The Lake Lothing (Lowestoft) Third Crossing Order 201[*]

Document 6.3: Environmental Statement Volume 3 Appendices

Appendix 18A

Flood Risk Assessment

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Foreword

This Flood Risk Assessment relates to an application ('the Application') submitted by Suffolk County Council ('the Council' / 'the Applicant') to the Secretary of State (through the Planning Inspectorate) for a Development Consent Order ('DCO') under the Planning Act 2008.

If made by the Secretary of State, the DCO would grant development consent for the Applicant to construct, operate and maintain a new bascule bridge highway crossing, which would link the areas north and south of Lake Lothing in Lowestoft, and which is referred to in the Application as the Lake Lothing Third Crossing (or 'the Scheme').

This Flood Risk Assessment has been prepared in accordance with the requirements of section 37(3)(d) of the Planning Act 2008 and regulation 5(2)(e) of the Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009 ('the APFP Regulations'), and in compliance with relevant guidance.

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Abbreviations

AAP	Area Action Plan
AEP	Annual Exceedance Probability
AOD	Above Ordnance Datum
BGS	British Geological Society
CFMP	Catchment Flood Management Plan
DEFRA	Department of Environment, Food and Rural Affairs
DMRB	Design Manual for Roads and Bridges
EA	Environment Agency
FRA	Flood Risk Assessment
FRMS	Flood Risk Management Strategy
IDB	Internal Drainage Board
MHWST	Mean High Water Spring Tide
MLWST	Mean Low Water Spring Tide
NNNPS	National Policy Statement for National Networks
NPPF	National Planning Policy Framework
NPS	National Policy Statement
NSIP	Nationally Significant Infrastructure Project
PFRA	Preliminary Flood Risk Assessment
PPG	Planning Practice Guidance
SCC	Suffolk County Council
SFRA	Strategic Flood Risk Assessment
SMP2	Shoreline Management Plan 2
SuDS	Sustainable Drainage Systems
WDC	Waveney District Council

Tables

1 Introduction

1.1 Description of the Scheme

1.1.1 The scheme involves the construction, operation and maintenance of a new bascule bridge highway crossing linking the areas north and south of Lake Lothing in Lowestoft, hereafter referred to as the Lake Lothing Third Crossing ("the Scheme").

1.1.2 The Scheme would provide a new single-carriageway road crossing of Lake Lothing, consisting of a multi-span bridge with associated approach roads, and would comprise:

- an opening bascule bridge over the Port of Lowestoft, in Lake Lothing;
- on the north side of Lake Lothing, a bridge over Network Rail's East Suffolk Line, and a reinforced earth embankment joining that bridge, via a new roundabout junction, to the C970 Peto Way, between Rotterdam Road and Barnards Way; and
- on the south side of Lake Lothing, a bridge over the northern end of Riverside Road including the existing access to commercial property (Nexen Lift Trucks) and a reinforced earth embankment (following the alignment of Riverside Road) joining this bridge to a new roundabout junction with the B1531 Waveney Drive.

1.1.3 The Scheme would be approximately 1 kilometre long and would be able to accommodate all types of vehicular traffic as well as non-motorised users (“NMUs”), such as cyclists and pedestrians.

1.1.4 The opening bascule bridge design would allow large vessels to continue to use the Port of Lowestoft.

1.1.5 A new control tower building would be located immediately to the south of Lake Lothing, on the west side of the new highway crossing, to facilitate the operation of the opening section of the new bascule bridge.

1.1.6 The Scheme would also entail the following changes to the existing highway network:

- the closure of Durban Road to vehicular traffic at its junction with Waveney Drive;
- the closure of Canning Road at its junction with Riverside Road, and the construction of a replacement road between Riverside Road and Canning Road to the west of the Registry Office; and
- a new access road from Waveney Drive west of Riverside Road, to provide access to property at Riverside Business Park;
- improvements to Kimberley Road at its junction with Kirkley Run; and
- part-signalisation of the junction of the B1531 Victoria Road / B1531 Waveney Drive with Kirkley Run;
- the provision of a pontoon for use by recreational vessels, located to the east of the new highway crossing, within the Inner Harbour of Lake Lothing; and

- works to facilitate the construction, operation and maintenance of the Scheme, including the installation of road drainage systems; landscaping and lighting; accommodation works for accesses to premises; the diversion and installation of utility services; and temporary construction sites and access routes.

1.1.7 The works required for the delivery of the Scheme are set out in Schedule 1 to the draft DCO (application document reference 3.1), where they are referred to as "the authorised development", with their key component parts being allocated reference numbers, which correspond to the layout of the numbered works as shown on the Works Plans (application document reference 2.4). The General Arrangement Plans (document reference 2.2) illustrate the key features of the Scheme.

1.1.8 Plate 1-1 below provides a diagrammatic representation of the Scheme:

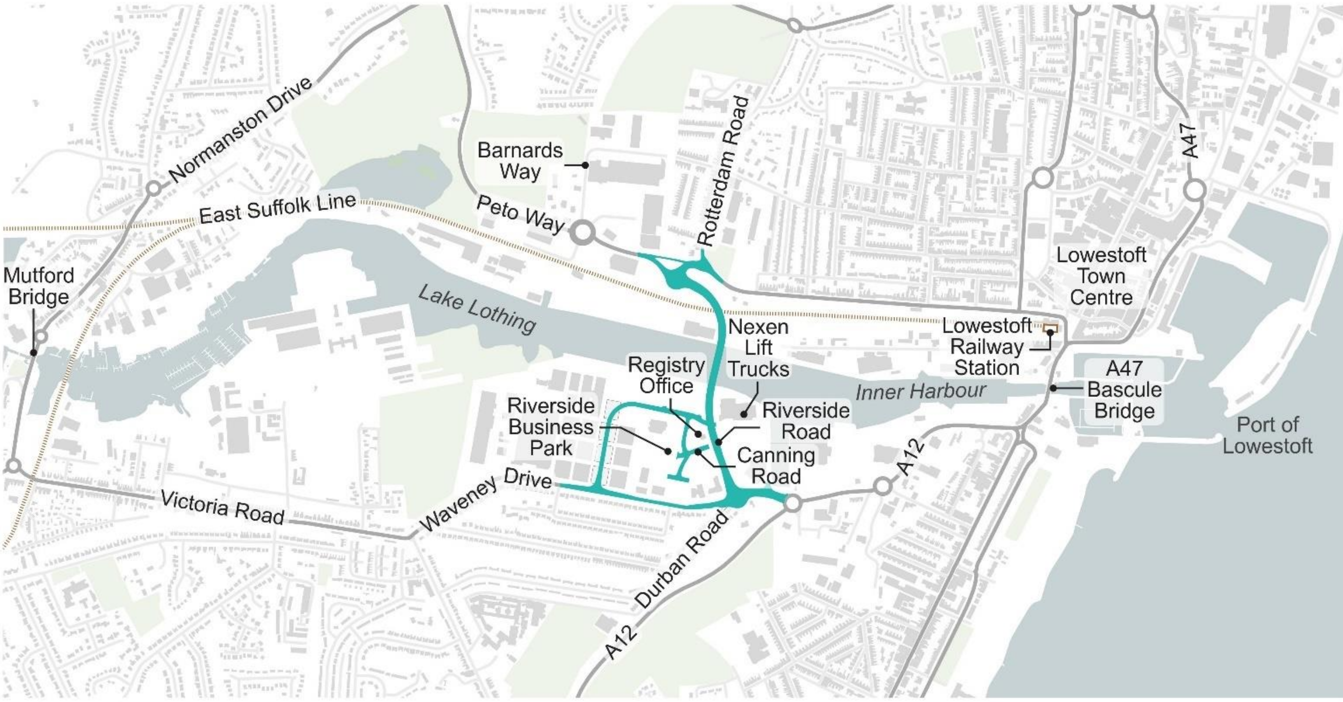

Plate 1-1: Location of the Scheme in Lowestoft

1.2 Scope of the Assessment

1.2.1 The National Policy Statement for National Networks (NNNPS) states that in preparing an FRA, the applicant should:

- "*consider the risk of all forms of flooding arising from the project (including in adjacent parts of the United Kingdom), in addition to the risk of flooding to the project, and demonstrate how these risks will be managed and, where relevant, mitigated, so that the development remains safe throughout its lifetime;*
- *take the impacts of climate change into account, clearly stating the development lifetime over which the assessment has been made;*
- *consider the vulnerability of those using the infrastructure including*

arrangements for safe access and exit;

- *include the assessment of the remaining (known as 'residual') risk after risk reduction measures have been taken into account and demonstrate that this is acceptable for the particular project;*
- *consider if there is a need to remain operational during a worst case flood event over the development's lifetime; and*
- *provide the evidence for the Secretary of State to apply the Sequential Test and Exception Test, as appropriate*".

1.2.2 More comprehensive guidance regarding the FRA process is provided in the NPPF and PPG, therefore this FRA has been carried out in accordance with the requirements of these documents as well as the NPS for National Networks.

1.2.3 The aim of this assessment is to establish the flood risk associated with the Scheme, during the construction phase and the operational phase. The objectives of this FRA are summarised as follows:

- Assess the risk to the Scheme from all potential sources of flooding (both during construction and operation);
- Establish the future flood risk to the Scheme;
- Assess the potential impacts of the Scheme on flood risk elsewhere (both during construction and operation);
- Determine appropriate mitigation measures to manage flooding issues during operation in a sustainable way; and
- Link to the drainage strategy for the Scheme that will address how any additional surface water runoff (from rainfall) generated by the Scheme will be managed.

1.3 Guidance Documents

National Planning Policy Framework

1.3.1 The NPPF sets out the framework for planning decisions made by local, regional and national government and the Environment Agency (EA). The NPPF advises that FRAs are required for all developments in Flood Zones 2, 3a and 3b and for all development sites in Flood Zone 1 that are 1 hectare (ha) or greater. The definitions of these zones are provided in Section 4 of this FRA. The majority of the Scheme site lies in Flood Zone 3 (3a)[1] (refer to Table 4-1), therefore a FRA is required.

Design Manual for Roads and Bridges

1.3.2 The Design Manual for Roads and Bridges (DMRB) Volume 11 (Environmental Assessment) - Section 3 (Environmental Assessment Techniques) - Part 10 HD 45/09 (Road Drainage and the Water Environment) provides guidance on the assessment and management of the impacts that roads projects may have on the water

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[1] This Flood Zone comprises land assessed having a 1% Annual Exceedance Probability (AEP) or greater annual probability of river flooding, or a 0.5% or greater annual probability of flooding from the sea in any year.

environment.

