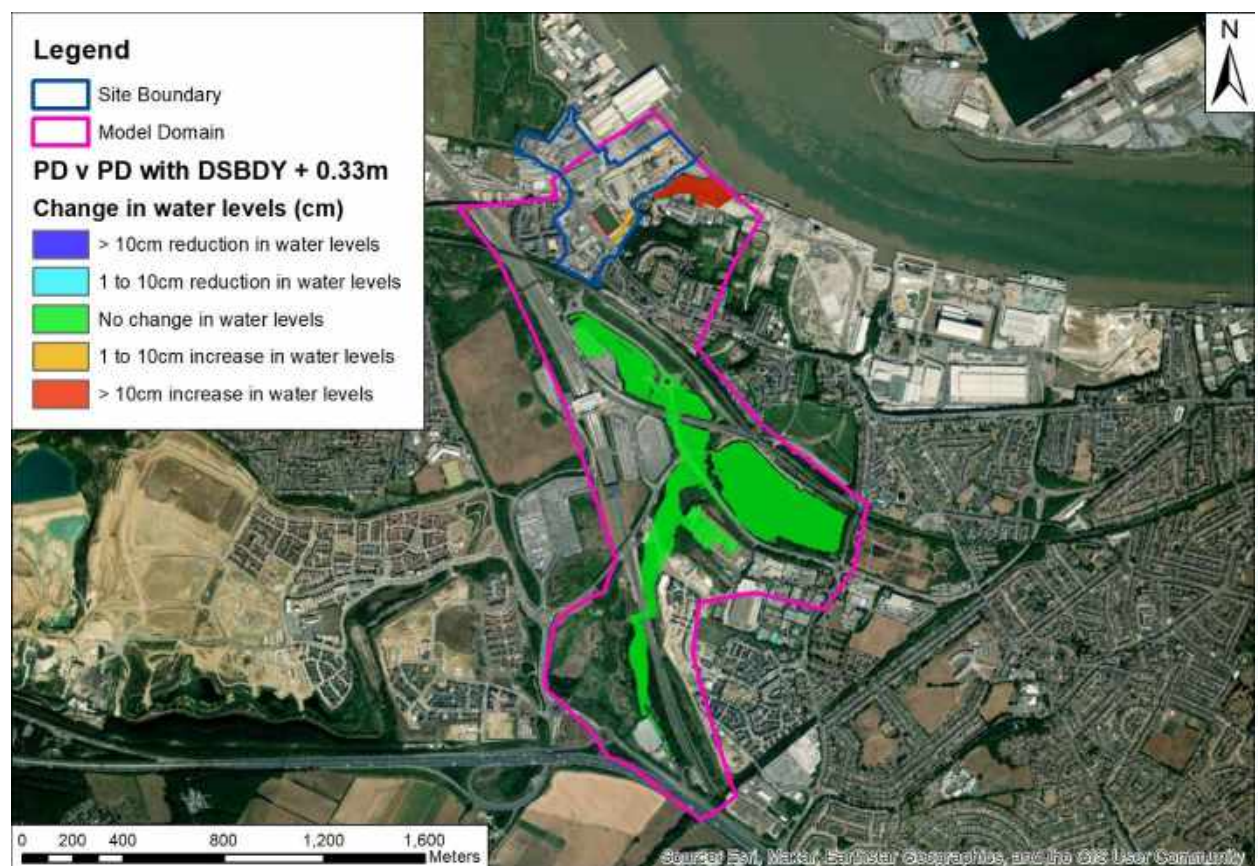


Figure 6-3: Downstream boundary increase sensitivity water level comparison

Figure 6-4 shows the modelled water level comparison with the MHWS tidal boundary reduced by 0.27m. This results in a reduction in water level within Robins Creek of over 10cm. Through the proposed daylighted reach, the water level at section B-B reduces by 1.4cm.

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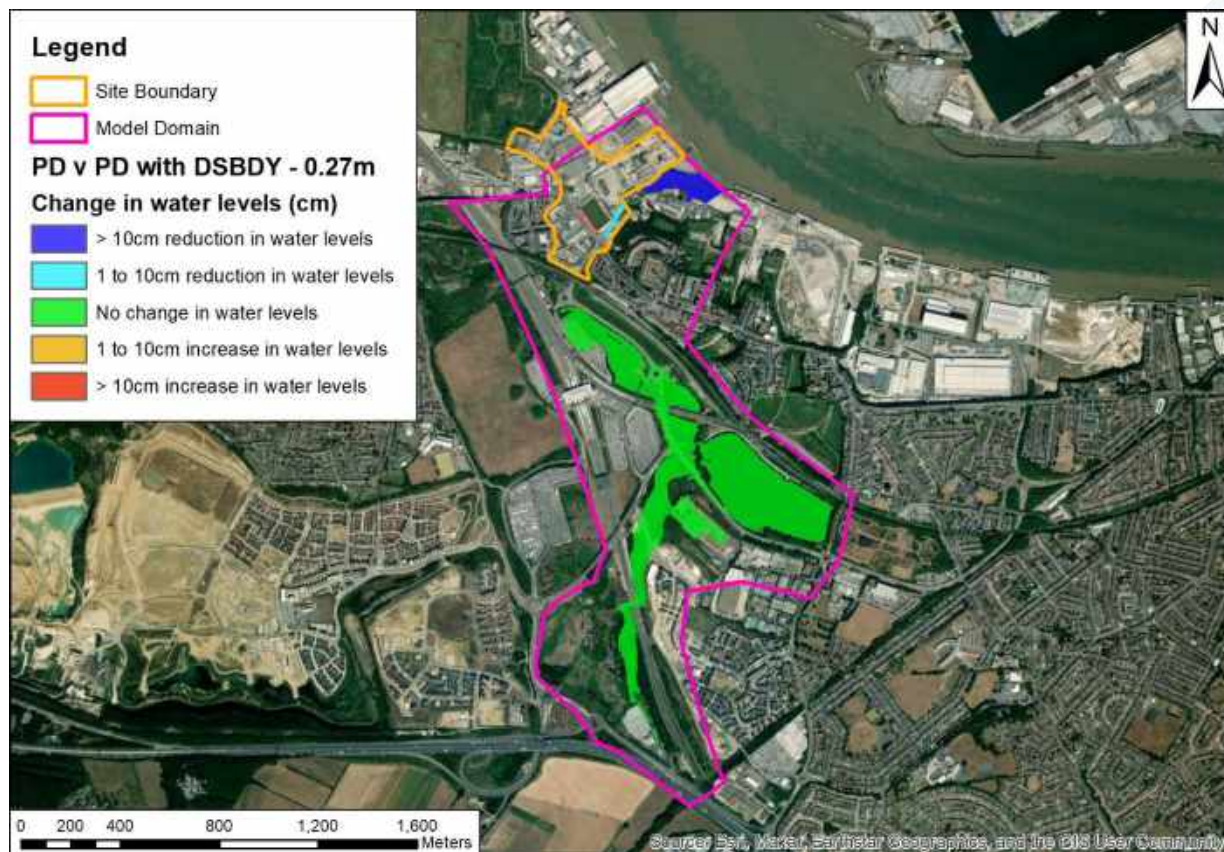


Figure 6-4: Downstream boundary decrease sensitivity water level comparison

The downstream boundary sensitivity testing has shown that altering the MHWS tide curve will have a significant influence within Robins Creek as would be expected but this does not propagate upstream. Through the proposed daylighted reach, the application of the downstream boundary is having a negligible impact on the modelled water levels and has no bearing on the modelled flood extents.

6.3 Blockage testing

As part of their final review of the model, the Environment Agency requested that blockage testing was completed looking at the culvert located at the downstream end of the proposed daylighted reach. This is to understand the potential impact that a blockage would have on water levels within the daylighted reach and to determine whether this would result in out of bank flooding to the proposed development area.

The culvert that has been tested for blockage is LngClv2f with the blockage applied within the inlet unit trash screen attribute, and it was agreed within the Environment Agency to apply a 50% blockage factor. As with the other sensitivity testing, the blockage analysis has been completed on the 1% AEP plus climate change (27%) event as this is considered most important design event for the flood risk assessment.

Figure 6-5 shows the modelled flood depth output with the application of 50% blockage applied to the culvert at the downstream end of the daylighted reach for the 1% AEP

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plus climate change (27%) event. The model demonstrates that there is no out of bank flooding from the daylighted reach with the application of blockage to the culvert.

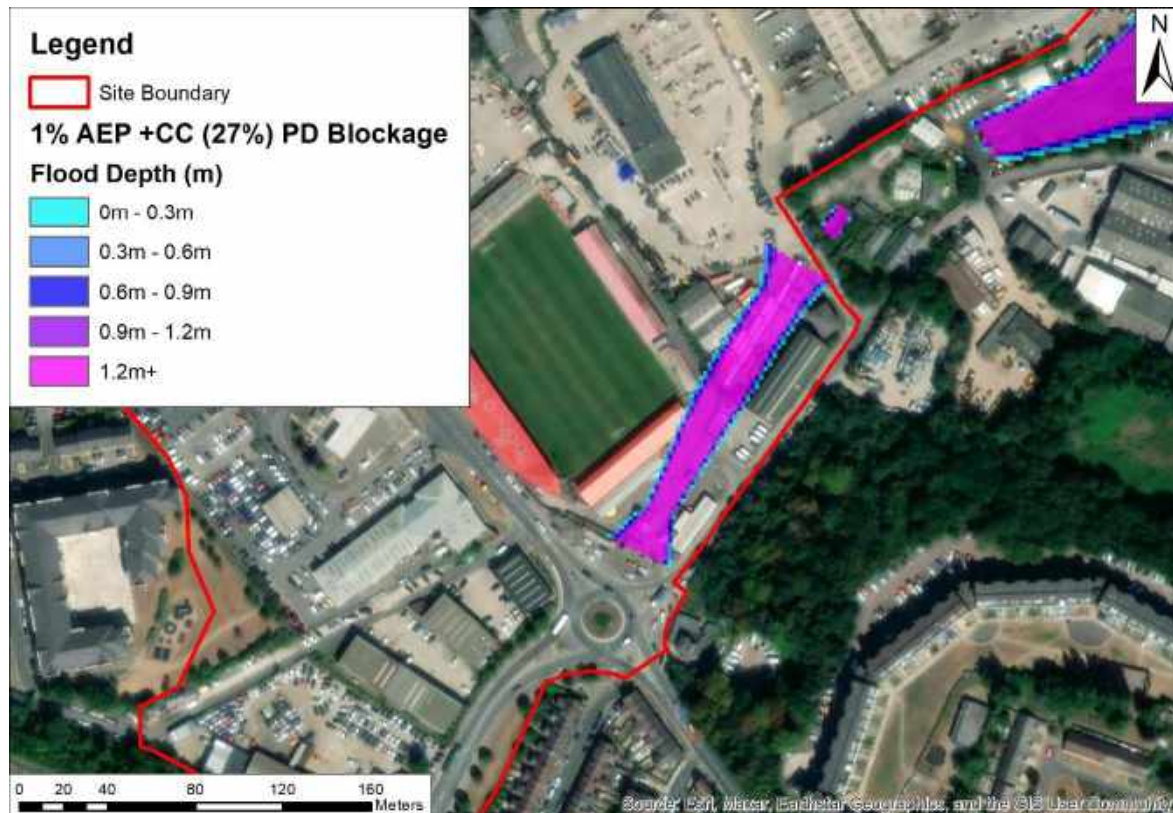


Figure 6-5: Modelled flood depth blockage scenario

The results were somewhat surprising, so it was decided to undertake an alternative approach to represent blockage of the structure to confirm that the use of the trash screen attribute within the inlet unit wasn't erroneous. The culvert diameter is 1.578m which has an opening area of 1.95m². To provide a 50% blockage, the opening area needed to be reduced by 50% and therefore, the culvert diameter has been reduced to 1.1m which constitutes an opening area of 0.95m². This alternative approach to blockage has been referred to as "BLK2".

Table 6-1 shows the modelled water levels at three nodes within the daylighted reach comparing the two approaches to blockage against the post-development daylighted scenario. The application of blockage is resulting in a 5mm increase in water levels through the daylighted reach.

Table 6-1: Blockage analysis daylighted reach water levels (mAOD)

	PD	PD_BLK	PD_BLK2
DAYBB	3.863	3.868	3.868
DAYFF	3.863	3.868	3.868
DAYII	3.863	3.868	3.868

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Analysis of the results have shown that the reduction in opening area of the culvert due to the application of 50% blockage is not having a significant impact on water levels through the daylighted reach and doesn't result in any out of bank flooding. This appears to have occurred due to a combination of the of tide locking on the River Ebbsfleet watercourse which limits the discharge of the River Ebbsfleet, and the constriction of the culverted unit located further downstream (1.005C_1) which acts as a control on water levels upstream. Even with blockage applied to the culvert at the downstream end of the daylighted reach, the structure 1.005C_1 is more of a constriction to flow.

7 Assumptions, limitations, and uncertainties

7.1 Summary of key assumptions, limitations, and uncertainties

Developing a hydraulic model requires the application of simplifications and generalisations. As such, several assumptions were made when building the model. This can lead to model uncertainties and subsequent limitations in the results. Some of the key assumptions, limitations, and uncertainties specific to this study are listed below:

- Hydrology
 - The level / flow gauge located at the entrance to the long culvert is closed and the data is not useful to this study (based on the 2015 study assessment).
 - There is no benefit to continued use of the groundwater level input at the upstream model extent (and conversion to flow in the model) due to numerous limitations to this approach. A fluvial inflow applied to the upstream model extent, varying with design event, is reasonable and no more uncertain than the previous approach.
 - There is insufficient confidence in local gauges being representative for QMED (median annual maximum flood) data transfer. Catchment descriptor estimates are most appropriate due to this.
 - One pooling group to represent growth curves at all locations is appropriate.
 - ReFH2 generates a reasonable hydrograph for EBB03 despite any influence of Sawyer's Lake not being accounted for by this method as the watercourse and lake are not included within the hydraulic model.
 - The main limitation is the lack of a flow gauge on the study watercourse with which to improve and check the derived estimates. There is no level gauge against which modelled levels could be compared. Lack of detailed flood history information also limits the ability to verify the hydraulic model results based on the derived model inflows.
- Two bridges across the watercourse could not be represented within the model as they were not surveyed as part of the 2013 survey dataset.
 - Springhead Park Bridge which appears to have been constructed after the 2013 survey and 2015 model were completed.
 - The railway bridge across Thames Way and the River Ebbsfleet located between Ebbsfleet International and Sawyers Lake.

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In both cases, examination of available LiDAR data, photographs and aerial imagery indicates both bridge decks are likely to be located at much higher elevations than the watercourse and it has therefore been assumed that the bridge soffit levels are likely to have minimal impact on water levels in the modelled events. This could not be confirmed and the omission of these structures from the model has been noted here as a limitation.

- Internal survey of the long culvert that it is proposed to partially daylight was not available. The path, connectivity and any changes in shape or dimensions are therefore unconfirmed and may not be fully accounted for within the model. The culvert representation has, however, been improved from the 2015 model as it makes use of the available invert level survey data from cover lifting undertaken as part of the 2013 survey. Topographical survey was collected in 2023 by Reed Geomatics which including lifting the manhole covers of the long culvert. Cover level and silted bed level were collected and, although this information was not used directly within the model, it has been used to sense check the 2013 survey which provides added confidence in its use. The 2023 topographical survey data can be found in Appendix C.
- A second outfall to Robin's Creek was identified from survey photographs close to the outfall of the long culvert. The connectivity and path of this additional connection to Robins Creek could not be confirmed based on the available survey data and may require further investigation as part of any detailed design stage.
- Some oscillations in 1D water levels occur around model node 1.011 and adjacent interpolate sections in some events. This appears to be linked to circulating flow in the 2D domain that re-enters the 1D domain. Attempts have been made to address this using interpolate sections, but the topography is very low-lying and the schematisation of the 1D-2D linkage at this section should be considered a limitation. Following the Environment Agency review, further updates have been made to this reach including additional interpolates, the addition of HX energy loss, and the realignment of the 2d_loc line. The reposition of the 2d_loc resulted in the TUFLOW ME% exceeding 6% which was deemed to be unacceptable. Therefore, the original 2d_loc line has been retained.
- Flood Modeller reports high mass error and poor model convergence at a number of model nodes in particular upstream of the Thames Way road bridge at sections between 1.011 and 1.010. The issue through this reach seems to be a 1D-2D linkage problem with recirculating water in the 2D domain, re-entering and leaving the 1D domain causing oscillations in both the 1D and 2D water levels through this reach. As noted previously, several measures have been adopted to help address these issues through additional interpolate sections, HX energy loss, and reorientation of the 2D location line. Unfortunately, these issues remain for the final design event simulations. Importantly, the 1D water level results through the daylighted reach are considered stable and given this section is the primary interest for this flood modelling study, then this has been treated as an acceptable limitation but should be noted for any future users of the model.
- No 2D negative depths occur which indicates a reasonable degree of stability in the 2D domain. The peak cumulative mass error is, however, outside the recommended range of $\pm 1\%$ in the 1% and 0.1% AEP events, and the 1% AEP event plus climate change scenario, at around -2% to -2.75% and occurs through the flood peak.

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- This high mass error appears to result from recirculation in the 2D domain within the very confined and relatively low elevation areas around the Thames Way Road embankments between sections 1.010 and 1.015. A realignment of grid orientation, addition of interpolate sections and HX energy loss A Flag of 0.5 were applied which reduced the impact of this issue, which was causing model failure, but could not be fully resolved.
- The combination of the tidal outfall arrangement and tidal boundary conditions result in the watercourse being tidally locked through most of the event length, with only short periods where water is able to drain from the outfall. As a result, water levels drain very slowly through the simulation; however, the use of the relatively long 31-hour storm duration and 96hr event simulation allows for this mechanism to be represented.
- For the updated model iteration 056 managed realignment scenario, 1% AEP plus climate change event (27%) has had the max iterations increased from 17 to 29. This event went unstable after the peak of the event at the time of the tidal trough. The increase of the max iterations was deemed to be an appropriate measure to get this event to run through to completion but should be noted for any future users of the model.
- The Environment Agency review noted two nodes with short spacing. Node 1.008 is required due to the short channel reach at this location but 1.013 could have been removed. However, it was decided not to remove this as the instabilities noted within the model are not associated with this section and are instead related to the reach downstream.
- The Environment Agency review highlighted that the model has adopted a matrix Dummy coefficient of 0.0001 which is not default. This is a remnant of the original Environment Agency model. A series of test simulations have been completed with this set to 0 (default) but this caused some of the design events to crash and therefore the 0.0001 has been retained for the final model simulations. This is considered an acceptable limitation necessary for the model to run through to completion.
- The updates applied to the model following the Environment Agency review have resulted in an increase in water levels in comparison to the REVB model submission. The changes have also led to additional stability problems, in particular with the reach upstream of the Thames Way Road embankment. Analysis of the 1D water level through the reach upstream of node 1.009, shows oscillations at the time of peak water level. Importantly, this instability does not propagate downstream and therefore the water levels through the daylighted reach are stable and this can be considered an acceptable limitation.
- The Environment Agency review queried the representation of the structure at 1.009 as this has been represented using a USBPR bridge unit, though given its length, could have been modelled as a culvert unit. A bridge unit doesn't account for the length of the structure which in this case is 22m. As such, the available storage volume associated with this structure hasn't been fully accounted for within the hydraulic model and is therefore considered a conservative approach. This has been discussed with the Environment Agency and it was agreed that there is no need to complete additional testing of the schematisation of this structure.

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- At the outlet to Robins Creek, there is a pipe outfall that is raised above the open channel bed elevation. To account for the drop in elevation within the model, a spill unit has been applied with a weir coefficient of 1.2 used. The Environment Agency review noted that this was on the low side and testing a higher weir coefficient may be appropriate. The current representation is considered conservative, and the use of a higher weir coefficient will only increase discharge into Robins Creek, thereby reducing water levels upstream. Therefore, it has been agreed with the Environment Agency that no further sensitivity testing of the outfall weir coefficient is required.
- The Environment Agency review noted the presence of Sawyer Lake which is an offline body of water. This is not directly connected to River Ebbsfleet within the hydraulic model and is therefore not having a significant influence on the assessment of flood risk. Within some of the design even simulations, the water level within the River Ebbsfleet is sufficient to cause spilling into the lake due to overtopping of the access road the runs along the northern and eastern boundary of the lake. Therefore, the lake provides some storage within the largest design events.

TECHNICAL NOTE

JBA Project Code	2022s1459
Contract	Northfleet Flood Modelling
Client	RMA Environmental Ltd
Date	05/02/2023
Author	Paul Redbourne BSc, PGCert, MCIWEM, C.WEM
Reviewer / Sign-off	Jenni Essex BSc MSc PhD CEnv MCIWEM C.WEM
Subject	Northfleet Flood Modelling Technical Note - REVD

8 Model runs

8.1 Baseline scenario

Run reference	Baseline - EBB1_~e1~_~s1~_055
Purpose of runs:	Baseline scenario to model the 3.33%, 1%, 1% plus climate change (27%, 37%, & 62%) and 0.1% AEP events
TUFLOW file names:	EBB1_~e1~_~s1~_053.tcf EBB_BSL_055.tgc EBB_BSL_053.tbc
Run time:	Simulation time: 96 hours
Flood Modeller file names:	EBB1_1s_2D_JPgW_053BL.DAT EBB1_ReFH2_XX_31hr_MHWS_038.ied EBB1_ReFH2_0030_31hr_MHWS_055BL.ief
Run settings:	TUFLOW version: 2023-03-AA-iSP-w64 Flood Modeller version: VER= 5.1.0.8423

8.2 Daylighted post-development scenario

Run reference	Daylighted PD - EBB1_~e1~_~s1~_056_PD1
Purpose of runs:	Daylighted scenario to model the 3.33%, 1%, 1% plus climate change (27%, 37%, & 62%) and 0.1% AEP events
TUFLOW file names:	EBB1_~e1~_~s1~_056_PD1.tcf EBB_PD1_056.tgc EBB_PD1_054.tbc
Run time:	Simulation time: 96 hours
Flood Modeller file names:	EBB1_1s_2D_JPgW_054PD1.DAT EBB1_ReFH2_XX_31hr_MHWS_038.ied EBB1_ReFH2_XX_31hr_MHWS_056PD1.ief
Run settings:	TUFLOW version: 2023-03-AA-iSP-w64 Flood Modeller version: VER= 5.1.0.8423

TECHNICAL NOTE

JBA Project Code	2022s1459
Contract	Northfleet Flood Modelling
Client	RMA Environmental Ltd
Date	05/02/2023
Author	Paul Redbourne BSc, PGCert, MCIWEM, C.WEM
Reviewer / Sign-off	Jenni Essex BSc MSc PhD CEnv MCIWEM C.WEM
Subject	Northfleet Flood Modelling Technical Note - REVD

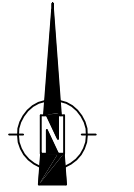
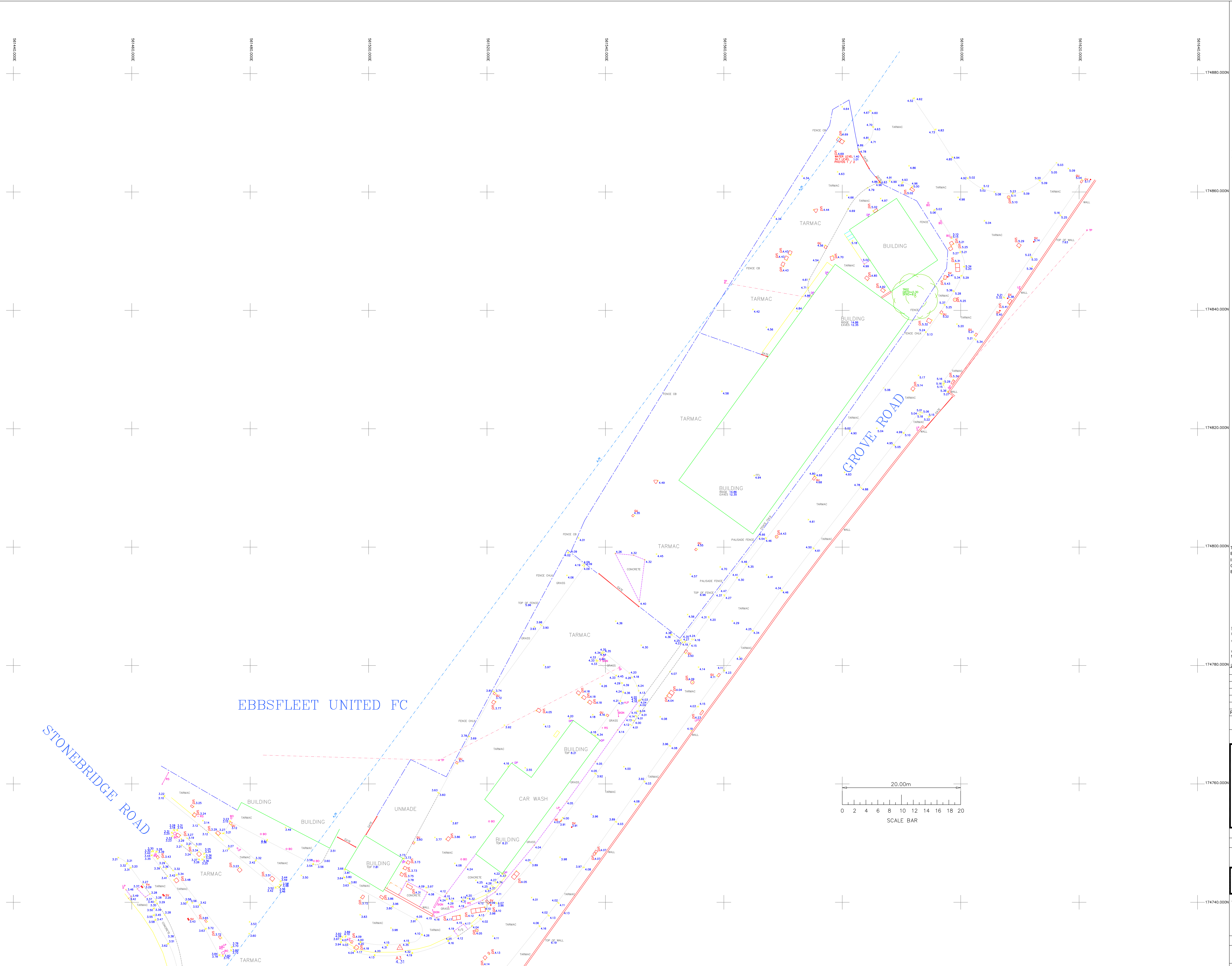
8.3 Managed realignment scenario

Run reference	Managed Realignment PD - EBB1_~e1~_~s1~_056_PD1_MR
Purpose of runs:	Daylighted scenario to model the 3.33%, 1%, 1% plus climate change (27%, 37%, & 62%) and 0.1% AEP events
TUFLOW file names:	EBB1_~e1~_~s1~_056_PD1_MR.tcf EBB_PD1_056_MR.tgc EBB_PD1_054_MR.tbc
Run time:	Simulation time: 96 hours
Flood Modeller file names:	EBB1_1s_2D_JPgW_054PD1_MR.DAT EBB1_ReFH2_XX_31hr_MHWS_049_MR.ied EBB1_ReFH2_XX_31hr_MHWS_056PD1_MR.ief
Run settings:	TUFLOW version: 2023-03-AA-iSP-w64 Flood Modeller version: VER= 5.1.0.8423

8.4 Blockage scenario

Run reference	Blockage PD - EBB1_~e1~_~s1~_056_PD1_BLK EBB1_~e1~_~s1~_056_PD1_BLK2
Purpose of runs:	Daylighted scenario with blockage applied to model the 1% plus climate change (27%) AEP event.
TUFLOW file names:	EBB1_~e1~_~s1~_056_PD1_BLK.tcf EBB1_~e1~_~s1~_056_PD1_BLK2.tcf EBB_PD1_056.tgc EBB_PD1_054.tbc
Run time:	Simulation time: 96 hours
Flood Modeller file names:	EBB1_1s_2D_JPgW_054PD1_BLK.DAT EBB1_1s_2D_JPgW_054PD1_BLK2.DAT EBB1_ReFH2_XX_31hr_MHWS_038.ied EBB1_ReFH2_XX_31hr_MHWS_056PD1_BLK.ief EBB1_ReFH2_XX_31hr_MHWS_056PD1_BLK2.ief
Run settings:	TUFLOW version: 2023-03-AA-iSP-w64 Flood Modeller version: VER= 5.1.0.8423

Appendix I: Culvert Survey



Building Abbreviations			
BL	Basement Level	HD	Heating Duct
BH	Beam Soffit Height	H	Height
BSL	Beam Soffit Level	RWP	Rain Water Pipe
C	Cill Height from FFL	SL	Soffit Level
CP	Down Pipe	SVP	Soil and Vent Pipe
DPC	Damp Proof Course	VP	Vent Pipe
DH	Door Height	W	Window Height from cill
DHL	Door Head Level	W	Window Height from cill
FFL	Finished Floor Level	W	Window Height from cill
FCL	Floor to Ceiling Height	C Level	C Level
(25.25)	or Ceiling Level	H Level	Window Head Level
CH	Ceiling Height	-----	Detail Approx.
		CSU	Ceiling slopes up
		F-H	Floor - Window head Ht