1.3.3 A general theme in this manual identifies that development within floodplains should be restricted to essential transport and utilities infrastructure, and further adds that the design and construction of such infrastructure should allow for full operation even in times of flood. As a result of construction there should be no net loss of floodplain storage, flood flows should not be impeded and the infrastructure should not increase the flood risk elsewhere.

1.3.4 Paragraph 3.30 states that "roads should only be located within functional floodplains....if there is no acceptable alternative and restricted to the shortest practical crossing, avoiding extensive construction within the floodplain. Where this is unavoidable, the level of the road should be above the level of the predicted event....an event with a 1% annual probability of occurrence for river floodplains, or the 0.5% annual event for tidal floodplains".

SuDS Manual (C753)

1.3.5 The SuDS Manual (C753), produced by CIRIA in November 2015, provides best practice guidance on the planning, design, construction, operation and maintenance of sustainable drainage systems (SuDS) to facilitate their effective implementation within developments. Refer to Section 7.2 of this FRA for more information.

The Flood and Water Management Act 2010

1.3.6 The Flood and Water Management Act 2010 designated the Unitary and County Councils as Lead Local Flood Authorities (LLFA). As the designated LLFA for Lowestoft, SCC have an obligation to carry out the following duties:

- Designation of features with a Flood Risk Management role and development and maintenance of a public register of Flood Risk Management Assets (Structures which has an effect on flood risk management);
- Development of a coordinated management of flooding from surface water (from rainfall), groundwater and ordinary watercourses, investigation and recording of flooding events and cooperation with relevant parties;
- Response to major planning applications in relation to sustainable drainage systems;
- Deliver a series of documents which include; Preliminary Flood Risk Assessments, Flood risk/Flood Hazard Maps; Flood Risk Management Plan; and Lead Flood Risk Management Strategy.

1.4 Information Provided

1.4.1 The following information has informed this study:

- the Scheme Design (as expressed in Chapter 5 of the ES);
- Existing A47 bridge alignments and elevations;

- Proposed wider development plans for the area (as described in the Case for the Scheme);
- Bathymetry survey data for Lake Lothing and Lowestoft harbour (collected Spring 2016 by ABP);
- Topographic survey for harbour walls (collected spring 2017 and summer 2016); and
- Existing 1D/2D Hydraulic Model for Lake Lothing used for the Lowestoft Flood Risk Management Strategy, 2016.

1.4.2 The following documents have also been used to gather information for this FRA:

- Suffolk Coastal and Waveney District Strategic Flood Risk Assessment (SFRA), February 2008;
- Broadland Rivers Catchment Flood Management Plan (CFMP), December 2009;
- Suffolk Shoreline Management Plan 2 (SMP2) - Sub-cell 3c, January 2010;
- Suffolk Preliminary Flood Risk Assessment (PFRA), June 2011;
- Suffolk Flood Risk Management Strategy (FRMS), March 2016;
- Flood Risk Management Strategy Overview, March 2016;
- EA data and web based mapping; and
- Lowestoft Cumulative Land Raising Study, June 2008.

2 Existing Site

2.1.1 Lowestoft is a seaside town in Suffolk on the East Anglian coast of England and the Scheme location is shown in Figure 2-1 The harbour at Lowestoft is split into an inner and outer section, the inner harbour is known as Lake Lothing. Lake Lothing is a tidal flushing basin with the water levels and stream currents being driven by the tidal regime in Lowestoft Outer Harbour and passing through the narrow access underneath the A47 Bascule Bridge. Lake Lothing is one of the sea boundaries for the Broadlands rivers catchment and is separated from Oulton Broad by the lock at Mutford Bridge. Lowestoft Outer Harbour is a network of small harbours separated by concrete piers used for boat mooring to the east of the A47 Bascule Bridge.

2.1.2 Lake Lothing is used as a commercial transport hub with a number of large ship berths. The lock at Mutford Bridge at the western upstream end of the lake controls the water flow between Oulton Broad and Lake Lothing and allows the passage of small leisure vessels. Lowestoft currently has two road bridge crossings; the A47 Bascule Bridge and Mutford Bridge as shown in Figure 2-1. These are the only two methods for traffic to cross Lake Lothing. In addition to the road crossings there is a railway crossing near Mutford Bridge as shown on Figure 2-1

2.1.3 Three small fluvial catchments discharge into Lake Lothing; the watercourses associated with these catchments are Kirkley Stream and two small unnamed drainage channels. Kirkley stream is approximately 4.4km long and flows in a northerly direction into Lake Lothing through Kirkley Ham. One of the unnamed drainage channels is also on the south side of Lake Lothing and the other is on the northern side, both are culverted through Lowestoft town centre and the exact course of each is unknown and the outfall location is uncertain.

2.1.4 The Suffolk Coastal and Waveney District SFRA refers to a number of existing flood defences built to protect Lowestoft from tidal surge events. Sea walls and granite stone breakwaters provide some protection on the coast and sheet pile harbour walls provide extra storage within Lake Lothing during high water events.

2.1.5 The existing surface water drainage network asset location mapping has been provided by Anglian Water for this assessment. The network maps show the surface water drains from the local roads and discharges directly into Lake Lothing.

3 The Scheme

3.1.1 The 19.18 hectare (ha) site of the Scheme is shown on Figure 3-1. The Scheme design consists of a central bascule bridge supported by piers with piled foundations, approximately 0.8km west of the A47 Bascule Bridge. See Chapter 5 of the Environmental Statement (ES) for further detail on the Scheme proposals.

3.1.2 Two large central piers support the centre bascule span within Lake Lothing. The central deck height is approximately 16mAOD (metres Above Ordnance Datum). Beneath the bridge deck, the cross-sectional area of the two piers within Lake Lothing totals 140m^2. On land the cross-sectional area of the piers supporting the access ramps underneath the bridge deck totals 62m^2 with the individual pier sizes ranging from 8-14m^2. The access road layout includes a total of two new roundabouts and two embankments on the north and south quays. Further amendments are also made to the existing road network on the north and south side of the Scheme, including a New Access Road on the south side linking Riverside Road and Waveney Drive.

3.1.3 The Scheme is considered a NSIP and deemed 'Safety Critical'. Safety critical is defined as any development that is required to remain accessible/functional in an emergency event. The design life of the Scheme is 120 years and, assuming the Scheme will not be constructed before 2020, it was deemed appropriate to use the year 2140 for future flood scenarios taking into account climate change as requested by the EA (Annex A).

3.1.4 Of the overall Scheme Order limits, 16.25ha (approximately 84% of the total site area) has been identified using aerial imagery and site walkovers as being impermeable in nature. The remaining 2.93ha (approximately 16%) of the site area has therefore been identified as having permeable surfaces. Table 3-1 shows the existing impermeable and permeable areas of the Scheme and the change in these areas upon operation. Figure 3-1 shows the Order limits for the Scheme which is predominately brownfield land and mostly impermeable concrete surfaces that are remnants of former dockside developments.

Table 3-1 - Existing and Scheme (operational phase) areas

	Existing development area (ha)		Scheme area (ha)	
Impermeable surfaces	16.25	(84%)	16.84	(88%)
Permeable surfaces	2.93	(16%)	2.34	(12%)
Total area	19.18		19.18	

3.1.5 The Scheme is mainly located within Flood Zone 3 (3a), which means there is a 0.5% Annual Exceedance Probability (AEP) of flooding from the sea or a 1% AEP chance of flooding from fluvial sources in any given year.

3.1.6 A tidal hydraulic model of Lake Lothing has been produced to carry out this assessment. The hydraulic model has been used to determine flood risk to the Scheme and the impact of the Scheme on flood risk elsewhere.

4 Planning Policy

4.1 National Policy Statements

4.1.1 The Scheme has been defined as a Nationally Significant Infrastructure Project (NSIP) and it has been agreed with the EA that it is 'safety critical infrastructure' for the purposes of paragraph 4.4.1 of the National Networks National Policy Statement (NNNPS).

4.1.2 The NNNPS recognises that as a result of climate change, the risk of flooding will increase within the lifetime of NSIPs. The NNNPS states that the FRA should be carried out with reference to the guidance from the National Planning Policy Framework (NPPF) and accompanying Planning Practice Guidance (PPG) document. The NNNPS also states that flood risk should not be increased elsewhere as a result of a NSIP development. The NPS for Ports (PNPS) provides guidance for assessing flood risk associated with development in ports and acknowledges that whilst development within ports is 'water-compatible' and therefore is permitted in high flood risk areas, it is still necessary to undertake a FRA in line with the NPPF.

4.2 National Planning Policy Framework

Flood Zone Definition

4.2.1 Table 4-1 shows the various Flood Zones as defined in the PPG. These Flood Zones refer to the probability of the river and sea flooding, ignoring the presence of any flood defences. The Scheme is predominantly located in Flood Zone 3 (3a), with smaller areas of the Order limits falling within Flood Zones 1 and 2. Section 6.1 discusses this in greater detail.

Table 4-1 - Flood Zone definitions (recreated from the PPG)

Flood Zone 1	This zone comprises land assessed as having a less than 1 in 1,000 annual probability of river or sea flooding (<0.1%).)	Low Probability
Flood Zone 2	This zone comprises land assessed as having between a 1 in 100 and 1 in 1,000 annual probability of river flooding (1% – 0.1%), or between a 1 in 200 and 1 in 1,000 annual probability of sea flooding (0.5% – 0.1%) in any year.	Medium Probability
Flood Zone 3a	This zone comprises land assessed as having a 1 in 100 or greater annual probability of river flooding (>1%), or a 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year.	High Probability
Flood Zone 3b	This zone comprises land where water has to flow or be stored in times of flood. The identification of functional floodplain should take account of local circumstances but land which would flood with an annual probability of 1 in 20 (5%) or greater in any year, or is designed to flood in an extreme (0.1%) flood, should provide a starting point for consideration.	Functional Floodplain

Flood Risk Vulnerability

4.2.2 In the PPG, developments are also classified according to their 'Flood Risk Vulnerability' as presented in the extract from the PPG in Table 4-2. The Scheme is classified as 'Essential Infrastructure' under the PPG as this covers '*essential transport infrastructure (including mass evacuation routes) which has to cross the area at risk'*.