Topographical Abbreviations			
A/R	Assumed Route	MKR	Marker
BH	Borehole	MT	Mercury Telecom Cover
BCL	Bollard	OHC	Overhead Cable
BT	British Telecom Cover	OHP	Overhead Pipe
BW	Barbed Wire Fence	OSBM	Ordnance Survey Bench Mark
BWK	Brickwork	PB	Post Box
CATV	Cable TV Cover	PGM	Permanent Ground Marker
CB	Close Boarded Fence	PR	Post & Rail Fence
CCTV	Closed Circuit TV	PW	Post & Wire Fence
CHLK	ChainLink Fence	PWM	Post & Wire Mesh Fence
CHPL	Chestnut Palling Fence	RE	Road Eye
CL	Cover Level	RG	Road Gully
CM	Cable Marker	RN	Road Name
CP	Catch Pit	RS	Road Sign
CPL	Catch Pit Base Level	RW	Retaining Wall
DIA	Diameter	RWP	Rain Water Pipe
DK	Drop Kerb	SAP	Sapping
DP	Down Pipe	SC	Stop Cock
EJB	Electricity Junction Box	SPR	Spread
EC	Electricity Cover	STA	Traverse Station
EP	Electricity Pole	SV	Stop Valve
ER	Earning Road	SVP	Soil Vent Pipe
FH	Fire Hydrant	SW	Storm Water
FIG	Feed Into Ground	TB	Telephone Box
FW	Foul Water	TBM	Temporary Bench Mark
GU	Gully	TFR	Taken From Records
H	Height	THL	Threshold Level
GV	Gas Valve	TJB	Telephone Junction Box
I	Inspection Cover	TPT	Trial Pit
IL	Invert Level	TL	Traffic Light
IR	Iron Railing Fence	TP	Telephone Pole
KO	Kerb Outlet	UTL	Unable To Lift
LS	Litter Bin	UTT	Unable To Trace
LC	Lamp Column	VP	Vent Pipe
LP	Lamp Post	WCH	Water Key Hole
MH	Marmole	WM	Water Meter
		WV	Water Valve
		---	Approximate

THIS SURVEY DATA HAS BEEN PREPARED FOR THE CLIENT DETAILED BELOW TO AN AGREED SPECIFICATION. UNLESS OTHERWISE AGREED IN WRITING THE LIABILITY OF REED GEOMATICS LTD IS LIMITED TO THE CLIENT OR HIS APPOINTED AGENT AND DOES NOT EXTEND TO USE BEYOND THE LIMITATIONS OF THE SPECIFICATION.

Survey Station Information				
STN No.	Easting	Northing	Level	Type
STN A1	561406.395	174605.654	3.01	Nail
STN A2	561456.388	174704.765	4.23	Nail
STN A3	561505.283	174732.302	4.31	Nail

Notes
G.S.D. Survey is based on a modified Ordnance Survey National Grid (OSGB36), site centered (or centered on STN A1 where present) with a scale factor of 1 applied.

Values have been derived via GPS using the OS active network using the OSGM15 transformation and OSGM15 geoid model.

Level datum: Ordnance Datum Newlyn (ODN)		
5	-	-
4	-	-
3	-	-
2	-	-
1	-	-
0	GR	First Complete Issue
Prelim	-	Preliminary - Not Complete
Rev	QA	Check
Check	Description	Date

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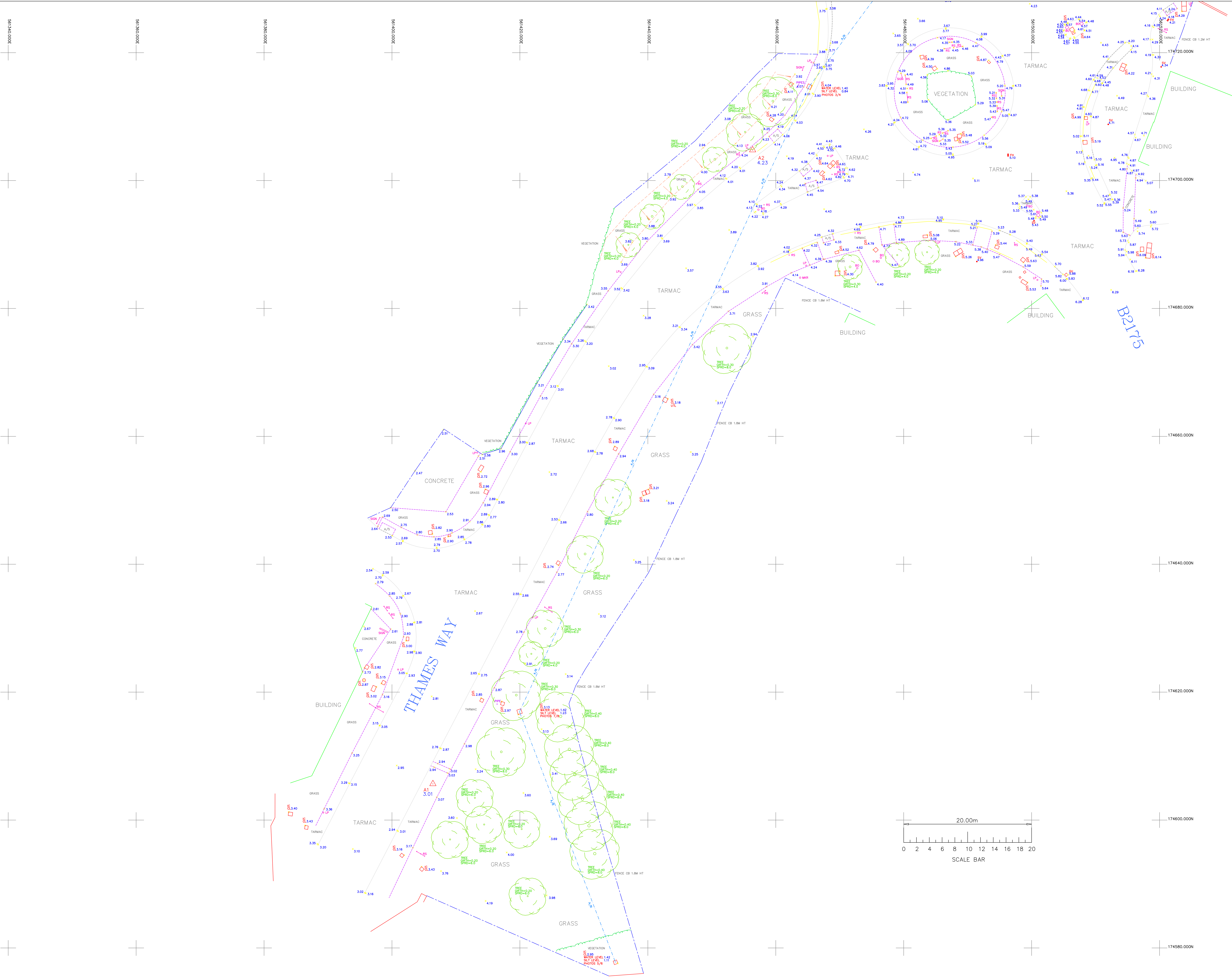
CELL 07939 100008
www.reedgeomatics.com

SURVEYED	TR	CLIENT:
DRAWN	TR	Northfleet Central 1 Ltd
SCALE	1:200	

TOPOGRAPHICAL SURVEY

ADDRESS: **RIVER EBBSFLEET
NORTHFLEET
GRAVESEND
DA11 9GN**

JOB No	DRAWING NUMBER
RG23 2575	01
A0 Sheet	



Building Abbreviations			
BL	Basement Level	HD	Heating Duct
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5	-	-	-
4	-	-	-
3	-	-	-
2	-	-	-
1	-	-	-
0	GR	First Complete Issue	25-04-2023
Prelim	-	Preliminary - Not Complete	-
Rev	QA	Description	Date
Check			

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SURVEYED	TR	CLIENT:
DRAWN	TR	Northfleet Central 1 Ltd.
SCALE	1:200	

TOPOGRAPHICAL SURVEY

ADDRESS: **RIVER EBBSFLEET
NORTHFLEET
GRAVESEND
DA11 9GN**

JOB No	DRAWING NUMBER
RG23 2575	02

A0 Sheet





Photo 3



Photo 4



Photo 5



Photo 6

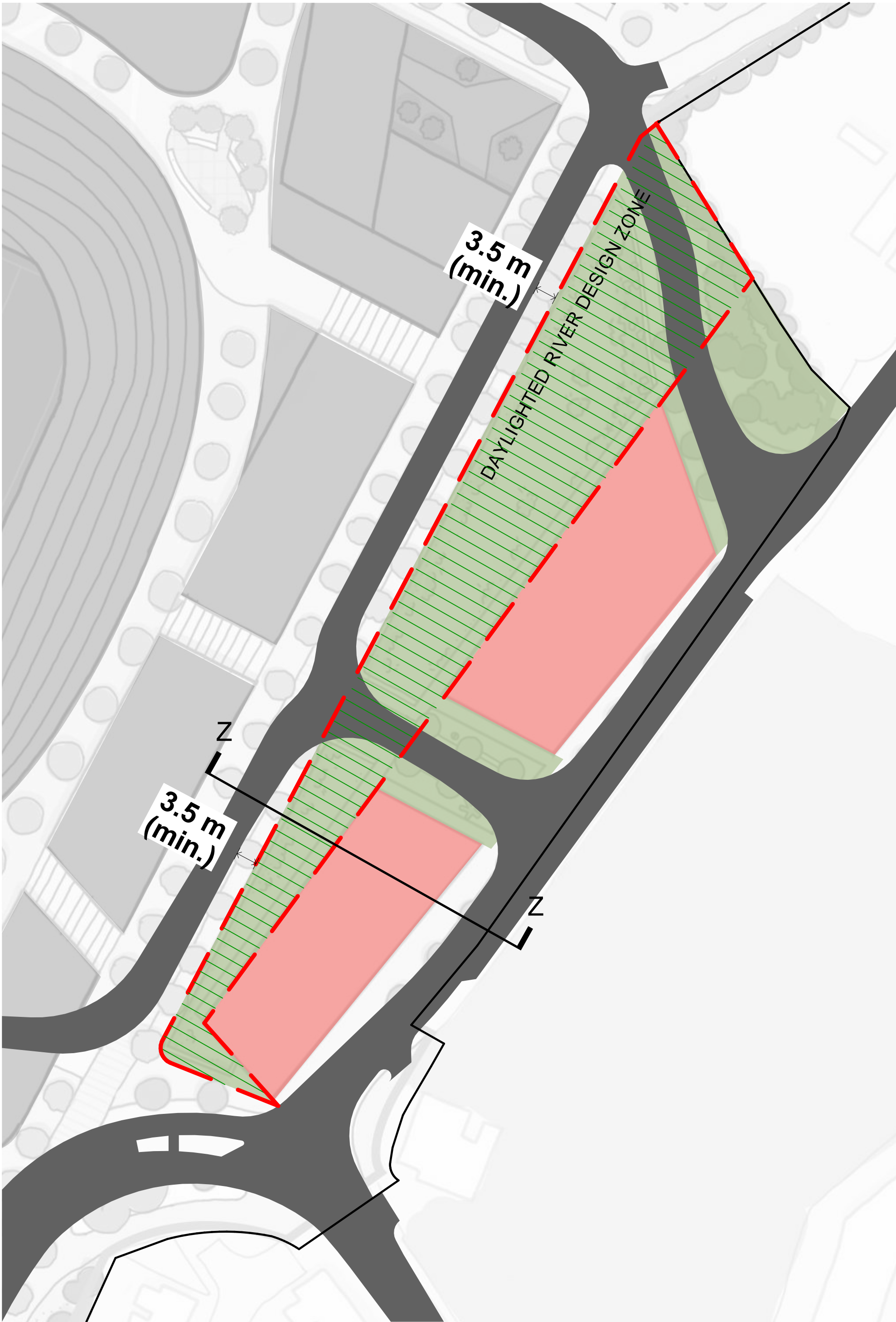


Photo 7



Photo 8

Appendix J: Proposed River Daylighting Options (HLM; 2023)



Notes

Do not scale from this drawing
Report any discrepancies and omissions to
HLM Architects
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R2 Updated Block Parameters	08.04.2024
R1 Updated Highways layout	28.03.2024
Revisions	Suitability
Project	

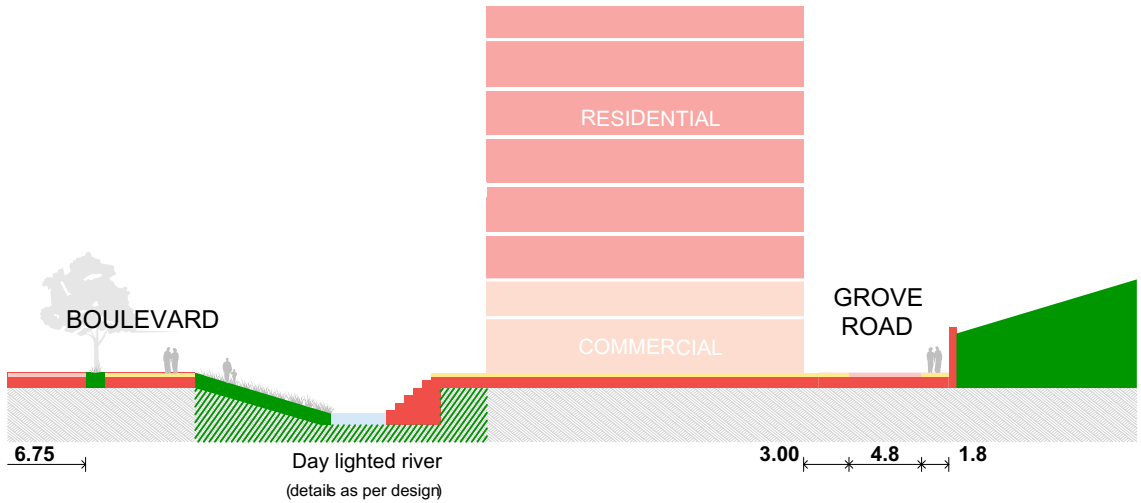
North fle et
Harbourside
Gravesham

Title

Proposed
River Daylighting
Zone

Drawing No.	Revision
A.5	R2

Scale	Drawn
1:250 @A2	HLM
Date	Checked
23.08.2023	HLM



Typical Section ZZ @ 1:500

-  Proposed daylighted river design zone
-  Proposed built form



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Appendix K

Surface Water Drainage Strategy

PURPOSE

The purpose of this Design Statement is to describe how the surface water drainage strategy for the proposed development at Northfleet Harbourside will manage runoff in a manner that will mitigate the risk of flooding and pollution to the environment.

SCOPE

This design addresses runoff from all areas within the planning application boundary.

DESIGN CONSTRAINTS

A ground investigation has yet to be carried out, therefore a precautionary approach has been adopted and it has been assumed that infiltration will not be feasible. It is proposed to carry out percolation tests in accordance with BRE365 prior to commencement of the detailed design.

The site lies at the confluence of the tidal River Thames and the River Ebbsfleet. The Environment Agency's 2015 report Flood Map Improvements: Ebbsfleet used the highest astronomical tide (HAT) level of 3.98mAOD to establish flood risk zones. Since it is proposed to discharge runoff in the vicinity of the confluence, it is necessary to allow for the constraint high tides will have on outflows from the site. This has been done by developing a tidal hydrograph based on HAT, mean low water springs (MLWS) and the rule of twelfths – refer to calculation 2 in Appendix B

A large proportion of the site is below HAT. Therefore, a precautionary approach has been adopted and it has been assumed that a pumped discharge will be required for these areas.

Information received from Southern Water shows only a limited network of public surface water sewers within the area. It is likely that many of the sites along the frontage of the Thames and Ebbsfleet discharge directly to these watercourses without attenuation. Given the scale of works proposed, including the construction of a new vehicular tunnel it is probable that most, if not all of the public sewer network within the site will need to be replaced.

The Lead Local Flood Authority has advised that (subject to infiltration not being feasible) it will accept an unrestricted discharge to the River Ebbsfleet.

DESIGN STANDARDS

The proposed surface water drainage system is to be designed to ensure that all runoff from the 100year rainfall event plus a 40% increase in rainfall intensity is managed in accordance with DEFRA's Technical Standards for Sustainable Drainage Systems.

DESIGN - STRATEGY

It is proposed to incorporate a range of SuDS features within the drainage strategy:

- Runoff from the roofs of residential buildings will be harvested and re-used, thereby reducing discharge to sewers.
- Runoff from podium areas will be attenuated in low-profile attenuation tanks (e.g. RoofBloxx by ACO).
- Runoff from the roof of the football stadium will be captured for re-use in a low-profile tank beneath the pitch.
- All other buildings will be provided with green roofs incorporating low-profile attenuation tanks.
- Park areas will be profiled to provide attenuation for rainfall events in excess of the 30year return period rainfall event.

The proposed drainage strategy is shown on drawing DR-001 in Appendix A. It can be seen that the site has been divided into three sub-catchments as shown on drawing DR-001:

- Sub-catchment A includes much of the west of the site. It is relatively low-lying with most of its area below HAT (3.98mAD)
- Sub-catchment B includes the eastern edge of the site adjacent to the Thames. Ground levels in this area are also below HAT.
- Sub-catchment C lies between A and B. Ground levels are generally above 4.2mAD.

It will be necessary to pump the discharge from sub-catchments A & B to Robins Creek. Runoff from sub-catchment C can gravitate to Robins Creek via a swale.

Treatment Design

The pollution treatment requirements for the site have been established using the Simple Index Approach set out in Table 26.1 of the SUDS Manual.

Pollution hazard levels have been derived from Table 26.2 and are shown in the following table.

Land Use	Pollution Hazard Level	Total Suspended Solids (TSS)	Metals	Hydro-Carbons
Roofs	Low	0.3	0.2	0.05
Low-traffic roads	Low	0.5	0.4	0.4
Other roads	Medium	0.7	0.6	0.7

Table 1 – Pollution Hazard Indices

The following forms of treatment will be provided:

- Parking spaces will be constructed of permeable paving
- Low-traffic roads will be constructed of permeable paving or drain to tree pits or swales;
- Other roads will drain to tree pits or swales;

The treatment parameters for the above forms of treatment are shown in the following table.

Treatment	Total Suspended Solids (TSS)	Metals	Hydro- Carbons
Permeable paving	0.7	0.6	0.7
Swale	0.5	0.6	0.6
Tree pit	0.8	0.8	0.8

Table 2 – Proposed SuDS Mitigation Indices

Compliance with Technical Standards for Sustainable Drainage Systems

The following sections describe how the proposed surface water drainage system meets the requirements of the DEFRA document Non-Statutory Technical Standards for Sustainable Drainage Systems.

S1 *Where the drainage system discharges to a surface water body that can accommodate uncontrolled surface water discharges without any impact on flood risk from that surface water body (e.g. the sea or a large estuary) the peak flow control standards (**S2** and **S3** below) and volume control technical standards (**S4** and **S6** below) need not apply*

There are no water bodies in the vicinity of the proposed development that are capable of accommodating uncontrolled runoff without increasing flood risk.

S2 *For greenfield developments, the peak runoff rate from the development to any highway drain, sewer or surface water body for the 1 in 1 year rainfall event and the 1 in 100 year rainfall event should never exceed the peak greenfield runoff rate for the same event.*

Not applicable – brownfield site.

S3 *For developments which were previously developed, the peak runoff rate from the development to any drain, sewer or surface water body for the 1 in 1 year rainfall event and the 1 in 100 year rainfall event must be as close as reasonably practicable to the greenfield runoff rate from the development for the same rainfall event, but should never exceed the rate of discharge from the development prior to redevelopment for that event.*

The inclusion of the following features will significantly reduce the amount of impermeable area within the site, which will in turn reduce the peak runoff rate.

- two large parks (3.08ha – 17% of site area)
- green roofs (1.32ha – 7% of site area)
- Rain water harvested roofs (1.45ha – 8% of site area).

The final rate of discharge will be determined on completion of the design of the proposed pumping stations. The rate will be a compromise between the attenuation storage required and the capacity of the pumps.

S4 *Where reasonably practicable, for greenfield development, the runoff volume from the development to any highway drain, sewer or surface water body in the 1 in 100 year, 6 hour rainfall event should never exceed the greenfield runoff volume for the same event.*

Not applicable – brownfield site.

S5 *Where reasonably practicable, for developments which have been previously developed, the runoff volume from the development to any highway drain, sewer or surface water body in the 1 in 100 year, 6 hour rainfall event must be constrained to a value as close as is reasonably practicable to the greenfield runoff volume for the same event, but should never exceed the runoff volume from the development site prior to redevelopment for that event.*

The inclusion of the areas described in S3 above will result in a significant decrease in the volume of runoff from the site.

S6 *Where it is not reasonably practicable to constrain the volume of runoff to any drain, sewer or surface water body in accordance with **S4** or **S5** above, the runoff volume must be discharged at a rate that does not adversely affect flood risk.*

Not applicable – compliant with S5.

S7 *The drainage system must be designed so that, unless an area is designated to hold and/or convey water as part of the design, flooding does not occur on any part of the site for a 1 in 30 year rainfall event.*

It is proposed to design the parks such that they will not flood during the 1 in 30year event, but will act as strategic storage areas for more severe rainfall events.

The drainage system will be designed such that there will be no flooding for all events up to the 100year +40%.

MicroDrainage calculations for typical drainage features are included in Appendix B.

S8 *The drainage system must be designed so that, unless an area is designated to hold and/or convey water as part of the design, flooding does not occur during a 1 in 100 year rainfall event in any part of: a building (including a basement); or in any utility plant susceptible to water (e.g. pumping station or electricity substation) within the development.*

See S7 above.

S9 *The design of the site must ensure that, so far as is reasonably practicable, flows resulting from rainfall in excess of a 1 in 100 year rainfall event are managed in exceedance routes that minimise the risks to people and property.*

Refer to Designing for Exceedance Section in the main body of the report.

S10 *Components must be designed to ensure structural integrity of the drainage system and any adjacent structures or infrastructure under anticipated loading conditions over the design life of the development taking into account the requirement for reasonable levels of maintenance.*

The drainage system will be located beyond the zone of influence of adjacent foundations. This will allow for the replacement of the drainage system without the need for special support.

S11 *The materials, including products, components, fittings or naturally occurring materials, which are specified by the designer must be of a suitable nature and quality for their intended use.*

The surface water system will be designed in accordance with the SuDS Manual. The design will allow for replacement of component parts without long-term detriment to the performance of the system.

S12 *Pumping should only be used to facilitate drainage for those parts of the site where it is not reasonably practicable to drain water by gravity.*

Due to the low-lying nature of sub-catchments A & B it will be necessary to pump runoff from these areas.

S13 *The mode of construction of any communication with an existing sewer or drainage system must be such that the making of the communication would not be prejudicial to the structural integrity and functionality of the sewerage or drainage system.*

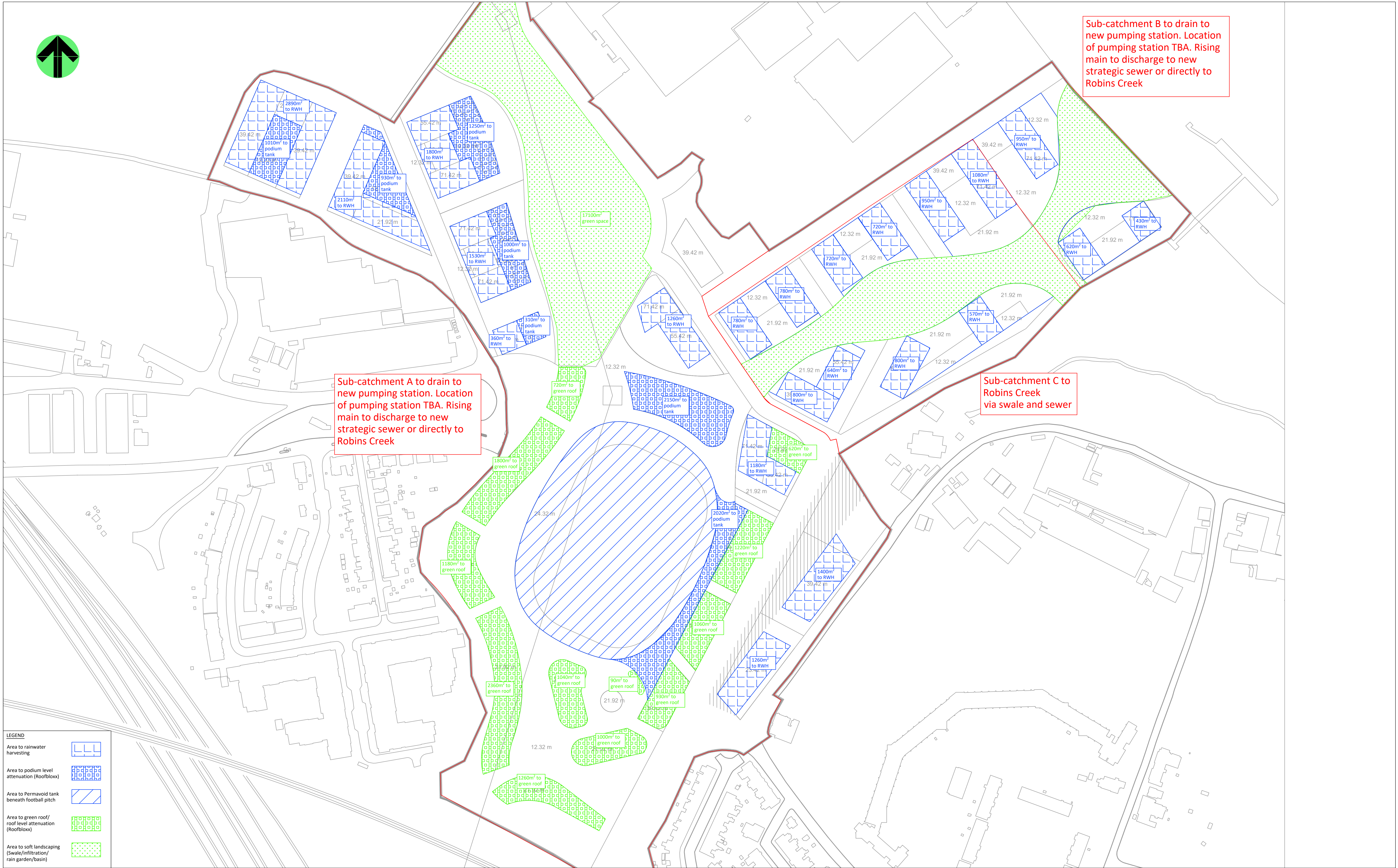
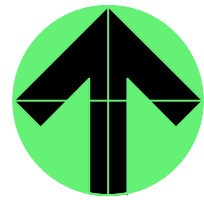
It is likely that the existing drainage systems will need to be replaced. The only communications are likely to be the outfalls to Robins Creek. This work will be carried out in accordance with the relevant permits and licenses.

S14 *Damage to the drainage system resulting from associated construction activities must be minimised and must be rectified before the drainage system is considered to be completed.*

See S13 above.

APPENDIX A DRAWINGS

DR-001 Surface Water Drainage Strategy



Sub-catchment B to drain to new pumping station. Location of pumping station TBA. Rising main to discharge to new strategic sewer or directly to Robins Creek

Sub-catchment A to drain to new pumping station. Location of pumping station TBA. Rising main to discharge to new strategic sewer or directly to Robins Creek

Sub-catchment C to Robins Creek via swale and sewer

LEGEND

Area to rainwater harvesting

Area to podium level attenuation (Roofbloxx)

Area to Permavoid tank beneath football pitch

Area to green roof/ roof level attenuation (Roofbloxx)

Area to soft landscaping (Swale/infiltration/ rain garden/basin)

NOTES
1. This drawing to be read in conjunction with the FRA report (RMA - September 2022).

REV	DATE	DESCRIPTION
A	22.09.2022	Initial issue
B	28.03.2024	Layout plan updated
C	10.04.2024	Layout plan updated
CLIENT:		

PROJECT: NORTHFLEET HARBOURSIDE		
TITLE: SURFACE WATER DRAINAGE STRATEGY		
REV: C	PROJECT No: 0622	DRAWING No: DR-001
SCALE @ A1: 1:1250		

DESIGN BY:

APPENDIX B

CALCULATIONS

1. Sub-catchments A & B
2. Sub-catchment C

1. Sub-catchments A & B

The calculations on the following pages have been provided to give an indication of the attenuated runoff rate from the following features that are to be included in the drainage strategy:

- Green roof (1,200m²)
- Green roof (2,360m²)
- Podium roof (1,000m²)
- Podium roof (2,150m²)
- Park (17,100m²)
- Football stadium (18,900m²)

The calculations show that the peak rate of discharge for the 100yr+40% rainfall event can be reduced to the following, whilst ensuring that the 50% drain down time for each attenuation feature is less than 24hrs.

- Green roof (1,200m²) = 0.8l/s
- Green roof (2,360m²) = 1.7l/s
- Podium roof (1,000m²) = 0.7l/s
- Podium roof (2,150m²) = 1.6l/s
- Park (17,100m²) = 10l/s
- Football stadium (18,900m²) = 15l/s

The following table provides a comparison of greenfield, existing, and proposed rates.

Feature	Greenfield Rate (100yrs) l/s	Existing Rate (100yrs) l/s	Proposed Rate (100yrs+40%) l/s	Reduction %
Green roof (1,200m ²)	0.8	66.3	0.8	98.7
Green roof (2,360m ²)	1.6	129.9	1.7	98.7
Podium roof (1,000m ²)	0.7	55.3	0.7	98.7
Podium roof (2,150m ²)	1.5	119.3	1.6	98.7
Park (17,100m ²)	11.9	931.2	10.0	98.9
Football stadium (18,900m ²)	13.2	490.7 (excludes pitch)	15.0	96.9

Runoff from areas not shown above would drain to a strategic attenuation tank adjacent to a pumping station serving each sub-catchment. The size of the pumping stations and tanks will be determined as part of the detailed design process.