Table 4-2 - Flood Risk Vulnerability (recreated from the PPG)

Vulnerability Classification	Development Type
Essential Infrastructure	• Essential transport infrastructure (including mass evacuation routes) which has to cross the area at risk. • Essential utility infrastructure which has to be located in a flood risk area for operational reasons, including electricity generating power stations and grid and primary substations: and water treatment works that need to remain operational in times of flood. • Wind turbines.
Highly Vulnerable	• Police stations, ambulance stations and fire stations and command centres and telecommunications installations required to be operational during flooding. • Emergency dispersal points. • Basement dwellings. • Caravans, mobile homes and park homes intended for permanent residential use. • Installations requiring hazardous substance consent. (Where there is a demonstrable need to locate such installations for bulk storage of materials with port or other similar facilities, or such installations with energy infrastructure or carbon capture and storage installations, that require coastal or water-side locations, or need to be located in other high flood risk areas, in these instances the facilities should be classified as "Essential infrastructure").
More Vulnerable	• Hospitals. • Residential institutions such as residential care homes, children's homes, social services homes, prisons and hostels. • Buildings used for dwelling housed, student halls of residence, drinking establishments, nightclubs and hotels. • Non-residential used 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 and cafes, hot food takeaways, offices, general industry, storage and distribution, non-residential institutions not included in "more vulnerable", 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).
Water Compatible Development	• Flood control infrastructure. • Water transmission infrastructure and pumping stations. • Sewage transmission infrastructure and pumping stations. • Sand and Gravel working. • Docks, marinas and wharves. • Navigation facilities • Ministry of Defence; defence installations

	• Ship building, repairing and dismantling, dockside fish processing and refrigeration and compatible activities requiring a waterside location. • Water-based recreation (excluding sleeping accommodation). • Lifeguard and coastguard stations. • Amenity open space, nature conservation and biodiversity, outdoor sports and recreation and essential facilities such as changing rooms. • Essential ancillary sleeping or residential accommodation for staff required by used in this category, *subject to a specific warning and evacuation plan*.

Appropriate Development

4.2.3 The Scheme was initially subject to the Sequential Test and Chapter 3 of Environmental Statement (document reference 6.1) and the Outline Business Case (OBC) (document reference 7.4) for the Scheme (document reference 7.1) explain the reasons for the choice of location for the Scheme and that it is the most appropriate location for the Scheme. The consideration of alternatives included a high level analysis of the likely flood risks from the location. It is also noted that by definition as a crossing scheme over a large watercourse, the Scheme would be required to interact with flood zones.

4.2.4 The Scheme is classified as 'Essential Infrastructure' in accordance with the PPG and is predominantly located in Flood Zone 3 (3a). Applying the flood risk vulnerability and Flood Zone 'compatibility' table from the PPG as shown in Table 4-3 shows that the Exception Test is required for the Scheme in this location.

4.2.5 As set out in the PPG, for the Exception Test to be passed the following must be met:

- *it must be demonstrated that the Scheme development provides wider sustainability benefits to the community that outweigh flood risk, informed by a Strategic Flood Risk Assessment where one has been prepared; and*
- *a site-specific flood risk assessment must demonstrate that the development will be safe for its lifetime taking account of the vulnerability of its users, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall.*

4.2.6 This FRA addresses part two of the Exception Test only. Part one is addressed in the Case for the Scheme (document reference 7.1).

Table 4-3 - Flood risk vulnerability and Flood Zone 'compatibility' (recreated from the PPG)

Flood risk vulnerability classification	Essential infrastructure	Water compatible	Highly vulnerable	More vulnerable	Less vulnerable
Flood Zone 1	√	√	√	√	√
Flood Zone 2	√	√	Exception Test required	√	√
Flood Zone 3a	Exception Test required	√	X	Exception Test required	√

Flood Zone 3b functional floodplain	Exception Test required	√	X	X	X

Key:

Development is appropriate √

Development should not be permitted X

4.3 Local Planning Policy

Adopted Core Strategy

4.3.1 WDC's core strategy of 2009, details the future development ambitions for the Lake Lothing area. The core strategy document is one of the first documents produced as part of the Waveney Local Development Framework. It sets out in strategic terms, the council's overall approach to future development; where it should take place and the key factors that need to be taken into account when considering proposals for development. An important part of this strategy is the redevelopment of Lake Lothing specifically dealt with in policy CS05 Lake Lothing and the Outer Harbour Area Action Plan (AAP).

Waveney Local Plan

4.3.2 WDC is preparing a new Local Plan, consultation on the First Draft Local Plan ran from 28th July to 22nd September 2017.

4.3.3 The First Draft Local Plan recognises that Lowestoft will benefit from improved infrastructure including the Scheme and strategic flood risk protection, both of which will allow the town to grow and thrive. The Lowestoft Flood Risk Management Strategy has considered options for flood protection in the town and the First Draft Local Plan states that the strategy involves reducing flood risk in central Lowestoft through a range of measures.

4.3.4 There is a specific policy on flood risk within the First Draft Local Plan – Policy WLP8.34 – that sets out how development proposals should take flood risk into account. The policy also states that the SFRA should be the starting point in assessing whether a proposal is at risk from flooding.

5 Previous Studies and Historic Flood Risk

5.1 Previous Studies

5.1.1 The following previous studies have been found that reference flooding in Lowestoft:

- Suffolk Coastal and Waveney District SFRA, February 2008;
- Broadland Rivers CFMP, December 2009;
- Suffolk SMP2 Sub-cell 3c, January 2010;
- Suffolk PFRA, June 2011;
- Suffolk FRMS, March 2016;
- Lowestoft Flood Risk Management Strategy Overview, March 2016; and
- Lowestoft Cumulative Land Raising Study, June 2008.

Suffolk Coastal and Waveney District Strategic Flood Risk Assessment.

5.1.2 The Suffolk Coastal and Waveney District SFRA was undertaken in February 2008 on behalf of WDC and Suffolk Coastal District Council. The document provides an overview of the flood risk issues across the districts from all sources. The Scheme lies within the area covered by the Suffolk Coastal and Waveney District SFRA and covers the entirety of the study area.

5.1.3 The SFRA states that Lowestoft is at significant risk of tidal flooding given the close proximity to the coast and the generally low lying land that makes up the urban area. In addition, Lake Lothing is located in the middle of the urban area of Lowestoft, providing an additional flood risk to the area.

5.1.4 The tides on the Suffolk coast are semidiurnal, which means the coastline experiences two high and two low tides of approximately equal size every lunar day. Major surges have occurred along this stretch of the coast in 1953, 1976 1978 and 2013, as well as a number of earlier events with significant flooding occurring in Lowestoft in 1953 and 2013. Tidal information for the North Sea at Lowestoft is available from the Admiralty Tide Tables (2006 edition). The reported mean high water spring tide (MHWST) at Lowestoft is 1.08mAOD and the reported mean low water spring tide (MLWST) is -0.86mAOD. These figures indicate a tidal range of approximately 1.9m under normal conditions, however, this does not account for the impact of waves or surges, which can increase water levels significantly.

5.1.5 According to the SFRA, Lowestoft is one of the areas with the greatest potential risk from a 0.5% AEP tidal event. The main flood mechanism is tidal flooding and fluvial systems therefore become tide-locked. Tide-locking occurs when rivers and streams cannot discharge their water load into estuaries or the sea, causing the river and stream water to 'back up' and reach high levels. Tide-locking has the greatest impact when tidal events coincide with high river flows.

5.1.6 A variety of different types of coastal defences within Lowestoft are highlighted in the

SFRA (see Plate 5-1 to Plate 5-3) and in their response to the Scoping Report for the Scheme, SCC in their role as lead local flood authority and WDC confirmed that temporary barriers are installed in times of foreseen flood risk. However, these temporary barriers have not been included within the assessment to provide a worst case scenario for the assessment.

Plate 5-1 - Lowestoft North Denes sea wall (extract from SFRA)

Plate 5-2 - Sheet pile wall in Lowestoft acting as informal flood defence (extract from SFRA)

Plate 5-3 - Mutford Bridge lock gates acting as informal flood defences (extract from SFRA)

5.1.7 The SFRA also provides an assessment of the risks associated with a breach of the coastal defences. For Lowestoft, this includes further information on the tidal flooding hazard (should a breach occur in the defences) and the probability of tidal flooding. Both the present-day situation and the potential situation in around 100 years' time (the year 2107) have been evaluated. Results show that Lowestoft is at risk from flooding as shown in Plate 5-4, this is due to informal flood defences of insufficient standard (i.e. not to the 0.5% AEP standard). New flood defences are planned in Lowestoft as part of the Lowestoft Flood Risk Management Strategy. Paragraph 5.1.22 discusses this in relation to the Scheme.

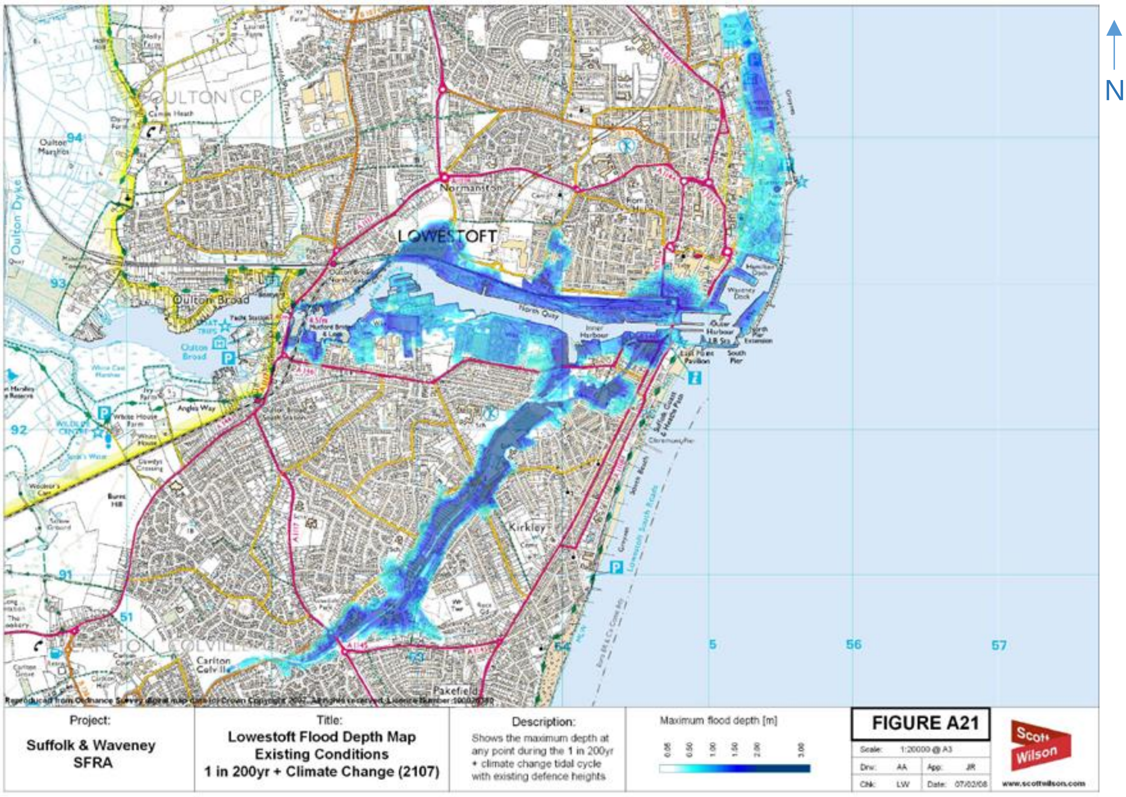

Plate 5-4 - Flood risk extent for 0.5% AEP tidal event for the year 2107 (extract from SFRA Figure A21)