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Summary of Results for 100 year Return Period (+40%)

Half Drain Time : 1402 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	9.867	0.032	0.0	0.2	0.2	31.6	Flood Risk
30 min Summer	9.879	0.044	0.0	0.4	0.4	42.4	Flood Risk
60 min Summer	9.890	0.055	0.0	0.5	0.5	53.9	Flood Risk
120 min Summer	9.904	0.069	0.0	0.6	0.6	67.5	Flood Risk
180 min Summer	9.913	0.078	0.0	0.6	0.6	75.6	Flood Risk
240 min Summer	9.918	0.083	0.0	0.7	0.7	81.0	Flood Risk
360 min Summer	9.925	0.090	0.0	0.7	0.7	87.3	Flood Risk
480 min Summer	9.928	0.093	0.0	0.7	0.7	90.1	Flood Risk
600 min Summer	9.929	0.094	0.0	0.7	0.7	91.3	Flood Risk
720 min Summer	9.929	0.094	0.0	0.7	0.7	91.5	Flood Risk
960 min Summer	9.928	0.093	0.0	0.7	0.7	90.3	Flood Risk
1440 min Summer	9.925	0.090	0.0	0.7	0.7	87.7	Flood Risk
2160 min Summer	9.922	0.087	0.0	0.7	0.7	84.6	Flood Risk
2880 min Summer	9.919	0.084	0.0	0.7	0.7	81.7	Flood Risk
4320 min Summer	9.913	0.078	0.0	0.6	0.6	76.1	Flood Risk
5760 min Summer	9.908	0.073	0.0	0.6	0.6	71.3	Flood Risk
7200 min Summer	9.904	0.069	0.0	0.6	0.6	67.4	Flood Risk
8640 min Summer	9.901	0.066	0.0	0.6	0.6	64.1	Flood Risk
10080 min Summer	9.898	0.063	0.0	0.5	0.5	61.3	Flood Risk
15 min Winter	9.872	0.037	0.0	0.3	0.3	36.0	Flood Risk
30 min Winter	9.885	0.050	0.0	0.5	0.5	48.2	Flood Risk
60 min Winter	9.898	0.063	0.0	0.5	0.5	61.1	Flood Risk
120 min Winter	9.914	0.079	0.0	0.6	0.6	76.4	Flood Risk
180 min Winter	9.923	0.088	0.0	0.7	0.7	85.6	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	173.460	0.0	14.0	103
30 min Summer	112.490	0.0	20.9	108
60 min Summer	69.747	0.0	39.8	124
120 min Summer	43.014	0.0	51.7	166
180 min Summer	32.102	0.0	58.8	212
240 min Summer	25.923	0.0	63.8	264
360 min Summer	18.962	0.0	70.0	376
480 min Summer	15.013	0.0	73.5	490
600 min Summer	12.462	0.0	75.6	606
720 min Summer	10.673	0.0	76.8	724
960 min Summer	8.322	0.0	77.8	910
1440 min Summer	5.832	0.0	76.4	1128
2160 min Summer	4.092	0.0	105.4	1512
2880 min Summer	3.189	0.0	106.7	1916
4320 min Summer	2.249	0.0	104.8	2732
5760 min Summer	1.766	0.0	124.3	3528
7200 min Summer	1.475	0.0	126.2	4320
8640 min Summer	1.280	0.0	127.5	5080
10080 min Summer	1.139	0.0	127.7	5848
15 min Winter	173.460	0.0	16.7	101
30 min Winter	112.490	0.0	24.8	107
60 min Winter	69.747	0.0	46.1	126
120 min Winter	43.014	0.0	59.2	166
180 min Winter	32.102	0.0	67.1	212

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Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max E Outflow (l/s)	Max Volume (m³)	Status
240 min Winter	9.929	0.094	0.0	0.7	0.7	91.7	Flood Risk
360 min Winter	9.937	0.102	0.0	0.7	0.7	99.0	Flood Risk
480 min Winter	9.940	0.105	0.0	0.8	0.8	102.3	Flood Risk
600 min Winter	9.942	0.107	0.0	0.8	0.8	103.8	Flood Risk
720 min Winter	9.942	0.107	0.0	0.8	0.8	104.2	Flood Risk
960 min Winter	9.941	0.106	0.0	0.8	0.8	103.2	Flood Risk
1440 min Winter	9.937	0.102	0.0	0.7	0.7	99.2	Flood Risk
2160 min Winter	9.932	0.097	0.0	0.7	0.7	94.6	Flood Risk
2880 min Winter	9.928	0.093	0.0	0.7	0.7	90.0	Flood Risk
4320 min Winter	9.919	0.084	0.0	0.7	0.7	81.3	Flood Risk
5760 min Winter	9.911	0.076	0.0	0.6	0.6	74.0	Flood Risk
7200 min Winter	9.905	0.070	0.0	0.6	0.6	68.2	Flood Risk
8640 min Winter	9.900	0.065	0.0	0.6	0.6	63.3	Flood Risk
10080 min Winter	9.896	0.061	0.0	0.5	0.5	59.2	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
240 min Winter	25.923	0.0	72.5	264
360 min Winter	18.962	0.0	79.4	372
480 min Winter	15.013	0.0	83.1	484
600 min Winter	12.462	0.0	85.3	598
720 min Winter	10.673	0.0	86.5	710
960 min Winter	8.322	0.0	87.3	928
1440 min Winter	5.832	0.0	85.1	1174
2160 min Winter	4.092	0.0	120.2	1624
2880 min Winter	3.189	0.0	121.7	2072
4320 min Winter	2.249	0.0	119.6	2940
5760 min Winter	1.766	0.0	142.5	3760
7200 min Winter	1.475	0.0	145.3	4552
8640 min Winter	1.280	0.0	147.3	5352
10080 min Winter	1.139	0.0	148.0	6080

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Rainfall Details

Rainfall Model	FEH
Return Period (years)	100
FEH Rainfall Version	2013
Site Location	GB 561475 174841 TQ 61475 74841
Data Type	Point
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.750
Cv (Winter)	0.840
Shortest Storm (mins)	15
Longest Storm (mins)	10080
Climate Change %	+40

Green Roof

Area (m ³)	1200	Evaporation (mm/day)	3
Depression Storage (mm)	5	Decay Coefficient	0.050

Time (mins) From:	To:	Area (ha)	Time (mins) From:	To:	Area (ha)	Time (mins) From:	To:	Area (ha)	Time (mins) From:	To:	Area (ha)
0	4	0.021806	32	36	0.004403	64	68	0.000889	96	100	0.000179
4	8	0.017854	36	40	0.003605	68	72	0.000728	100	104	0.000147
8	12	0.014617	40	44	0.002951	72	76	0.000596	104	108	0.000120
12	16	0.011968	44	48	0.002416	76	80	0.000488	108	112	0.000098
16	20	0.009798	48	52	0.001978	80	84	0.000399	112	116	0.000081
20	24	0.008022	52	56	0.001620	84	88	0.000327	116	120	0.000066
24	28	0.006568	56	60	0.001326	88	92	0.000268			
28	32	0.005377	60	64	0.001086	92	96	0.000219			

Time Area Diagram

Total Area (ha) 0.000

Time (mins) From:	To:	Area (ha)
0	4	0.000

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Model Details

Storage is Online Cover Level (m) 10.000

Cellular Storage Structure

Invert Level (m) 9.835 Safety Factor 2.0
Infiltration Coefficient Base (m/hr) 0.00000 Porosity 0.90
Infiltration Coefficient Side (m/hr) 0.00000

Depth (m)	Area (m ²)	Inf. Area (m ²)	Depth (m)	Area (m ²)	Inf. Area (m ²)
0.000	1080.0	0.0	0.165	1080.0	0.0

Orifice Outflow Control

Diameter (m) 0.035 Discharge Coefficient 0.600 Invert Level (m) 9.835

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Summary of Results for 100 year Return Period (+40%)

Half Drain Time : 1414 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	9.868	0.033	0.0	0.4	0.4	62.6	Flood Risk
30 min Summer	9.879	0.044	0.0	0.6	0.6	84.3	Flood Risk
60 min Summer	9.891	0.056	0.0	0.8	0.8	106.7	Flood Risk
120 min Summer	9.905	0.070	0.0	1.2	1.2	133.2	Flood Risk
180 min Summer	9.913	0.078	0.0	1.3	1.3	148.9	Flood Risk
240 min Summer	9.918	0.083	0.0	1.4	1.4	159.3	Flood Risk
360 min Summer	9.925	0.090	0.0	1.5	1.5	171.3	Flood Risk
480 min Summer	9.928	0.093	0.0	1.5	1.5	176.6	Flood Risk
600 min Summer	9.929	0.094	0.0	1.5	1.5	178.6	Flood Risk
720 min Summer	9.929	0.094	0.0	1.5	1.5	178.7	Flood Risk
960 min Summer	9.927	0.092	0.0	1.5	1.5	176.4	Flood Risk
1440 min Summer	9.925	0.090	0.0	1.5	1.5	172.1	Flood Risk
2160 min Summer	9.922	0.087	0.0	1.4	1.4	166.8	Flood Risk
2880 min Summer	9.920	0.085	0.0	1.4	1.4	161.7	Flood Risk
4320 min Summer	9.915	0.080	0.0	1.4	1.4	152.0	Flood Risk
5760 min Summer	9.910	0.075	0.0	1.3	1.3	144.0	Flood Risk
7200 min Summer	9.907	0.072	0.0	1.2	1.2	138.0	Flood Risk
8640 min Summer	9.905	0.070	0.0	1.2	1.2	132.9	Flood Risk
10080 min Summer	9.902	0.067	0.0	1.1	1.1	128.6	Flood Risk
15 min Winter	9.872	0.037	0.0	0.4	0.4	71.4	Flood Risk
30 min Winter	9.885	0.050	0.0	0.7	0.7	95.6	Flood Risk
60 min Winter	9.898	0.063	0.0	1.0	1.0	120.7	Flood Risk
120 min Winter	9.914	0.079	0.0	1.3	1.3	150.4	Flood Risk
180 min Winter	9.923	0.088	0.0	1.5	1.5	168.3	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	173.460	0.0	21.5	107
30 min Summer	112.490	0.0	34.3	113
60 min Summer	69.747	0.0	68.8	128
120 min Summer	43.014	0.0	92.2	166
180 min Summer	32.102	0.0	106.7	212
240 min Summer	25.923	0.0	116.8	264
360 min Summer	18.962	0.0	129.6	374
480 min Summer	15.013	0.0	136.7	490
600 min Summer	12.462	0.0	141.1	606
720 min Summer	10.673	0.0	143.8	722
960 min Summer	8.322	0.0	146.5	856
1440 min Summer	5.832	0.0	145.9	1090
2160 min Summer	4.092	0.0	198.4	1484
2880 min Summer	3.189	0.0	200.7	1892
4320 min Summer	2.249	0.0	196.6	2696
5760 min Summer	1.766	0.0	237.5	3480
7200 min Summer	1.475	0.0	240.6	4264
8640 min Summer	1.280	0.0	242.1	5024
10080 min Summer	1.139	0.0	241.4	5784
15 min Winter	173.460	0.0	26.8	106
30 min Winter	112.490	0.0	41.0	111
60 min Winter	69.747	0.0	81.0	126
120 min Winter	43.014	0.0	107.5	166
180 min Winter	32.102	0.0	123.6	212

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Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max E Outflow (l/s)	Max Volume (m³)	Status
240 min Winter	9.929	0.094	0.0	1.5	1.5	180.2	Flood Risk
360 min Winter	9.937	0.102	0.0	1.6	1.6	194.1	Flood Risk
480 min Winter	9.940	0.105	0.0	1.6	1.6	200.4	Flood Risk
600 min Winter	9.941	0.106	0.0	1.7	1.7	203.0	Flood Risk
720 min Winter	9.942	0.107	0.0	1.7	1.7	203.5	Flood Risk
960 min Winter	9.940	0.105	0.0	1.6	1.6	201.2	Flood Risk
1440 min Winter	9.937	0.102	0.0	1.6	1.6	194.3	Flood Risk
2160 min Winter	9.932	0.097	0.0	1.6	1.6	185.7	Flood Risk
2880 min Winter	9.928	0.093	0.0	1.5	1.5	177.2	Flood Risk
4320 min Winter	9.920	0.085	0.0	1.4	1.4	161.4	Flood Risk
5760 min Winter	9.913	0.078	0.0	1.3	1.3	148.8	Flood Risk
7200 min Winter	9.908	0.073	0.0	1.2	1.2	139.7	Flood Risk
8640 min Winter	9.904	0.069	0.0	1.1	1.1	132.5	Flood Risk
10080 min Winter	9.901	0.066	0.0	1.1	1.1	126.5	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
240 min Winter	25.923	0.0	134.6	262
360 min Winter	18.962	0.0	148.8	370
480 min Winter	15.013	0.0	156.7	482
600 min Winter	12.462	0.0	161.5	596
720 min Winter	10.673	0.0	164.6	706
960 min Winter	8.322	0.0	167.6	918
1440 min Winter	5.832	0.0	166.7	1142
2160 min Winter	4.092	0.0	227.6	1596
2880 min Winter	3.189	0.0	230.7	2044
4320 min Winter	2.249	0.0	226.9	2896
5760 min Winter	1.766	0.0	273.4	3696
7200 min Winter	1.475	0.0	277.9	4480
8640 min Winter	1.280	0.0	280.6	5280
10080 min Winter	1.139	0.0	280.8	6056

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Rainfall Details

Rainfall Model	FEH
Return Period (years)	100
FEH Rainfall Version	2013
Site Location	GB 561475 174841 TQ 61475 74841
Data Type	Point
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.750
Cv (Winter)	0.840
Shortest Storm (mins)	15
Longest Storm (mins)	10080
Climate Change %	+40

Green Roof

Area (m³)	2360	Evaporation (mm/day)	3
Depression Storage (mm)	5	Decay Coefficient	0.050

Time (mins) From:	To:	Area (ha)	Time (mins) From:	To:	Area (ha)	Time (mins) From:	To:	Area (ha)	Time (mins) From:	To:	Area (ha)
0	4	0.042886	32	36	0.008659	64	68	0.001748	96	100	0.000353
4	8	0.035112	36	40	0.007089	68	72	0.001431	100	104	0.000289
8	12	0.028747	40	44	0.005804	72	76	0.001172	104	108	0.000237
12	16	0.023536	44	48	0.004752	76	80	0.000959	108	112	0.000194
16	20	0.019270	48	52	0.003891	80	84	0.000785	112	116	0.000159
20	24	0.015777	52	56	0.003185	84	88	0.000643	116	120	0.000130
24	28	0.012917	56	60	0.002608	88	92	0.000527			
28	32	0.010576	60	64	0.002135	92	96	0.000431			

Time Area Diagram

Total Area (ha) 0.000

Time (mins) From:	To:	Area (ha)
0	4	0.000

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Model Details

Storage is Online Cover Level (m) 10.000

Cellular Storage Structure

Invert Level (m) 9.835 Safety Factor 2.0
Infiltration Coefficient Base (m/hr) 0.00000 Porosity 0.90
Infiltration Coefficient Side (m/hr) 0.00000

Depth (m)	Area (m ²)	Inf. Area (m ²)	Depth (m)	Area (m ²)	Inf. Area (m ²)
0.000	2120.0	0.0	0.165	2120.0	0.0

Orifice Outflow Control

Diameter (m) 0.053 Discharge Coefficient 0.600 Invert Level (m) 9.835

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Summary of Results for 100 year Return Period (+40%)

Half Drain Time : 1408 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Σ Outflow (l/s)	Max Volume (m ³)	Status
15 min Summer	9.875	0.040	0.0	0.3	0.3	32.4	Flood Risk
30 min Summer	9.887	0.052	0.0	0.4	0.4	41.8	Flood Risk
60 min Summer	9.899	0.064	0.0	0.5	0.5	51.4	Flood Risk
120 min Summer	9.912	0.077	0.0	0.5	0.5	62.5	Flood Risk
180 min Summer	9.920	0.085	0.0	0.6	0.6	69.1	Flood Risk
240 min Summer	9.926	0.091	0.0	0.6	0.6	73.4	Flood Risk
360 min Summer	9.932	0.097	0.0	0.6	0.6	78.4	Flood Risk
480 min Summer	9.934	0.099	0.0	0.6	0.6	80.5	Flood Risk
600 min Summer	9.935	0.100	0.0	0.6	0.6	81.4	Flood Risk
720 min Summer	9.936	0.101	0.0	0.6	0.6	81.4	Flood Risk
960 min Summer	9.934	0.099	0.0	0.6	0.6	80.3	Flood Risk
1440 min Summer	9.931	0.096	0.0	0.6	0.6	78.1	Flood Risk
2160 min Summer	9.928	0.093	0.0	0.6	0.6	75.3	Flood Risk
2880 min Summer	9.925	0.090	0.0	0.6	0.6	72.8	Flood Risk
4320 min Summer	9.919	0.084	0.0	0.6	0.6	67.8	Flood Risk
5760 min Summer	9.913	0.078	0.0	0.5	0.5	63.5	Flood Risk
7200 min Summer	9.909	0.074	0.0	0.5	0.5	60.0	Flood Risk
8640 min Summer	9.905	0.070	0.0	0.5	0.5	57.0	Flood Risk
10080 min Summer	9.902	0.067	0.0	0.5	0.5	54.4	Flood Risk
15 min Winter	9.880	0.045	0.0	0.4	0.4	36.2	Flood Risk
30 min Winter	9.893	0.058	0.0	0.4	0.4	46.8	Flood Risk
60 min Winter	9.906	0.071	0.0	0.5	0.5	57.6	Flood Risk
120 min Winter	9.922	0.087	0.0	0.6	0.6	70.1	Flood Risk
180 min Winter	9.931	0.096	0.0	0.6	0.6	77.5	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m ³)	Discharge Volume (m ³)	Time-Peak (mins)
15 min Summer	173.460	0.0	15.8	19
30 min Summer	112.490	0.0	22.1	34
60 min Summer	69.747	0.0	38.9	64
120 min Summer	43.014	0.0	48.8	124
180 min Summer	32.102	0.0	54.9	182
240 min Summer	25.923	0.0	59.0	242
360 min Summer	18.962	0.0	64.4	362
480 min Summer	15.013	0.0	67.4	482
600 min Summer	12.462	0.0	69.2	602
720 min Summer	10.673	0.0	70.4	720
960 min Summer	8.322	0.0	71.3	894
1440 min Summer	5.832	0.0	70.2	1112
2160 min Summer	4.092	0.0	98.1	1492
2880 min Summer	3.189	0.0	100.5	1904
4320 min Summer	2.249	0.0	101.1	2724
5760 min Summer	1.766	0.0	121.1	3520
7200 min Summer	1.475	0.0	125.7	4320
8640 min Summer	1.280	0.0	129.6	5096
10080 min Summer	1.139	0.0	132.2	5848
15 min Winter	173.460	0.0	18.4	19
30 min Winter	112.490	0.0	25.3	34
60 min Winter	69.747	0.0	44.1	64
120 min Winter	43.014	0.0	55.1	122
180 min Winter	32.102	0.0	61.7	180

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Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max E Outflow (l/s)	Max Volume (m³)	Status
240 min Winter	9.937	0.102	0.0	0.6	0.6	82.4	Flood Risk
360 min Winter	9.944	0.109	0.0	0.7	0.7	88.1	Flood Risk
480 min Winter	9.947	0.112	0.0	0.7	0.7	90.7	Flood Risk
600 min Winter	9.948	0.113	0.0	0.7	0.7	91.8	Flood Risk
720 min Winter	9.949	0.114	0.0	0.7	0.7	92.0	Flood Risk
960 min Winter	9.947	0.112	0.0	0.7	0.7	91.1	Flood Risk
1440 min Winter	9.943	0.108	0.0	0.6	0.6	87.6	Flood Risk
2160 min Winter	9.938	0.103	0.0	0.6	0.6	83.6	Flood Risk
2880 min Winter	9.933	0.098	0.0	0.6	0.6	79.6	Flood Risk
4320 min Winter	9.924	0.089	0.0	0.6	0.6	72.1	Flood Risk
5760 min Winter	9.916	0.081	0.0	0.5	0.5	65.6	Flood Risk
7200 min Winter	9.910	0.075	0.0	0.5	0.5	60.4	Flood Risk
8640 min Winter	9.904	0.069	0.0	0.5	0.5	56.1	Flood Risk
10080 min Winter	9.900	0.065	0.0	0.5	0.5	52.4	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
240 min Winter	25.923	0.0	66.3	240
360 min Winter	18.962	0.0	72.1	356
480 min Winter	15.013	0.0	75.2	472
600 min Winter	12.462	0.0	77.1	584
720 min Winter	10.673	0.0	78.1	698
960 min Winter	8.322	0.0	78.8	914
1440 min Winter	5.832	0.0	76.9	1154
2160 min Winter	4.092	0.0	110.3	1604
2880 min Winter	3.189	0.0	112.8	2048
4320 min Winter	2.249	0.0	113.3	2936
5760 min Winter	1.766	0.0	136.2	3752
7200 min Winter	1.475	0.0	141.4	4544
8640 min Winter	1.280	0.0	145.9	5360
10080 min Winter	1.139	0.0	149.0	6144

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Rainfall Details

Rainfall Model	FEH
Return Period (years)	100
FEH Rainfall Version	2013
Site Location	GB 561475 174841 TQ 61475 74841
Data Type	Point
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.750
Cv (Winter)	0.840
Shortest Storm (mins)	15
Longest Storm (mins)	10080
Climate Change %	+40

Time Area Diagram

Total Area (ha) 0.100

Time (mins)	Area
From: To:	(ha)

0	4	0.100
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Model Details

Storage is Online Cover Level (m) 10.000

Cellular Storage Structure

Invert Level (m) 9.835 Safety Factor 2.0
Infiltration Coefficient Base (m/hr) 0.00000 Porosity 0.90
Infiltration Coefficient Side (m/hr) 0.00000

Depth (m)	Area (m ²)	Inf. Area (m ²)	Depth (m)	Area (m ²)	Inf. Area (m ²)
0.000	900.0	0.0	0.165	900.0	0.0

Orifice Outflow Control

Diameter (m) 0.032 Discharge Coefficient 0.600 Invert Level (m) 9.835

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Summary of Results for 100 year Return Period (+40%)

Half Drain Time : 1389 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	9.875	0.040	0.0	0.5	0.5	69.7	Flood Risk
30 min Summer	9.886	0.051	0.0	0.7	0.7	90.1	Flood Risk
60 min Summer	9.898	0.063	0.0	1.0	1.0	110.9	Flood Risk
120 min Summer	9.912	0.077	0.0	1.2	1.2	134.6	Flood Risk
180 min Summer	9.920	0.085	0.0	1.3	1.3	148.4	Flood Risk
240 min Summer	9.925	0.090	0.0	1.4	1.4	157.5	Flood Risk
360 min Summer	9.931	0.096	0.0	1.4	1.4	168.0	Flood Risk
480 min Summer	9.933	0.098	0.0	1.5	1.5	172.4	Flood Risk
600 min Summer	9.934	0.099	0.0	1.5	1.5	173.8	Flood Risk
720 min Summer	9.934	0.099	0.0	1.5	1.5	173.7	Flood Risk
960 min Summer	9.933	0.098	0.0	1.5	1.5	171.5	Flood Risk
1440 min Summer	9.931	0.096	0.0	1.4	1.4	167.7	Flood Risk
2160 min Summer	9.928	0.093	0.0	1.4	1.4	162.7	Flood Risk
2880 min Summer	9.925	0.090	0.0	1.4	1.4	157.9	Flood Risk
4320 min Summer	9.920	0.085	0.0	1.3	1.3	148.6	Flood Risk
5760 min Summer	9.915	0.080	0.0	1.3	1.3	140.5	Flood Risk
7200 min Summer	9.911	0.076	0.0	1.2	1.2	134.0	Flood Risk
8640 min Summer	9.908	0.073	0.0	1.2	1.2	128.7	Flood Risk
10080 min Summer	9.906	0.071	0.0	1.1	1.1	124.5	Flood Risk
15 min Winter	9.879	0.044	0.0	0.6	0.6	78.0	Flood Risk
30 min Winter	9.892	0.057	0.0	0.8	0.8	100.8	Flood Risk
60 min Winter	9.906	0.071	0.0	1.1	1.1	124.1	Flood Risk
120 min Winter	9.921	0.086	0.0	1.3	1.3	150.8	Flood Risk
180 min Winter	9.930	0.095	0.0	1.4	1.4	166.5	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	173.460	0.0	27.2	19
30 min Summer	112.490	0.0	39.1	34
60 min Summer	69.747	0.0	73.7	64
120 min Summer	43.014	0.0	95.6	124
180 min Summer	32.102	0.0	109.0	182
240 min Summer	25.923	0.0	118.4	242
360 min Summer	18.962	0.0	130.4	362
480 min Summer	15.013	0.0	137.3	482
600 min Summer	12.462	0.0	141.7	600
720 min Summer	10.673	0.0	144.6	720
960 min Summer	8.322	0.0	147.7	830
1440 min Summer	5.832	0.0	148.4	1068
2160 min Summer	4.092	0.0	201.8	1468
2880 min Summer	3.189	0.0	206.8	1872
4320 min Summer	2.249	0.0	208.3	2680
5760 min Summer	1.766	0.0	253.5	3464
7200 min Summer	1.475	0.0	262.4	4248
8640 min Summer	1.280	0.0	269.5	5008
10080 min Summer	1.139	0.0	273.9	5744
15 min Winter	173.460	0.0	32.1	19
30 min Winter	112.490	0.0	45.6	34
60 min Winter	69.747	0.0	85.1	64
120 min Winter	43.014	0.0	109.5	122
180 min Winter	32.102	0.0	124.4	180

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Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max E Outflow (l/s)	Max Volume (m³)	Status
240 min Winter	9.936	0.101	0.0	1.5	1.5	176.8	Flood Risk
360 min Winter	9.943	0.108	0.0	1.6	1.6	188.8	Flood Risk
480 min Winter	9.946	0.111	0.0	1.6	1.6	194.0	Flood Risk
600 min Winter	9.947	0.112	0.0	1.6	1.6	196.1	Flood Risk
720 min Winter	9.947	0.112	0.0	1.6	1.6	196.4	Flood Risk
960 min Winter	9.946	0.111	0.0	1.6	1.6	194.0	Flood Risk
1440 min Winter	9.942	0.107	0.0	1.5	1.5	187.6	Flood Risk
2160 min Winter	9.937	0.102	0.0	1.5	1.5	179.5	Flood Risk
2880 min Winter	9.933	0.098	0.0	1.5	1.5	171.4	Flood Risk
4320 min Winter	9.924	0.089	0.0	1.4	1.4	156.2	Flood Risk
5760 min Winter	9.917	0.082	0.0	1.3	1.3	143.7	Flood Risk
7200 min Winter	9.911	0.076	0.0	1.2	1.2	134.1	Flood Risk
8640 min Winter	9.907	0.072	0.0	1.2	1.2	126.6	Flood Risk
10080 min Winter	9.904	0.069	0.0	1.1	1.1	120.8	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
240 min Winter	25.923	0.0	134.6	238
360 min Winter	18.962	0.0	147.9	356
480 min Winter	15.013	0.0	155.5	470
600 min Winter	12.462	0.0	160.3	584
720 min Winter	10.673	0.0	163.5	694
960 min Winter	8.322	0.0	166.9	904
1440 min Winter	5.832	0.0	167.2	1124
2160 min Winter	4.092	0.0	228.3	1576
2880 min Winter	3.189	0.0	234.0	2020
4320 min Winter	2.249	0.0	235.7	2856
5760 min Winter	1.766	0.0	285.8	3688
7200 min Winter	1.475	0.0	296.0	4464
8640 min Winter	1.280	0.0	304.2	5192
10080 min Winter	1.139	0.0	309.4	5952

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Rainfall Details

Rainfall Model	FEH
Return Period (years)	100
FEH Rainfall Version	2013
Site Location	GB 561475 174841 TQ 61475 74841
Data Type	Point
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.750
Cv (Winter)	0.840
Shortest Storm (mins)	15
Longest Storm (mins)	10080
Climate Change %	+40

Time Area Diagram

Total Area (ha) 0.215

Time (mins) Area
From: To: (ha)

0 4 0.215

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Model Details

Storage is Online Cover Level (m) 10.000

Cellular Storage Structure

Invert Level (m) 9.835 Safety Factor 2.0
Infiltration Coefficient Base (m/hr) 0.00000 Porosity 0.90
Infiltration Coefficient Side (m/hr) 0.00000

Depth (m)	Area (m ²)	Inf. Area (m ²)	Depth (m)	Area (m ²)	Inf. Area (m ²)
0.000	1950.0	0.0	0.165	1950.0	0.0