5.1.8 The overtopping of man-made banks around Lake Lothing would cause inundation of large parts of Lowestoft. The defences surrounding the Lake Lothing area are significantly below standard, with their crest heights below the 0.5% AEP, 0.1 AEP and 0.5% AEP plus climate change water levels. A breach in the flood defence, combined with the overtopping of existing man-made banks would cause widespread inundation of Lowestoft.

5.1.9 Lowestoft is particularly sensitive to flooding due to the situation of Lake Lothing and the surrounding developed areas. As identified in the SFRA flooding around the margins of the Lake occurs when gravity outfalls to Lake Lothing become tide-locked and this is a concern to both present and future developments. Flooding also occurs in the town following heavy rainfall due to limited sewer capacity and the tide-locking of sewer outfalls. The SFRA therefore recommends that developments within

Lowestoft should aim to mimic green field runoff rates by incorporating SuDS into development designs to limit runoff to surrounding areas. In addition, it suggests that steps should be taken to improve the tidal outfall systems to limit tide-locking.

5.1.10 The SFRA goes on to say that restrictions to greenfield runoff rates should be employed in developments in Lowestoft and any other areas that experience regular flooding, to ease surface water (from rainfall) flooding and drainage capacity exceedance. Further, it suggests that developments in the locality of Lowestoft should assess whether capacity is available within the system to attenuate their excess site runoff and provide a contribution to the maintenance of the Scheme; and that any future development should ensure that improvements to infrastructure in the district include drainage and considerations of access and egress for emergency planning purposes.

5.1.11 Lowestoft is divided by Lake Lothing and there are restricted access points across this waterbody. Therefore in the event of a flood the SFRA makes clear that it is essential that any emergency plan takes into consideration that the infrastructure across this water body may be flooded, and alternatives will need to be incorporated into the evacuation plans.

Broadland Rivers Catchment Flood Management Plan

5.1.12 The Broadlands Rivers CFMP was published in December 2009 by the EA. Its purpose is to provide an overview of the flood risk for the Broadlands Rivers catchment and sets out the preferred plan for sustainable flood risk management over the next 50-100 years. Produced through a wider consultation and appraisal process, it identifies flood risk management policies to assist all key decision makers in the catchment.

5.1.13 The Broadlands River catchment includes five major rivers: the Rivers Ant, Bure, Wensum, Yare and Waveney. These catchments drain into the tidally dominated area of inland waterways known as The Broads, and finally out to sea through the mouth of the River Yare at Great Yarmouth. The downstream limit of the CFMP area is located at the boundary between the Norfolk SMP2 and the Suffolk SMP2. Although the SMP2 boundary is in Lowestoft, the Scheme sits fully within the Suffolk SMP2 area therefore Norfolk SMP2 has not been reviewed as part of this assessment.

5.1.14 The topography of the Broadland Rivers catchment is predominately flat. The area upstream of Norwich is relatively hilly, however as the rivers reach the Broads, they become wide and flat. Here the land is mostly below sea level and as such is mostly tidal in nature.

5.1.15 The Scheme is located within Lowestoft Sub-area 6 where the preferred policy option is 5; *'Areas of moderate to high flood risk where we can generally take further action to reduce flood risk'*. This policy applies to those areas where the case for further action to reduce flood risk is most compelling, for example where there are many people at high risk, or where changes in the environment have already increased risk. Taking further action to reduce risk will require additional appraisal to assess whether there are socially and environmentally sustainable, technically viable and economically justified options.

5.1.16 The CFMP states that the main source of flooding in Lowestoft is from tidal sources, with 941 properties at risk during the 0.5% AEP, however there is also a risk from surface water (from rainfall) and sewer flooding. The key messages for Lowestoft, Sub-area 6 are:

- "Continue with and implement the recommendations from the Lowestoft Standards of Protection study;
- Any redevelopment of floodplain areas is an opportunity to increase their flood resilience;
- Organisations must work together to provide an integrated approach to urban drainage issues and surface water flooding; and
- Flood awareness and emergency response plans should be used to manage the consequences of flooding".

5.1.17 The document considers that essential actions to achieve the preferred approach are as follows:

- "Continue with and implement the recommendations from the Lowestoft Standards of Protection study;
- Investigate the feasibility of improving current maintenance activities;
- Develop a flood warning plan to consider improvements to the current flood warning service;
- Reduce the consequences of flooding by: improving public awareness of flooding; encouraging people to sign up to, and respond to flood warnings;
- Work with partners to develop a Surface Water Management Plan for Lowestoft; and
- Encourage planners to develop policies for new development and regeneration (including commercial sites) to incorporate resilience measures so that the location, layout and design of development can help to reduce flood risk. Planners should prevent inappropriate development in the floodplain using measures set out in Planning Policy Statement 25 (now replaced by the NPPF), and ensure that any new development does not increase the risk to existing development. Any new development or regeneration should provide opportunities to improve the river environment and make space for water".

Suffolk Shoreline Management Plan 2 Sub-cell 3c, January, 2010

5.1.18 The SMP2 deals with the protection of the shoreline from erosion and high surge events. The SMP2 states that the present-day policy is to continue to hold the existing line to protect the Lowestoft town frontage, through maintenance of the existing assets. The medium to long term plan foresees no change in the present-day plan however it does state considerable investment may be required to maintain defences.

Suffolk Preliminary Flood Risk Assessment, June 2011

5.1.19 The Suffolk PFRA was published in June 2011. The report states that the main source of fluvial flooding is from a tidal locking situation where water is unable to leave the estuary and backs up into the town. There is limited information regarding tidal flooding in this document.

Suffolk Flood Risk Management Strategy, March 2016

5.1.20 Suffolk County Council produced the Suffolk FRMS in 2016, a replacement for a 2013 document, with the aim to try and reduce the risk of flooding and the effect it has. SCC as local lead flood authority aim to do this by firstly finding new ways of managing flood risk and not simply relying of traditional approaches such as defences built by statutory agencies. Secondly, individual responsibility is promoted by encouraging people to protect themselves and their property as much as possible.

Lowestoft Flood Risk Management Strategy Overview, March 2016

5.1.21 WDC published the Lowestoft FRMS Summary in 2016 and this summarises the work carried out by WDC thus far on the strategy. The document states that the main source of flooding is from sea surge events which are increasingly experienced along the east coast. The council wishes to put together a business case for funding to increase the flood defences and prepare for climate change. As part of this overview, the council commissioned a study looking at potential tidal defence structures in Lake Lothing for future development.

5.1.22 CH2M-Hill carried out an assessment[2] looking at all the potential solutions to tidal flooding. Options considered ranged from small property level protection to large scale coastal defence barriers to protect against tidal surge events by restricting access to Lake Lothing. The favoured option is a combination of a new tidal defence gate at the A47 Bascule Bridge, increases to existing defences and temporary flood barriers to provide 0.5% AEP standard of protection. As the proposed tidal barrier scheme has not yet been built, it has been assumed for this flood risk assessment that it will not be in place when the scheme is built and therefore the benefit of the new defences are not incorporated.

Lowestoft Cumulative Land Raising Study.

5.1.23 The Lowestoft Cumulative Land Raising Study was completed by Scott-Wilson on behalf of Waveney District Council and involved a 2D modelling assessment of Lake Lothing to assess the impact on flooding if sections of Lowestoft adjacent to Lake Lothing were raised. A number of different land raising scenarios were considered in the study, the modelling showed that the maximum increase in flood depths across all the scenarios was 0.02m, which was considered a minor increase.

5.2 Historic Flooding

5.2.1 Lowestoft town centre has been subject to tidal surge flooding twice in recent history,

[2] Lowestoft Tidal Defences Additional Modelling Studies, CH2M Hill on behalf of Waveney District Council, 2014

once in 1953 and again in 2013. The cause of the flooding is believed to be a combination of a high tide and a tidal surge peaking concurrently. The EA historic flood maps show that a number of waterfront locations have been flooded in the past. The CFMP reports that surface water (from rainfall) and sewer flooding has caused problems in Lowestoft due to the inadequate capacity of the sewage system, or by surface water sewers unable to drain freely into rivers.

5.2.2 The SFRA states that there are significant urban areas, such as the centre of Lowestoft, that are reliant on pump-drained surface water sewerage systems. Sewer capacity and tide-locking of combined sewer outfalls into the harbour has led to the flooding of low-lying areas of the town (notably Station Square, Beven Street, Tonning Street and Norwich Road) north of the harbour following periods of heavy rainfall. A major tunnelling project, undertaken and now constructed by Anglian Water, is intended to reduce the risk of flooding from surface water sewers, however this has not been taken into account for the purposes of this FRA. To the south of the harbour, (notably Belvedere Road, London Road, St John's Road and Marine Parade) a similar problem exists. This area is dependent on storm water overflows into the harbour and Anglian Water's harbour pumping station which pumps sewage to Ness Point.

5.2.3 In late January 1953 Lowestoft, and the wider North Sea coast experienced tidal flooding from the North Sea following a northwest gale and a swelling spring tide, causing the sea to rise to very dangerous levels. Coastal flood defences were breached by huge waves in 1200 locations, inundating coastal towns along the east coast from Hull in the north to Deal in the south, including Lowestoft, Southwold, Aldeburgh and Felixstowe amongst others. This event resulted in 300 deaths in England and 24,000 flooded properties, including 400 in Lowestoft. A number of communication networks were also seriously affected, including the railway line from Lowestoft to Norwich.

5.2.4 A period of high intensity rainfall in September 2006 resulted in surface water flooding in the Lowestoft area. In addition, a combination of high tides and high rainfall intensity lead to widespread flooding across the district of Waveney in 2006. Strong winds, high tides and a storm surge also occurred along the East Anglian coast in November 2007. Extensive flooding resulted from Lowestoft to Felixstowe in Suffolk.

6 Flood Risk Assessment

6.1 Flood Risk from Rivers and the Sea

6.1.1 The EA Flood Map for Planning in Figure 6-1 shows that the majority of the Scheme lies within Flood Zone 3 (3a). This is land assessed as having a 0.5% AEP or greater risk of flooding from the sea or a 1% AEP or greater risk of flooding from rivers. Based on the information available, the site is considered to be at high risk from tidal flooding and is not considered to be at risk of flooding from rivers.

6.1.2 The northern embankment and northern roundabout are all within Flood Zone 3 (3a). The south bank approach road network is predominately within Flood Zone 3 (3a), although parts of it are in Flood Zones 2 and 1. The Scheme lies within an EA Flood Warning Area.

6.1.3 As part of the FRA, detailed hydraulic assessment of tidal flood risk from Lake Lothing to the Scheme and the impact of the Scheme on flood risk elsewhere has been undertaken. The hydraulic modelling work undertaken for this FRA is summarised in Paragraphs 6.1.5 to 6.1.11 and full details are provided in Annex B.

Consultation

6.1.4 As Lake Lothing is designated as Main River, the EA have been consulted as part of this assessment. The EA have reviewed the methodology for this assessment and the hydraulic model developed for this assessment (see Annex A for EA consultation responses). The consultation responses from the EA included their requirements for this assessment and these have been taken into account. Similarly, comments from Anglian Water at the scoping opinion stage (Appendix 6B of the ES) have been incorporated within the scope of this FRA.

Hydraulic Model Development

6.1.5 A 2D TUFLOW model of Lake Lothing and the outer harbour has been developed for this assessment. This section of the FRA presents the outputs of the hydraulic modelling undertaken, full details of the hydraulic model build are provided in the hydraulic modelling report in Annex B. A summary of the model scenarios developed is provided in paragraphs 6.1.6 to 6.1.11, the model results are described in paragraphs 6.1.15 to 6.1.35.

6.1.6 A baseline model was developed to represent the existing flood risk within Lowestoft. The baseline model was subject to sensitivity testing to ensure the model was robust and could be used to undertake hydraulic assessments as part of the FRA process. It was not possible to fully calibrate the hydraulic model due to a lack of suitable data as discussed in the Hydraulic Modelling Report (refer to Annex B). The 2013 storm surge event has been modelled and the predicted flooding checked against historic flood extents for Lowestoft and photos/anecdotal evidence to verify the model results. These are discussed in full in the Hydraulic Modelling Report (refer to Annex B). The model has been reviewed by the EA the model has been deemed robust and suitable for use in this assessment.

6.1.7 The model has been used to investigate the risk of flooding in Lowestoft for the present day scenario and, in order to consider the impact of and resilience to future flooding, the model has also been used to simulate future flood events with an allowance for climate change included (based on allowances for the year 2140, 120 years in the future). Due to the designation of the Scheme as a NSIP and safety critical infrastructure, the EA have requested that the low probability, high risk flood event (H++) within the UK Climate Projections 2009[3] (UKCP09) predictions is also modelled to assess a credible maximum scenario, although mitigation is not required for the H++ scenario. The study area for this assessment has been defined based on the 0.1% AEP H++ scenario flood extent, the study area is shown on Figure 6-2.

6.1.8 The hydrology of Lake Lothing has been analysed to derive inflows to the hydraulic model. Tidal levels have been derived to define the eastern boundary of the hydraulic model that represents sea levels along the Lowestoft coast. The latest extreme sea levels calculated for the Open Coast (CFBD) Flood Risk Study[4] have been used in the tidal level assessment. There are a range of methods to determine climate change allowance in terms of sea level rise and following consultation the EA recommended reviewing all of the scenarios and selecting the highest potential future sea level rise calculated for use in this FRA. Sea level rise at Lowestoft 120 years in the future was therefore calculated using the following:

- NPPF Flood risk assessments: climate change allowances[5];
- UKCP09 50% High Emissions;
- UKCP09 95% High Emissions;
- UKCP09 95% Medium Emissions; and
- Upper End Allowance, Table 5 of Adapting to Climate Change[6].

6.1.9 The highest sea level rise was calculated using the climate change allowances given in the NPPF (a rise of 1.54m by 2140) and this value has been used in this assessment as agreed with the EA. The impact of fluvial flows on flood risk to the Scheme was considered as part of the hydraulic assessment but these were found to have a negligible impact on flooding of the Scheme. Therefore only tidal flooding has been modelled as part of this assessment and this was agreed with the EA.

6.1.10 Once the baseline model had been developed and verified, a version of the model was developed to represent Lowestoft during the operational phase of the Scheme and to understand the flood risk to the Scheme. The results from the baseline and Scheme scenarios have been compared to ascertain the impact of the Scheme on flooding

[3] http://ukclimateprojections.metoffice.gov.uk/

[4] Open Coast (CFBD) Flood Risk Study, JBA, 2014

[5] NPPF Flood risk assessments: climate change allowances, Environment Agency, 2016

[6] Adapting to Climate Change, Environment Agency, April 2016

elsewhere.

6.1.11 It has been agreed with the EA that the Scheme design does not need to mitigate for the impacts predicted by the model for the high risk, low probability H++ event. The climate change scenario representing flood risk in Lowestoft in 2140 (using Table 3 of the NPPF) allowance for sea level rise has been used to inform the design and mitigation of the Scheme.

6.1.12 Additional model runs have been undertaken for the 0.5% AEP event to understand the impact of the Scheme if the bridge piers were 50% larger than the reference design. As explained in Annex B, a 10% blockage of the total cross-sectional area underneath the bridge deck has been used to represent the bridge piers for the Scheme scenario. In the ‘Scheme Worst Case’ scenario, a 15% blockage of the total cross-sectional area underneath the bridge deck was applied to represent a reasonable worst case scenario if the bridge piers were increased in size by approximately 150%. The scenarios modelled for this assessment are listed in Table 6-1.

Table 6-1 – Modelled Scenarios

Scenario	Return Period	Present Day - 2017	Climate Change - 2140	H++ (UKCP09 high risk, low probability scenario)
Baseline	5% AEP	Lowestoft_baseline_20	Lowestoft_baseline_20cc	Lowestoft_baseline_20cc+
	0.5% AEP	Lowestoft_baseline_200	Lowestoft_baseline_200cc	Lowestoft_baseline_200cc+
	0.1% AEP	Lowestoft_baseline_1000	Lowestoft_baseline_1000cc	Lowestoft_baseline_1000cc+
Scheme	5% AEP	Lowestoft_scheme_20	Lowestoft_scheme_20cc	Lowestoft_scheme_20cc+
	0.5% AEP	Lowestoft_scheme_200	Lowestoft_scheme_200cc	Lowestoft_scheme_200cc+
	0.1% AEP	Lowestoft_scheme_1000	Lowestoft_scheme_1000cc	Lowestoft_scheme_1000cc+
Scheme Worst Case	0.5% AEP	Lowestoft_scheme_worst_case_200	Lowestoft_scheme_worst_case_200cc	Lowestoft_scheme_worst_case_200cc+

Methodology for Assessing the Results

6.1.13 The results of the model runs representing the Scheme scenario have been compared to the baseline model results for each simulation. In order to assess the impact of the Scheme, water levels predicted for the different model runs have been compared at the comparison points shown on Figure 6-3. Changes in water level across the floodplain have also been investigated.

6.1.14 The need for flood mitigation is dependent on the magnitude of impact and the vulnerability of the receptors that are affected by any increase in flood depth. Table 6-2 shows how a given increase in flood depth from the baseline scenario to the Scheme scenario will be classified in terms of impact. Table 6-3 compares the magnitude of impact with the flood risk vulnerability of a receptor (taken from Table 2 within the NPPF PPG for flood risk and coastal change) to demonstrate when mitigation is required. The tables are valid up to and including the 0.5% AEP plus climate change event as the scheme has to be designed and mitigated up to this level in line with current guidance[7]. The 0.1% AEP event has been included to provide a more detailed understanding of flood risk to Lowestoft and mitigation is not required for this event as agreed with the EA. Table 6-3 is used to determine when mitigation is required based on the receptor sensitivity and magnitude of impact. Professional judgement is implicit within this process through the interpretation of the model results which inform the magnitude of impact and is also required to ensure that mitigation is technically viable.

Table 6-2 Classification of magnitude of flooding Impact

Magnitude of Impact	Change in depth (m)
No change	0
Negligible	>0.0 – <=0.02
Moderate	>0.02 – <=0.3
Major	0.3+ **OR** Flooding in areas that were previously not flooding.

Table 6-3 Significance of flood impact

Magnitude of Impact	Receptor Sensitivity				
	Water Compatible	**Less Vulnerable**	**More Vulnerable**	**Highly Vulnerable**	**Essential infrastructure**
No change	No Mitigation required	No Mitigation required	No Mitigation required	No Mitigation required	No Mitigation required
Negligible	No Mitigation required	No Mitigation required	No Mitigation required	Mitigation	Mitigation
Moderate	No Mitigation required	Mitigation	Mitigation	Mitigation	Mitigation
Major	No Mitigation required	Mitigation	Mitigation	Mitigation	Mitigation

Hydraulic Model Results

Introduction

6.1.15 The baseline scenario within the hydraulic model has been used to determine the existing tidal flood risk to the Scheme. The baseline flood extents, as predicted by the model, are shown in Figure 6-4. The model predicts flooding within the red line boundary for the 5% AEP, 0.5% AEP and 0.1% AEP events (Figure 6-4). The baseline 0.5% AEP model predicted flood extent is similar to the existing Flood Zone 3 (3a).

[7] Flood Risk Assessment: standing advice, https://www.gov.uk/guidance/flood-risk-assessment-standing-advice, 2017.

6.1.16 There is only a small amount of flooding predicted within the red line boundary for the 5% AEP event to the south of Kirkley Ham. Flooding predicted by the 0.5% and 0.1% AEP events covers a large proportion of the Scheme within the Order limits.