Orifice Outflow Control

Diameter (m) 0.051 Discharge Coefficient 0.600 Invert Level (m) 9.835

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Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
15 min Summer	9.721	0.221	10.0	264.2	Flood Risk
30 min Summer	9.774	0.274	10.0	340.4	Flood Risk
60 min Summer	9.822	0.322	10.0	415.1	Flood Risk
120 min Summer	9.871	0.371	10.0	495.9	Flood Risk
180 min Summer	9.895	0.395	10.0	538.4	Flood Risk
240 min Summer	9.908	0.408	10.0	562.1	Flood Risk
360 min Summer	9.918	0.418	10.0	578.7	Flood Risk
480 min Summer	9.914	0.414	10.0	572.2	Flood Risk
600 min Summer	9.907	0.407	10.0	560.2	Flood Risk
720 min Summer	9.900	0.400	10.0	546.5	Flood Risk
960 min Summer	9.882	0.382	10.0	515.7	Flood Risk
1440 min Summer	9.847	0.347	10.0	455.6	Flood Risk
2160 min Summer	9.799	0.299	10.0	378.6	Flood Risk
2880 min Summer	9.757	0.257	10.0	316.1	Flood Risk
4320 min Summer	9.695	0.195	9.9	227.9	O K
5760 min Summer	9.658	0.158	9.7	179.4	O K
7200 min Summer	9.640	0.140	8.7	157.5	O K
8640 min Summer	9.629	0.129	7.9	142.7	O K
10080 min Summer	9.620	0.120	7.2	131.9	O K
15 min Winter	9.721	0.221	10.0	264.2	Flood Risk
30 min Winter	9.774	0.274	10.0	340.5	Flood Risk
60 min Winter	9.822	0.322	10.0	415.2	Flood Risk
120 min Winter	9.870	0.370	10.0	495.8	Flood Risk
180 min Winter	9.895	0.395	10.0	538.2	Flood Risk
240 min Winter	9.908	0.408	10.0	561.7	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	173.460	0.0	254.6	28
30 min Summer	112.490	0.0	333.6	42
60 min Summer	69.747	0.0	431.1	70
120 min Summer	43.014	0.0	533.1	128
180 min Summer	32.102	0.0	597.4	188
240 min Summer	25.923	0.0	643.5	246
360 min Summer	18.962	0.0	706.2	362
480 min Summer	15.013	0.0	745.4	460
600 min Summer	12.462	0.0	773.2	512
720 min Summer	10.673	0.0	794.3	572
960 min Summer	8.322	0.0	825.0	688
1440 min Summer	5.832	0.0	864.9	946
2160 min Summer	4.092	0.0	925.5	1332
2880 min Summer	3.189	0.0	960.8	1708
4320 min Summer	2.249	0.0	1011.8	2388
5760 min Summer	1.766	0.0	1068.9	3064
7200 min Summer	1.475	0.0	1115.4	3752
8640 min Summer	1.280	0.0	1159.2	4496
10080 min Summer	1.139	0.0	1199.1	5240
15 min Winter	173.460	0.0	254.6	28
30 min Winter	112.490	0.0	333.6	42
60 min Winter	69.747	0.0	431.1	70
120 min Winter	43.014	0.0	533.1	126
180 min Winter	32.102	0.0	597.4	184
240 min Winter	25.923	0.0	643.5	240

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Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m ³)	Status
360 min Winter	9.917	0.417	10.0	578.4	Flood Risk
480 min Winter	9.914	0.414	10.0	572.1	Flood Risk
600 min Winter	9.905	0.405	10.0	556.0	Flood Risk
720 min Winter	9.894	0.394	10.0	537.4	Flood Risk
960 min Winter	9.872	0.372	10.0	499.0	Flood Risk
1440 min Winter	9.825	0.325	10.0	419.8	Flood Risk
2160 min Winter	9.758	0.258	10.0	317.3	Flood Risk
2880 min Winter	9.704	0.204	10.0	240.5	Flood Risk
4320 min Winter	9.646	0.146	9.1	163.9	O K
5760 min Winter	9.623	0.123	7.4	136.0	O K
7200 min Winter	9.610	0.110	6.3	120.3	O K
8640 min Winter	9.601	0.101	5.5	109.5	O K
10080 min Winter	9.594	0.094	5.0	101.6	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m ³)	Discharge Volume (m ³)	Time-Peak (mins)
360 min Winter	18.962	0.0	706.2	354
480 min Winter	15.013	0.0	745.5	462
600 min Winter	12.462	0.0	773.3	562
720 min Winter	10.673	0.0	794.5	584
960 min Winter	8.322	0.0	825.3	726
1440 min Winter	5.832	0.0	865.4	1010
2160 min Winter	4.092	0.0	925.6	1404
2880 min Winter	3.189	0.0	960.9	1756
4320 min Winter	2.249	0.0	1012.2	2380
5760 min Winter	1.766	0.0	1068.9	3064
7200 min Winter	1.475	0.0	1115.5	3816
8640 min Winter	1.280	0.0	1159.4	4504
10080 min Winter	1.139	0.0	1199.9	5240

Rainfall Details

Rainfall Model	FEH
Return Period (years)	100
FEH Rainfall Version	2013
Site Location	GB 561475 174841 TQ 61475 74841
Data Type	Point
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.370
Cv (Winter)	0.370
Shortest Storm (mins)	15
Longest Storm (mins)	10080
Climate Change %	+40

Time Area Diagram

Total Area (ha) 1.710

Time (mins)	Area	Time (mins)	Area	Time (mins)	Area	Time (mins)	Area
From: To:	(ha)	From: To:	(ha)	From: To:	(ha)	From: To:	(ha)
0 4	0.500	4 8	0.500	8 12	0.500	12 16	0.210

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Model Details

Storage is Online Cover Level (m) 10.000

Tank or Pond Structure

Invert Level (m) 9.500

Depth (m)	Area (m ²)	Depth (m)	Area (m ²)
0.000	1000.0	0.500	2000.0

Hydro-Brake® Optimum Outflow Control

Unit Reference	MD-SHE-0152-1000-0500-1000
Design Head (m)	0.500
Design Flow (l/s)	10.0
Flush-Flo™	Calculated
Objective	Minimise upstream storage
Application	Surface
Sump Available	Yes
Diameter (mm)	152
Invert Level (m)	9.500
Minimum Outlet Pipe Diameter (mm)	225
Suggested Manhole Diameter (mm)	1200

Control Points	Head (m)	Flow (l/s)	Control Points	Head (m)	Flow (l/s)
Design Point (Calculated)	0.500	10.0	Kick-Flo®	0.396	9.0
Flush-Flo™	0.225	10.0	Mean Flow over Head Range	-	7.9

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)
0.100	5.5	0.800	12.5	2.000	19.3	4.000	26.9	7.000	35.3
0.200	10.0	1.000	13.9	2.200	20.2	4.500	28.5	7.500	36.5
0.300	9.8	1.200	15.1	2.400	21.1	5.000	30.0	8.000	37.7
0.400	9.0	1.400	16.3	2.600	21.9	5.500	31.2	8.500	38.9
0.500	10.0	1.600	17.3	3.000	23.4	6.000	32.6	9.000	40.1
0.600	10.9	1.800	18.3	3.500	25.2	6.500	34.0	9.500	41.2

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XP Solutions	Source Control 2020.1	

Summary of Results for 100 year Return Period (+40%)

Half Drain Time : 1432 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Σ Outflow (l/s)	Max Volume (m ³)	Status
15 min Summer	9.573	0.073	0.0	3.0	3.0	612.8	O K
30 min Summer	9.594	0.094	0.0	4.7	4.7	792.2	O K
60 min Summer	9.616	0.116	0.0	6.4	6.4	976.7	O K
120 min Summer	9.641	0.141	0.0	8.8	8.8	1189.6	O K
180 min Summer	9.656	0.156	0.0	10.3	10.3	1313.8	O K
240 min Summer	9.666	0.166	0.0	11.3	11.3	1395.3	O K
360 min Summer	9.677	0.177	0.0	12.4	12.4	1489.1	O K
480 min Summer	9.682	0.182	0.0	12.9	12.9	1529.1	O K
600 min Summer	9.684	0.184	0.0	13.1	13.1	1543.6	O K
720 min Summer	9.684	0.184	0.0	13.1	13.1	1543.8	O K
960 min Summer	9.682	0.182	0.0	12.9	12.9	1529.9	O K
1440 min Summer	9.679	0.179	0.0	12.6	12.6	1505.0	O K
2160 min Summer	9.675	0.175	0.0	12.2	12.2	1474.6	O K
2880 min Summer	9.672	0.172	0.0	11.9	11.9	1444.5	O K
4320 min Summer	9.665	0.165	0.0	11.2	11.2	1384.6	O K
5760 min Summer	9.658	0.158	0.0	10.5	10.5	1331.9	O K
7200 min Summer	9.653	0.153	0.0	10.0	10.0	1289.8	O K
8640 min Summer	9.649	0.149	0.0	9.6	9.6	1253.5	O K
10080 min Summer	9.645	0.145	0.0	9.2	9.2	1221.9	O K
15 min Winter	9.582	0.082	0.0	3.8	3.8	686.0	O K
30 min Winter	9.606	0.106	0.0	5.5	5.5	887.1	O K
60 min Winter	9.630	0.130	0.0	7.7	7.7	1093.5	O K
120 min Winter	9.658	0.158	0.0	10.5	10.5	1331.4	O K
180 min Winter	9.675	0.175	0.0	12.2	12.2	1470.4	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m ³)	Discharge Volume (m ³)	Time-Peak (mins)
15 min Summer	173.460	0.0	177.3	27
30 min Summer	112.490	0.0	275.2	42
60 min Summer	69.747	0.0	555.7	72
120 min Summer	43.014	0.0	734.1	130
180 min Summer	32.102	0.0	847.9	188
240 min Summer	25.923	0.0	929.1	248
360 min Summer	18.962	0.0	1036.5	366
480 min Summer	15.013	0.0	1098.2	484
600 min Summer	12.462	0.0	1137.4	602
720 min Summer	10.673	0.0	1162.9	720
960 min Summer	8.322	0.0	1188.9	834
1440 min Summer	5.832	0.0	1190.6	1072
2160 min Summer	4.092	0.0	1665.3	1472
2880 min Summer	3.189	0.0	1699.9	1880
4320 min Summer	2.249	0.0	1698.2	2688
5760 min Summer	1.766	0.0	2148.7	3512
7200 min Summer	1.475	0.0	2218.4	4264
8640 min Summer	1.280	0.0	2270.1	5024
10080 min Summer	1.139	0.0	2295.4	5848
15 min Winter	173.460	0.0	215.7	27
30 min Winter	112.490	0.0	329.6	41
60 min Winter	69.747	0.0	648.4	70
120 min Winter	43.014	0.0	852.5	128
180 min Winter	32.102	0.0	982.4	186

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Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max E Outflow (l/s)	Max Volume (m³)	Status
240 min Winter	9.686	0.186	0.0	13.3	13.3	1561.4	O K
360 min Winter	9.698	0.198	0.0	14.6	14.6	1666.4	O K
480 min Winter	9.704	0.204	0.0	15.0	15.0	1711.6	Flood Risk
600 min Winter	9.706	0.206	0.0	15.1	15.1	1729.3	Flood Risk
720 min Winter	9.706	0.206	0.0	15.1	15.1	1731.6	Flood Risk
960 min Winter	9.704	0.204	0.0	15.0	15.0	1711.9	Flood Risk
1440 min Winter	9.699	0.199	0.0	14.6	14.6	1671.4	O K
2160 min Winter	9.692	0.192	0.0	14.0	14.0	1616.5	O K
2880 min Winter	9.686	0.186	0.0	13.3	13.3	1561.4	O K
4320 min Winter	9.674	0.174	0.0	12.1	12.1	1459.4	O K
5760 min Winter	9.664	0.164	0.0	11.1	11.1	1375.6	O K
7200 min Winter	9.656	0.156	0.0	10.3	10.3	1309.4	O K
8640 min Winter	9.649	0.149	0.0	9.6	9.6	1254.7	O K
10080 min Winter	9.644	0.144	0.0	9.1	9.1	1208.2	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
240 min Winter	25.923	0.0	1074.4	242
360 min Winter	18.962	0.0	1194.7	358
480 min Winter	15.013	0.0	1263.7	472
600 min Winter	12.462	0.0	1307.1	584
720 min Winter	10.673	0.0	1335.4	694
960 min Winter	8.322	0.0	1365.3	896
1440 min Winter	5.832	0.0	1369.9	1106
2160 min Winter	4.092	0.0	1898.7	1564
2880 min Winter	3.189	0.0	1939.5	2016
4320 min Winter	2.249	0.0	1939.3	2860
5760 min Winter	1.766	0.0	2430.8	3696
7200 min Winter	1.475	0.0	2510.7	4536
8640 min Winter	1.280	0.0	2571.5	5280
10080 min Winter	1.139	0.0	2604.2	6056

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Rainfall Details

Rainfall Model	FEH
Return Period (years)	100
FEH Rainfall Version	2013
Site Location	GB 561475 174841 TQ 61475 74841
Data Type	Point
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.750
Cv (Winter)	0.840
Shortest Storm (mins)	15
Longest Storm (mins)	10080
Climate Change %	+40

Time Area Diagram

Total Area (ha) 1.890

Time (mins)	Area	Time (mins)	Area	Time (mins)	Area
From: To:	(ha)	From: To:	(ha)	From: To:	(ha)
0 4	0.630	4 8	0.630	8 12	0.630

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Model Details

Storage is Online Cover Level (m) 10.000

Cellular Storage Structure

Invert Level (m) 9.500 Safety Factor 2.0
Infiltration Coefficient Base (m/hr) 0.00000 Porosity 0.95
Infiltration Coefficient Side (m/hr) 0.00000

Depth (m)	Area (m ²)	Inf. Area (m ²)	Depth (m)	Area (m ²)	Inf. Area (m ²)	Depth (m)	Area (m ²)	Inf. Area (m ²)
0.000	8850.0	0.0	0.300	8850.0	0.0	0.301	0.0	0.0

Orifice Outflow Control

Diameter (m) 0.140 Discharge Coefficient 0.600 Invert Level (m) 9.500

2. Sub-catchment C

The following MicroDrainage printout shows how sub-catchment C can discharge to Robins Creek during times of high tide. The model is based on an indicative swale design which will be developed as part of the detailed design.

The level of surcharge at the outfall has been determined using a tidal hydrograph based on HAT, mean low water springs (MLWS) and the rule of twelfths and is shown in the following table.

Tide Height Calculator					
Enter time in 00:00 format					
Start Time	00:00		End Time	00:00	
Start Level	3.98		End Level	-2.42	
Calculate >					
Start	End	Rule of 12	Change m/hr	Start Level	End Level
00:00	00:00	1	-0.53	3.98	3.45
00:00	00:00	2	-1.07	3.45	2.38
00:00	00:00	3	-1.60	2.38	0.78
00:00	00:00	3	-1.60	0.78	-0.82
00:00	00:00	2	-1.07	-0.82	-1.89
00:00	00:00	1	-0.53	-1.89	-2.42
© The Tidal Press - www.thetidalpress.com - 07975 830411 Supplier of tide tables for over 700 locations in the UK and Ireland					

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STORM SEWER DESIGN by the Modified Rational Method

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	100.000	0.200	500.0	0.618	5.00	0.0	0.600	\	-10	Pipe/Conduit	
S1.001	100.000	0.100	1000.0	0.618	0.00	0.0	0.600	\	-10	Pipe/Conduit	
S1.002	50.000	0.100	500.0	0.618	0.00	0.0	0.600	\	-10	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	75.00	5.87	4.100	0.618	0.0	0.0	0.0	1.91	2867.1	125.5
S1.001	75.00	7.11	3.900	1.236	0.0	0.0	0.0	1.35	2021.9	251.1
S1.002	75.00	7.54	3.800	1.854	0.0	0.0	0.0	1.91	2867.1	376.6

Conduit Sections for Storm

NOTE: Diameters less than 66 refer to section numbers of hydraulic conduits. These conduits are marked by the symbols:- [] box culvert, \ open channel, oo dual pipe, ooo triple pipe, O egg.

Section numbers < 0 are taken from user conduit table

Section Number	Conduit Type	Major Dimn. (mm)	Minor Dimn. (mm)	Side Slope (Deg)	Corner Splay (mm)	4*Hyd Radius (m)	XSect Area (m²)
-10	\	3000	500	90.0		1.500	1.500

Manhole Schedules for Storm

MH Name	MH CL (m)	MH Depth (m)	MH Connection	MH Diam., L*W (mm)	PN	Pipe Out Invert Level (m)	Diameter (mm)	PN	Pipes In Invert Level (m)	Diameter (mm)	Backdrop (mm)
S1	4.600	0.500	Junction		S1.000	4.100	-10				
S2	4.400	0.500	Junction		S1.001	3.900	-10	S1.000	3.900	-10	
S3	4.300	0.500	Junction		S1.002	3.800	-10	S1.001	3.800	-10	
S	4.500	0.800	Open Manhole	0		OUTFALL		S1.002	3.700	-10	

No coordinates have been specified, layout information cannot be produced.

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PIPELINE SCHEDULES for Storm

Upstream Manhole

PN	Hyd Sect	Diam (mm)	MH Name	C.Level (m)	I.Level (m)	D.Depth (m)	MH Connection	MH DIAM., L*W (mm)
S1.000	\/	-10	S1	4.600	4.100	0.000	Junction	
S1.001	\/	-10	S2	4.400	3.900	0.000	Junction	
S1.002	\/	-10	S3	4.300	3.800	0.000	Junction	

Downstream Manhole

PN	Length (m)	Slope (1:X)	MH Name	C.Level (m)	I.Level (m)	D.Depth (m)	MH Connection	MH DIAM., L*W (mm)
S1.000	100.000	500.0	S2	4.400	3.900	0.000	Junction	
S1.001	100.000	1000.0	S3	4.300	3.800	0.000	Junction	
S1.002	50.000	500.0	S	4.500	3.700	0.300	Open Manhole	0

Area Summary for Storm

Pipe Number	PIMP Type	PIMP Name	PIMP (%)	Gross Area (ha)	Imp. Area (ha)	Pipe Total (ha)
1.000	-	-	100	0.618	0.618	0.618
1.001	-	-	100	0.618	0.618	0.618
1.002	-	-	100	0.618	0.618	0.618
				Total	Total	Total
				1.854	1.854	1.854

Surcharged Outfall Details for Storm

Outfall Pipe Number	Outfall Name	C. Level (m)	I. Level (m)	Min I. Level (m)	D,L (mm)	W (mm)
---------------------	--------------	--------------	--------------	------------------	----------	--------

S1.002	S	4.500	3.700	0.000	0	0
--------	---	-------	-------	-------	---	---

Datum (m) 0.000 Offset (mins) 0

Time (mins)	Depth (m)	Time (mins)	Depth (m)	Time (mins)	Depth (m)	Time (mins)	Depth (m)	Time (mins)	Depth (m)	Time (mins)	Depth (m)	Time (mins)	Depth (m)
60	3.980	480	-1.890	900	2.380	1320	0.780	1740	-0.820	2160	3.450	2580	-2.420
120	3.450	540	-0.820	960	0.780	1380	2.380	1800	-1.890	2220	3.980	2640	-1.890
180	2.380	600	0.780	1020	-0.820	1440	3.450	1860	-2.420	2280	3.450	2700	0.820
240	0.780	660	2.380	1080	-1.890	1500	3.980	1920	-1.890	2340	2.380	2760	0.780
300	-0.820	720	3.450	1140	-2.420	1560	3.450	1980	-0.820	2400	0.780	2820	2.380
360	-1.890	780	3.980	1200	-1.890	1620	2.380	2040	0.780	2460	-0.820	2880	3.450
420	-2.420	840	3.450	1260	-0.820	1680	0.780	2100	2.380	2520	-1.890		

Simulation Criteria for Storm

Volumetric Runoff Coeff	0.750	Additional Flow - % of Total Flow	0.000
Areal Reduction Factor	1.000	MADD Factor * 10m ³ /ha Storage	2.000
Hot Start (mins)	0	Inlet Coefficient	0.800
Hot Start Level (mm)	0	Flow per Person per Day (l/per/day)	0.000
Manhole Headloss Coeff (Global)	0.500	Run Time (mins)	60
Foul Sewage per hectare (l/s)	0.000	Output Interval (mins)	1

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

Synthetic Rainfall Details

Rainfall Model	FEH
Return Period (years)	100
FEH Rainfall Version	2013
Site Location	GB 561475 174841 TQ 61475 74841
Data Type	Point
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.750
Cv (Winter)	0.840
Storm Duration (mins)	30

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

Simulation Criteria

Volumetric Runoff Coeff 0.750 Foul Sewage per hectare (l/s) 0.000
 Areal Reduction Factor 1.000 Additional Flow - % of Total Flow 0.000
 Hot Start (mins) 0 MADD Factor * 10m³/ha Storage 2.000
 Hot Start Level (mm) 0 Inlet Coefficient 0.800
 Manhole Headloss Coeff (Global) 0.500 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 0 Number of Storage Structures 0 Number of Real Time Controls 0
 Margin for Flood Risk Warning (mm) 300.0 DVD Status OFF
 Analysis Timestep Fine 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) 2, 30, 100
 Climate Change (%) 0, 0, 40

									Water	Surcharged	Flooded
	US/MH		Return	Climate	First (X)	First (Y)	First (Z)	Overflow	Level	Depth	Volume
PN	Name	Storm	Period	Change	Surcharge	Flood	Overflow	Act.	(m)	(m)	(m³)
S1.000	S1	15 Winter	2	+0%					4.161	-0.439	0.000
S1.001	S2	15 Winter	2	+0%					4.012	-0.388	0.000
S1.002	S3	120 Summer	2	+0%					3.953	-0.347	0.000

				Half Drain	Pipe		
PN	US/MH Name	Flow / Cap.	Overflow (l/s)	Time (mins)	Flow (l/s)	Status	Level Exceeded
S1.000	S1	0.04			102.7	OK	
S1.001	S2	0.08			168.5	OK	
S1.002	S3	0.06			168.5	OK	

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

Simulation Criteria

Volumetric Runoff Coeff 0.750 Foul Sewage per hectare (l/s) 0.000
 Areal Reduction Factor 1.000 Additional Flow - % of Total Flow 0.000
 Hot Start (mins) 0 MADD Factor * 10m³/ha Storage 2.000
 Hot Start Level (mm) 0 Inlet Coefficient 0.800
 Manhole Headloss Coeff (Global) 0.500 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 0 Number of Storage Structures 0 Number of Real Time Controls 0

Margin for Flood Risk Warning (mm) 300.0 DVD Status OFF
 Analysis Timestep Fine 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) 2, 30, 100
 Climate Change (%) 0, 0, 40

									Water	Surcharged	Flooded
	US/MH		Return	Climate	First (X)	First (Y)	First (Z)	Overflow	Level	Depth	Volume
PN	Name	Storm	Period	Change	Surcharge	Flood	Overflow	Act.	(m)	(m)	(m³)
S1.000	S1	15 Winter	30	+0%					4.211	-0.389	0.000
S1.001	S2	15 Winter	30	+0%					4.092	-0.308	0.000
S1.002	S3	120 Summer	30	+0%					3.993	-0.307	0.000

		Half Drain Pipe			Level	
PN	US/MH Name	Flow / Cap.	Overflow (l/s)	Time (mins)	Flow (l/s)	Status Exceeded
S1.000	S1	0.09			251.3	OK
S1.001	S2	0.20			413.0	OK
S1.002	S3	0.11			325.9	OK

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

Simulation Criteria

Volumetric Runoff Coeff 0.750 Foul Sewage per hectare (l/s) 0.000
 Areal Reduction Factor 1.000 Additional Flow - % of Total Flow 0.000
 Hot Start (mins) 0 MADD Factor * 10m³/ha Storage 2.000
 Hot Start Level (mm) 0 Inlet Coefficient 0.800
 Manhole Headloss Coeff (Global) 0.500 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 0 Number of Storage Structures 0 Number of Real Time Controls 0

 Margin for Flood Risk Warning (mm) 300.0 DVD Status OFF
 Analysis Timestep Fine 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) 2, 30, 100
 Climate Change (%) 0, 0, 40

									Water	Surcharged	Flooded
PN	US/MH Name	Storm	Return Period	Climate Change	First (X) Surge	First (Y) Flood	First (Z) Overflow	Overflow Act.	Level (m)	Depth (m)	Volume (m³)
S1.000	S1	15 Winter	100	+40%					4.274	-0.326	0.000
S1.001	S2	15 Winter	100	+40%					4.182	-0.218	0.000
S1.002	S3	15 Winter	100	+40%					4.059	-0.241	0.000

PN	US/MH Name	Flow / Cap.	Overflow (l/s)	Half Drain Time (mins)	Pipe Flow (l/s)	Status	Level Exceeded		
S1.000	S1	0.16			461.5	OK			
S1.001	S2	0.37			753.7	FLOOD RISK*			
S1.002	S3	0.37			1064.1	FLOOD RISK*			

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Discharge Wizard Results for Storm

Summary

Discharge Rates Check - Pass

Discharge Volumes Check - Not Run

Minimal Discharge Check - Not Run

Discharge Rates Check

PN	RP(yrs) / CC(%)	Pre-development Discharge Rate (l/s)	Post-development Discharge Rate (l/s)	Pass/Fail
1.002	2yr +0%	243.7	243.7	Pass
1.002	30yr +0%	575.4	575.4	Pass
1.002	100yr +40%	1064.1	1064.1	Pass

Appendix L: SuDS Maintenance Schedule

Table L1: Geocellular Storage Operation and Maintenance Requirements

Schedule	Required Action	Frequency
Regular maintenance	Inspect and identify any areas that are not operating correctly. If required, take remedial action.	Monthly for 3 months, then annually
	Remove debris from the catchment surface (where it may cause risks to performance).	Monthly
	For systems where rainfall infiltrates into the tank from above, check surface of filter for blockage by sediment, algae or other matter; remove and replace surface infiltration medium as necessary.	Annually
	Remove sediment from pre-treatment structures and/or internal forebays.	Annually or as required
Remedial Actions	Repair/rehabilitate inlets, outlets, overflows and vents	As required
Monitoring	Inspect/check all inlets, outlets, vents and overflows to ensure that they are in good condition and operating as designed	Annually
	Survey inside of tank for sediment build-up and remove if necessary	Every 5 years or as required

Table L2: Swale Operation and Maintenance Requirements

Schedule	Required Action	Frequency
Regular maintenance	Remove litter and debris.	Monthly, or as required.
	Cut grass – to retain grass height within specified design range.	Monthly (during growing season), or as required.
	Manage other vegetation and remove nuisance plants.	Monthly at start, then as required.
	Inspect inlets, outlets and overflows for blockage, and clear if required.	Monthly.
	Inspect infiltration surface for ponding, compaction, silt accumulation, record areas where water is ponding for >48 hours.	Monthly, or when required.
	Inspect vegetation coverage.	Monthly for 6 months, quarterly for 2 years, then half yearly.
	Inspect inlets and facility surface for silt accumulation, establish appropriate silt removal frequencies.	Half yearly.
Occasional maintenance	Reseed areas of poor vegetation growth, alter plant types to better suit conditions, if required.	As required or if bare soil is exposed over 10% or more of the swale treatment area.

Schedule	Required Action	Frequency
Remedial actions	Repair of erosion or other damage by reseeding or re-turfing.	As required.
	Relevel uneven surfaces and reinstate design levels	As required.
	Scarify and spike topsoil layer to improve infiltration performance, break up silt deposits and prevent compaction of the soil surface.	As required.
	Remove build-up of sediment on upstream gravel trench, flow spreader or at top of filter strip.	As required.
	Remove and dispose of oils or petrol residues using safe standard practices.	As required.
	Inspect inlets and facility surfaces for silt accumulation. Establish appropriate silt removal frequencies.	Half yearly.

Table L3: Green Roofs Operation and Maintenance Requirements

Schedule	Required Action	Frequency
Regular inspections	Inspect all components including soil substrate, vegetation, drains, irrigation systems (if applicable), membranes and roof structure for proper operation, integrity of waterproofing and structural stability.	Annually and after severe storms
	Inspect soil substrate for evidence of erosion channels and identify any sediment sources.	Annually and after severe storms
	Inspect drain inlets to ensure unrestricted runoff from the drainage layer to the conveyance or roof drain system.	Annually and after severe storms
	Inspect underside of roof for evidence of leakage.	Annually and after severe storms
Regular maintenance	Remove debris and litter to prevent clogging of inlet drains and interference with plant growth.	Six monthly and annually or as required
	During establishment (i.e. year one), replace dead plants as required.	Monthly (but usually responsibility of manufacturer)
	Post establishment, replace dead plants as required (where > 5% of coverage).	Annually (in autumn)
	Remove fallen leaves and debris from deciduous plant foliage.	Six monthly or as required
	Remove nuisance and invasive vegetation, including weeds.	Six monthly or as required
	Mow grasses, prune shrubs and manage other planting (if appropriate) as required – clipping should be removed and not allowed to accumulate.	Six monthly or as required

Schedule	Required Action	Frequency
Remedial actions	If erosion channels are evident, these should be stabilised with extra soil substrate similar to the original material, and sources of erosion damage should be identified and controlled.	As required
	If drainage inlet has settled, cracked or moved, investigate and repair as appropriate.	As required

Table L4: Rainwater Harvesting Operation and Maintenance Requirements

Schedule	Required Action	Frequency
Regular maintenance	Inspection of the tank for debris and sediment build-up, inlets/outlets/withdrawal devices, overflow areas, pumps, filters.	Annually (and following poor performance)
	Cleaning of tank, inlets, outlets, gutters, withdrawal devices and roof drain filters of silts and other debris	Annually (and following poor performance)
Occasional maintenance	Cleaning and/or replacement of any filters	Three monthly (or as required)
Remedial Actions	Repair of overflow erosion damage or damage to tanks	As required
	Pump repairs	As required