Present Day - 2017

6.1.17 Table 6-4 shows the water levels predicted by the model in Lake Lothing in the baseline and operational scenarios for the present day at each of the comparison points on Figure 6-3. The results in Table 6-4 show that within Lake Lothing the Scheme has a negligible impact on peak water levels for the present day scenario. There is no change in water levels predicted within Lake Lothing during the operational phase of the Scheme during the 5% AEP present day event. For the 0.5% AEP present day event, no increase in water levels within Lake Lothing is predicted and there is a negligible decrease in water levels predicted to the west of the Scheme. During the 0.1% AEP event, there is a negligible increase, as defined in Table 6-2 (up to 0.01m) in water levels on the eastern side of the new bascule bridge and a moderate decrease in water levels on the western side (up to 0.03m). There is no increase in predicted water levels for the 0.5% AEP present day event for the Scheme Worst Case scenario compared to the Scheme scenario.

Table 6-4 Present Day 2017 Hydraulic Modelling Results

Present Day	Baseline (mAOD)			Difference (Proposed – Baseline (m)		
Point	5%	0.5%	0.1%	5%	0.5%	0.1%
P1	2.74	3.39	3.91	0.00	0.00	0.00
P2	2.74	3.39	3.90	0.00	0.00	0.00
P3	2.74	3.39	3.91	0.00	0.00	0.01
P4	2.74	3.39	3.91	0.00	0.00	0.00
P5	2.73	3.35	3.82	0.00	0.00	0.01
P6	2.73	3.33	3.77	0.00	0.00	0.00
P7	2.74	3.34	3.76	0.00	0.00	0.01
P8	2.74	3.34	3.76	0.00	0.00	0.01
P9	2.74	3.34	3.76	0.00	0.00	0.01
P10	2.74	3.34	3.76	0.00	0.00	0.01
P11	2.74	3.34	3.76	0.00	-0.02	-0.03
P12	2.74	3.34	3.76	0.00	-0.02	-0.03
P13	2.74	3.34	3.76	0.00	-0.02	-0.02
P14	2.74	3.34	3.76	0.00	-0.02	-0.03
P15	2.74	3.32	3.73	0.00	-0.02	-0.03
P16	2.73	3.28	3.63	0.00	-0.02	-0.03

6.1.18 The impact of the Scheme on water levels on the floodplain has also been considered in this FRA. Difference flood maps have been calculated and presented in the Annex

B – Modelling report. For the 5% AEP present day event, there is no change in flood levels on the floodplain between the baseline and Scheme scenarios. For the 0.5% AEP present day event a negligible increase in water level (up to 0.01m) compared to the baseline is predicted on the floodplain to the east of the Scheme and there is a decrease in water levels of up to 0.06m to the west of the Scheme. During the 0.1% AEP present day a negligible increase of up to 0.02m is predicted across the floodplain on the eastern side of the Scheme. There is a small area within the model results for this event where an increase of 0.06m is predicted in the Scheme scenario compared to the baseline but this covers a small number of cells within the model and corresponds with a low point in the LiDAR within the carpark of Asda and Dunelm near the A12.

6.1.19 The bascule bridge deck of the Scheme is not predicted to flood during any of the present day scenarios modelled but flooding is predicted to other parts of the Scheme as shown on Figure 6-5 An observation point has been chosen on each of the access roads to the north and south of the proposed bascule bridge in order to determine the depth of flooding predicted on the approach to the proposed bascule bridge and to give an indication of the safety and operability of the new crossing during flood events.

6.1.20 The flooding predicted to the Scheme during the 5% AEP present day event is minimal and no flooding is predicted at either of the observation points shown on Figure 6-5. There is flooding predicted to the proposed road network to the south of Kirkley Ham during the 5% AEP present day scenario (as shown by the purple flood outline on Figure 6-5), the flood depth predicted by the model in this location is 0.12m.

6.1.21 During the 0.5% AEP present day event, flooding is predicted at the observation point to the south of Lake Lothing (shown on Figure 6-5). In the baseline scenario, the predicted flood depth at this southern observation point is 0.13m and this is not predicted to increase in the Scheme scenario. Flooding is also predicted at the observation point to the south of Lake Lothing during the 0.1% AEP event and the flood depth predicted here is 0.56m in the baseline and Scheme scenarios. At the observation point to the north of Lake Lothing, there is a decrease in flood depth predicted with the Scheme in place during both the 0.5% AEP and 0.1% AEP present day events. The baseline predicted flood depth at the northern observation point is 0.95m for the 0.5% AEP present day event and 1.37m for the 0.1% AEP present day event. With the Scheme in place, the predicted flood depths are reduced to 0.93m and 1.35m for the 0.5% and 0.1% AEP present day events respectively.

6.1.22 Figure 6-6 and 6-7 show the 0.5% AEP present day Hazard Map for the baseline and Scheme respectively using the Department of Environment, Food and Rural Affairs (DEFRA) flood hazard categories. Figure 6-6 shows that in the baseline scenario the majority of the floodplain is within the significant category with some areas showing moderate risk. Figure 6-7 shows that there are very small differences in the hazard categories between the baseline and Scheme simulations. The differences are localised due to the influence of the access roads on the flow patterns and alternate between "moderate" and "significant" categories and are within the port infrastructure areas. There is no additional risk to buildings in the 0.5% AEP present day event because of the Scheme.

6.1.23 Figure 6-8 shows a comparison between the flood extents in the 0.5% AEP event for the baseline and Scheme scenarios. This shows that there is no increase in flood extent due to the Scheme. There is a small decrease in flood extent to the west of the Scheme as a result of the increase in flood depth to the east of the Scheme. Increasing the flood depth to the east of the Scheme does not increase the extent of flooding and there are no additional properties at risk of flooding due to the presence of the Scheme.

Climate Change 2140

6.1.24 Table 6-5 shows the peak water levels predicted by the model in the baseline and Scheme scenarios at the comparison points within Lake Lothing (Figure 6-3) for the climate change events modelled (highlighted comparison points are those closest to the Scheme). For both the 5% and 0.5% AEP climate change events, there is a negligible increase (up to 0.02m) in water levels predicted within Lake Lothing with the Scheme in place on the eastern side of the proposed bridge. A moderate decrease in water levels within Lake Lothing is predicted to the west of the Scheme for both the 5% and 0.5% AEP climate change events. The Scheme has a greater impact during the climate change events due to the higher tidal levels for these events compared to the present day events. The tidal levels during all of the climate change events are high enough for a small head loss to be generated across the bridge in the Scheme model. There is no increase in predicted water levels for the 0.5% AEP climate change event for the Scheme Worst Case scenario compared to the Scheme scenario.

Table 6-5 Climate Change 2140 Hydraulic Modelling Results

Climate Change	Baseline (mAOD)			Difference (Proposed – Baseline (m)		
Point	5%	0.5%	0.1%	5%	0.5%	0.1%
P1	4.27	4.93	5.45	0.00	0.00	0.00
P2	4.26	4.92	5.44	0.00	0.00	0.00
P3	4.27	4.93	5.45	0.00	0.00	0.00
P4	4.27	4.93	5.46	0.00	0.00	0.00
P5	4.16	4.75	5.25	0.01	0.01	0.01
P6	4.05	4.63	5.11	0.01	0.01	0.02
P7	4.03	4.56	5.01	0.01	0.02	0.02
P8	4.03	4.57	5.01	0.02	0.02	0.04
P9	4.03	4.57	5.01	0.01	0.02	0.03
P10	4.03	4.58	5.01	0.02	0.02	0.04
P11	4.03	4.57	5.01	-0.03	-0.04	-0.04
P12	4.03	4.58	5.01	-0.03	-0.04	-0.05
P13	4.03	4.57	5.01	-0.03	-0.04	-0.04
P14	4.03	4.57	5.01	-0.04	-0.06	-0.07

Climate Change	Baseline (mAOD)			Difference (Proposed – Baseline (m)		
Point	5%	0.5%	0.1%	5%	0.5%	0.1%
P15	3.99	4.52	4.95	-0.04	-0.05	-0.07
P16	3.84	4.27	4.58	-0.03	-0.04	-0.05

6.1.25 As shown in Table 6-5 for the 5% AEP climate change event, water levels on the floodplain to the east of the Scheme are predicted to increase by up to 0.02m (negligible) within the Scheme scenario compared to the baseline scenario. To the west of the Scheme, decreases of up to 0.04m (moderate) are predicted compared to the baseline scenario. In the 0.5% AEP climate change event floodplain water levels are predicted to increase by up to 0.02m (negligible) to the east of the Scheme above the baseline scenario and water levels are predicted to decrease by up to 0.06m (moderate) to the west of the Scheme. The 0.1% AEP plus climate change events shows water level increases of up to 0.05m (moderate) on the floodplain in the Scheme scenario. Predicted water levels to the west of the Scheme decrease by up to 0.08m (moderate) during the 0.1% AEP Scheme scenario. Difference flood maps have been calculated and presented in the Annex B – Modelling report.

6.1.26 The bascule bridge deck of the Scheme is not predicted to flood during any of the climate change scenarios modelled but other parts of the Scheme will as shown on Figure 6-9. The two observation points have been used to report the predicted flood depth in the baseline and Scheme climate change scenarios.

6.1.27 Both the northern and southern observation points are flooded during the 5% AEP climate change event in both the baseline and Scheme scenario. The depth of flooding at the observation point to the south of Lake Lothing during the 5% AEP climate change event is 0.82m in the baseline scenario and 0.83m in the Scheme scenario. At the observation point to the north of Lake Lothing, the flood depth is reduced in the Scheme scenario compared to the baseline; a flood depth of 1.64m is predicted for the 5% AEP climate change event baseline scenario and a flood depth of 1.61m is predicted for the 5% AEP climate change event Scheme scenario. During the 0.5% AEP climate change event, the predicted flood depth at the observation point to the south of Lake Lothing is 1.36m in both the baseline and Scheme scenarios. The predicted depth of flooding does not change between the baseline and Scheme scenario at the southern observation point for the 0.1% AEP climate change event either with a flood depth of 1.79m predicted in both scenarios.

6.1.28 At the observation point to the north of Lake Lothing, there is a reduction in flood depth predicted by the model in the Scheme scenario compared to the baseline scenario during both the 0.5% AEP and 0.1% AEP climate change events. The predicted depth of flooding decreases from 2.19m in the baseline scenario to 2.15m in the Scheme scenario for the 0.5% AEP climate change event. The predicted depth of flooding decreases from 2.62m in the baseline scenario to 2.57m in the Scheme scenario for the 0.1% AEP climate change event.

6.1.29 Figure 6-10 and 6-11 show the 0.5% AEP climate change event Hazard Map for the baseline and Scheme respectively. The figures plots the DEFRA flood hazard categories. Figure 6-10 shows there are significant areas of extreme hazard for the baseline scenario, this was expected due to the flood depths caused by the extreme tide. Figure 6-11 shows there is a small difference between the baseline and Scheme. This is a localised difference due to the change in flow patterns around the Scheme and causes some areas to move from significant and extreme hazard. The areas that change from significant to extreme are open areas around the port buildings and caused by the localised change in flow pattern of the approach roads. These areas are considered 'Water Compatible Development' (Table 4-2) therefore no additional mitigation is required. There are no buildings at additional risk because of the Scheme.

6.1.30 Figure 6-12 shows a comparison between the flood extents in the 0.5% AEP climate change event for the baseline and Scheme scenarios. This shows that there is no increase in flood extent due to the Scheme. There is a small decrease in flood extent to the west of the Scheme as a result of the increase in flood depth to the east of the Scheme. Increasing the flood depth to the east of the Scheme does not increase the extent of flooding and there are no additional properties at risk of flooding due to the presence of the Scheme.

H++ (UKCP09 high risk, low probability scenario)

6.1.31 Table 6-6 shows the peak water levels predicted by the model in the baseline and Scheme scenarios at the comparison points within Lake Lothing (Figure 6-3) for the H++ events modelled (highlighted comparison points are those closest to the Scheme). The H++ events have been modelled to assess a credible maximum scenario and understand the safety and operability of the Scheme during an extreme flood event. As previously agreed with the EA design and mitigation for the Scheme will not be based on the H++ event results. The Scheme is predicted to have a greater impact on water levels within Lake Lothing during the H++ events due to increased tidal levels. A moderate increase in water levels in Lake Lothing with the Scheme in place is predicted for each event modelled. The maximum increase in water levels predicted within Lake Lothing is 0.14m during the 0.1% H++ event. In the Scheme Worst Case scenario, there is an increase of 0.01m in the predicted flood level at comparison point 4 in the outer harbour compared to the Scheme scenario. To the west of the Scheme, the Scheme Worst Case scenario actually shows 0.01m lower water levels than the Scheme scenario due to increased blockage at the new bridge location. The increase in blockage underneath the bridge deck (from 10% to 15%) between the Scheme and Scheme Worst Case scenario has a negligible impact on the model results even in the 0.5 % AEP H++ event and the only negative impact is shown within the outer harbour.

6.1.32 On the floodplain for the 5% AEP H++ event, water levels are predicted to increase up to 0.09m. This is a moderate increase in water level based on Table 6-6 and there are areas where the water level has decreased by 0.1m to the west of the Scheme. The predicted increases in water level on the floodplain for the 0.5% AEP H++ event are moderate (up to 0.1m) and decreases of up to 0.1m are predicted to the west of the Scheme. The 0.1% AEP H++ event shows an increase of up to a 0.14m in predicted water depths on the floodplain, this is classified as a moderate change. There are decreases of up to 0.16m predicted to the west of the Scheme during the 0.1% AEP

H++ event.

6.1.33 The bascule bridge deck of the Scheme is not predicted to flood during any of the H++ scenarios modelled. Flooding is predicted to other parts of the Scheme; at the observation point to the south of Lake Lothing (shown on Figure 6-5 and Figure 6-9), a water depth of 2.17m is predicted for the baseline and Scheme scenarios. During the 0.5% AEP H++ event, the predicted flood depth at the southern observation point in the baseline scenario is 2.72m, an increase of 0.01m is predicted in the Scheme model. An increase of 0.01m in flood depth at the southern observation point is also predicted for the 0.1% AEP H++ Scheme scenario compared to the baseline scenario, the predicted flood depth in the baseline scenario at this location is 3.15m.

Table 6-6 H++ Scenario Hydraulic Modelling Results

H++	Baseline (mAOD)			Difference (Proposed – Baseline (m)		
Point	5%	0.5%	0.1%	5%	0.5%	0.1%
P1	5.83	6.51	7.06	0.00	0.00	0.01
P2	5.82	6.49	7.02	0.00	0.00	0.00
P3	5.83	6.52	7.06	0.00	0.00	0.00
P4	5.85	6.57	7.04	0.00	0.00	0.00
P5	5.67	6.32	6.85	0.01	0.01	0.02
P6	5.56	6.20	6.71	0.02	0.02	0.03
P7	5.40	5.96	6.40	0.03	0.04	0.06
P8	5.40	5.95	6.38	0.05	0.08	0.10
P9	5.40	5.95	6.38	0.04	0.06	0.08
P10	5.40	5.95	6.39	0.06	0.11	0.14
P11	5.40	5.95	6.38	-0.07	-0.06	-0.07
P12	5.40	5.95	6.38	-0.07	-0.06	-0.07
P13	5.40	5.95	6.38	-0.07	-0.05	-0.07
P14	5.40	5.94	6.37	-0.10	-0.11	-0.13
P15	5.33	5.85	6.25	-0.10	-0.10	-0.13
P16	4.85	5.22	5.49	-0.07	-0.07	-0.08

6.1.34 In conclusion, the impact of the Scheme on flood water levels both in Lake Lothing and on the floodplain for events up to and including the 0.5% AEP climate change event is negligible. A moderate increase in water levels is predicted for the 0.1% AEP climate change event. For each of the return periods modelled, a moderate increase is predicted for the H++ scenario. The increase in predicted water levels within Lake Lothing as a result of the Scheme can be attributed to afflux (a rise in water level on the upstream side of a bridge due to the constriction caused by the bridge structure) at the proposed bascule bridge rather than the displacement of water by the bascule bridge piers in the channel as there is a reduction in water levels predicted for most events to the west of the proposed bascule bridge.

6.1.35 It has been agreed with the EA that the results of the hydraulic modelling for the present day and climate change events should be used to inform the design and any mitigation required for the Scheme. The H++ events have been simulated in order to assess the Scheme against a credible maximum scenario but it has likewise been agreed that the Scheme does not have to provide mitigation for the predicted impacts of these events. Mitigation is discussed in Section 7.

Receptor Assessment

6.1.36 As part of the FRA process, a high level receptor assessment has been carried out. Potentially vulnerable receptors have been identified in the floodplain in Lowestoft. Table 6-7 shows the impact of the Scheme on flood risk at each of the potentially vulnerable receptors identified. Receptors have all been considered as 'More Vulnerable' based on Table 4-2 with the exception of the police station which is considered 'Highly Vulnerable'. Table 6-7 shows that none of the vulnerable receptors within Lowestoft require mitigation.

Table 6-7 - Receptor Assessment

Receptor	Location	Magnitude		Sensitivity
		0.5% AEP	0.5% AEP + Climate Change	
A47	654758 292712	Negligible	Negligible	No mitigation required
Railway	654068 292905	Negligible	Negligible	No mitigation required
Bascule Bridge	654758 292712	Negligible	Negligible	No mitigation required
CRI Suffolk Recovery Centre	654390 292410	No impact	No Impact	No mitigation required
Meadow Community Primary School	653755 291852	Negligible	Negligible	No mitigation required
Fen Park Community Primary School	653997 292057	Negligible	Negligible	No mitigation required
The Attic learning Centre	654034 291937	No Impact	No Impact	No mitigation required
Rainbow Day Nursery	654641 293411	No Impact	No Impact	No mitigation required

Receptor	Location	Magnitude		Sensitivity
		0.5% AEP	0.5% AEP + Climate Change	
East Point Academy	653363 292111	No Impact	No Impact	No mitigation required
Lowestoft Police Station	655155 293407	No Impact	No Impact	No mitigation required
Lowestoft Combined Court	655146 293357	No Impact	No Impact	No mitigation required
Clifton Road Fire Station	654311 292124	Negligible	Negligible	No mitigation required

6.2 Flood Risk from Surface Water

6.2.1 The EA web based Risk of Flooding from Surface Water Map is shown in Figure 6-13. To the south of Lake Lothing, there is minimal surface water (from rainfall) flood risk and the majority of surface water flooding shown is classified as ‘low’ risk which means that in each year there is between a 0.1% and 1% chance of flooding occurring. There are two small areas where the risk of surface water flooding is classified as ‘high’ (each year this area has a greater than 3.3% chance of flooding) to the south of Lake Lothing; along a small reach of Durban Road near to the junction with Waveney Drive and along a short stretch of the A12 south west of the roundabout adjacent to Kirkley Ham.

6.2.2 To the north of Lake Lothing a ‘medium’ surface water flood risk (each year this area has a chance of flooding between 1% and 3.33%) is shown along the East Suffolk railway line. The area between the East Suffolk railway line and Denmark Road is shown to be at ‘high’ risk of surface water flooding.

6.2.3 Based on the information available the overall flood risk from surface water (from rainfall) runoff to the Scheme is assessed as being high. The EA Risk of Flooding from Surface Water Map represents the baseline scenario and the following sections describe the impact of the Scheme on surface water runoff from the site.

Surface Water Runoff Rates

6.2.4 The NPPF states that an FRA should include an assessment to determine the potential increase in flood risk as a result of an increase in hard surfaces within the red line boundary and the effect of the Scheme on surface water (from rainfall) runoff.

6.2.5 Any increase in hard surfaces could increase the surface water (from rainfall) runoff from the Scheme to the adjoining drainage network if no mitigation measures are included. To gain a full understanding of surface water runoff from the Scheme, a pre-development (greenfield) scenario has been assessed along with a post-development scenario.

Pre-Development Scenario (Greenfield)

6.2.6 This scenario assumes that the area within the red line boundary is wholly greenfield with no impermeable surfaces. In reality a large proportion of the Scheme site is paved, however, in order to be conservative this assumption has been made. The pre-developed runoff values from the Scheme in the Qbar (approximately the 50% AEP), 3.33% AEP and 1% AEP rainfall events, calculated based on the IH124 method, are summarised in Table 6-8. Flood Estimation Handbook[8] catchment descriptors for the catchment were used in the IH124 method.

Table 6-8 Pre-development (greenfield) runoff

Rainfall event (return period)	Pre-development (greenfield) runoff from the Scheme (m^3/s)
Qbar (approximately the 50% AEP)	0.01
3.33% AEP	0.02
1% AEP	0.02

Climate Change

6.2.7 Climate change within the UK over the next few decades is likely to result in changes to observed weather patterns. This could lead to milder, wetter winters and hotter, drier summers. Short duration, high intensity rainfall and more periods of long duration rainfall are expected, in addition to rising sea levels. These factors may lead to an increased risk of flooding to the Scheme and so the consequences of climate change need to be anticipated and mitigated.

6.2.8 The importance of climate change with regard to flooding and development is highlighted in the EA guidance published in February 2016[9]. It is recommended in the EA guidance for FRAs that both the central and upper end allowances are used to understand the impact of increased rainfall. The recommended climate change precautionary sensitivity ranges are shown in Table 6-9. Based on a 120 year Scheme design life the peak rainfall intensity increase for the dates furthest into the future (total potential change anticipated for 2060 to 2115) has been applied in this assessment. The central estimate of total potential change for this time period is 20% and the upper end estimate is 40%. The upper end estimate has been used in the greenfield calculations to represent a worst case scenario.

8 https://fehweb.ceh.ac.uk/

9 https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances

Table 6-9 Peak rainfall intensity allowance for climate change (from EA Guidance February 2016)

Applies across all of England	Total potential change anticipated for 2010 to 2039	Total potential change anticipated for 2040 to 2059	Total potential change anticipated for 2060 to 2115
Upper end	10%	20%	40%
Central	5%	10%	20%

6.2.9 In terms of applying climate change allowances to the increase in peak flows (runoff) from the Scheme, the EA guidance recommends that allowances are applied based on the Flood Zone and flood risk vulnerability classification. The Scheme is classified as ‘Essential Infrastructure’ in accordance with the NPPF PPG and parts of the Scheme boundary are located within Flood Zones 2 and 3 (3a), therefore the EA guidance recommends using the upper end climate change allowance. The climate change recommended precautionary sensitivity ranges are shown in Table 6-10 for the Anglian river basin district (which the Scheme lies within). Based on a 120 year design life, the total potential change for the 2080’s is 65% (upper end); this has been applied in the calculations for the post-development runoff.

Table 6-10 Peak flow allowances for climate change (from EA Guidance February 2016)

River Basin District	Allowance category	Total potential change anticipated for the ‘2020s’ (2015 to 2039)	Total potential change anticipated for the ‘2050s’ (2040 to 2069)	Total potential change anticipated for the ‘2080s’ (2070 to 2115)
Anglian	Upper End	25%	35%	65%
	Central	10%	15%	25%

6.2.10 Surface water runoff accounting for climate change was assessed to ensure that an increased risk of flooding and the consequences of climate change are anticipated and mitigated. Accounting for this, the revised pre-development (greenfield) runoff value for the 1% AEP event plus climate change allowance from the Scheme area is $0.04m^3/s$.

Post-Development Scenario

6.2.11 For the purpose of these calculations, the Scheme will lead to an increase in impermeable areas from entirely greenfield (0%) to 84% of the 19.18ha site. Table 6-11 provides a comparison of the pre-development greenfield surface water runoff rates (calculated using the IH124 method) with the post-development runoff rates (using a combination of the IH124 and modified rational methods).

Table 6-11 Runoff rates for the greenfield and post-development scenarios

Rainfall event (return period)	Pre-development (greenfield) runoff from the Scheme (m^3/s)	Total post-development runoff for both impermeable and permeable areas (m^3/s)*	Difference between greenfield and post – development runoff ($m^{3/}/s$)*
3.33 AEP	0.02	0.51	0.49
1% AEP	0.02	0.70	0.68
1% and climate change allowance (upper end)	0.04	0.98	0.9489

* Based on a 6 hour storm duration

6.2.12 Best practice informed by the SuDS Manual (C753) (2015) sets out that runoff from the Scheme should be restricted to the greenfield runoff rate in order to limit the impact of the Scheme on surface water flooding elsewhere. In order to restrict runoff from the site to the greenfield runoff rate, 16,100m^3 of storage for the 1% AEP plus climate change allowance (upper end) event for the six hour storm duration is required. The storage volume quoted above is intended to be an initial, worst-case estimate of instantaneous surface water ponding on site. The Drainage Strategy (Appendix 18B to the ES) for the Scheme considers surface water flooding in further detail and outlines the specific surface water mitigation measures that will be implemented as part of the Scheme to ensure the restriction of runoff from the site to the greenfield runoff rate during a 1% plus climate change event.

6.3 Flood Risk from Sewers

6.3.1 The existing surface water sewer network within the Scheme boundary has been investigated as part of this assessment. There are existing surface water sewers and foul sewers along Denmark Road and Waveney Drive. There have been recorded sewer flooding events in Lowestoft town centre, however a scheme was completed by Anglian Water in 2016 that aimed to reduce the risk. There are no recorded sewer flooding events in close proximity of the Scheme. The flood risk from sewers can be considered to be low based on the information available.

6.4 Flood Risk from Groundwater

Geology and Groundwater

6.4.1 The British Geological Survey (BGS) online geology maps show that the underlying geology beneath the Scheme is undifferentiated Neogene and Quaternary bedrock (gravel, sand, slit and clay). This is sedimentary bedrock formed up to 23 million years ago in the Quaternary and Neogene periods. The local environment was previously dominated by shallow seas.

6.4.2 The superficial geology for the site comprises Happisburgh Glacigenic formations (sand). Deposits were formed up to 3 million years ago in the Quaternary period. The local environment was previously dominated by ice age conditions.

6.4.3 According to the BGS Aquifer Maps, the Scheme is located on bedrock geology with

'Principal Aquifer' designation. This suggests that the bedrock has high intergranular and/or fracture permeability. This means the bedrock usually provides a high level of water storage and may support water supply and/or river base flow on a strategic scale.

6.4.4 The superficial deposits have a 'Secondary A' designation. This means the permeable layers are capable of supporting water supplies at a local rather than strategic scale. In some cases they form an important source of base flow to rivers.

6.4.5 The Scheme is located entirely in an area which is defined as 'Major Aquifer High'. This is shown in Figure 6-14 showing the Groundwater Vulnerability Zones from the EA website.

6.4.6 There are no historical records of groundwater flooding reported in the SFRA. However, it is stated that a small number of houses may be at risk of groundwater flooding depending on local capacity and geology. There are no records of groundwater flooding in the Scheme site. The site is predominately an urban area with approximately 91% existing impermeable surface. Based on the available information the flood risk from groundwater is considered to be low.

6.5 Flood Risk from Artificial Sources

Flood Risk from Reservoirs

6.5.1 The EA web based mapping includes the maximum extent for flooding from reservoirs. The Scheme is not located within the maximum extent area of any nearby reservoirs. As such the site is assessed as being at low flood risk from reservoirs based on the information available.

Flood Risk from other artificial sources

6.5.2 The Scheme is not in an Internal Drainage Board (IDB) area. There are no pumping stations in Lowestoft that have an impact on the Scheme and there are also no canals nearby. Given the location of the site, the flood risk from artificial sources is considered low based on the information available.

7 Flood Risk Mitigation

7.1 Flood risk from Rivers and Sea Mitigation

7.1.1 Based on the results of the hydraulic modelling undertaken for this FRA and Table 6-3, mitigation is not required for the Scheme as the impact on flooding is negligible up to and including the 0.5% AEP climate change event. It is noted that although Table 6-3 states that mitigation is required for a negligible increase in flood depth to highly vulnerable and essential infrastructure, using professional judgement, it is deemed impractical to provide mitigation for this in this scenario. In the baseline scenario for the 0.5% AEP climate change event flood depths on the floodplain are over 2m, therefore the negligible increase as a result of the Scheme does not alter the scale of risk during this event. As the flood risk to the site is tidal, the mitigation in order to prevent the negligible increase during the 0.5% AEP climate change event would be substantial (e.g. raising the height of coastal defences) and given the baseline scenario flood depths, receptors would still be at high risk of significant flooding even with the mitigation in place.

7.1.2 In terms of the safety and operability of the Scheme, the bascule bridge deck itself is not predicted to flood in any of the events modelled for this assessment including the 0.1% AEP present day event and the H++ scenarios, which have been included in the assessment to provide a full picture of the flood risk in Lowestoft. Parts of the approach roads leading to the bascule bridge are predicted to flood with the Scheme in place, however this flooding is also predicted for the baseline scenario. As the impacts of the Scheme on flood risk are negligible, the relative level of flood risk during flood events remains the same as for the baseline scenario. As stated in paragraph 5.109 of the NNNPS essential infrastructure proposed within Flood Zone 3 should be designed and constructed to remain operational and safe for users in times of flood. The bridge itself remains operational and safe during all flood events modelled but the access roads leading to the bridge do not. Given the baseline level of flood risk within Lowestoft, it is not possible to completely remove the risk of flooding to the access roads during tidal flood events.

7.1.3 The Scheme does have a safety critical element, being the bridge deck. Although the bridge deck itself is not predicted to flood in any of the scenarios modelled (including the extreme 0.1% H++ scenario), the approach roads to the bridge are predicted to flood and on the north bank of Lake Lothing would be impassable even in the baseline 0.5% and 0.1% present day events where flood depths up to 0.95m and 1.37m respectively for each event are predicted. On the south bank of Lake Lothing, the predicted flood depth on the approach road to the proposed bridge is 0.13m for the 0.5% AEP event rising to 0.56m for the 0.1% AEP event. Due to the small increases in water levels predicted on the floodplain during the operational phase of the Scheme, the risk to safety during a flood event is the same as for the current baseline scenario.

7.2 Flood Risk from Surface Water Runoff Mitigation

7.2.1 The Scheme will result in an increase in impermeable area compared to the existing site and in turn will lead to an increase in the surface water runoff for the site post-development.

7.2.2 The NPS and the EA in general promotes the use of SuDS to attenuate peak flows, provide water quality improvements and environment enhancements where ground conditions are suitable.

7.2.3 The use of any SuDS features within the Scheme is dependent on the site constraints, underlying ground conditions and available funding for the Scheme. The Drainage Strategy document considers this in detail and discusses the proposed mitigation for additional surface water runoff. The proposed SuDS features to be used as part of the Scheme as detailed in the Drainage Strategy (Appendix 18B to the ES) are a combination of ponds and buried attenuation tanks.

8 Flood Risk During Construction

8.1.1 This FRA has shown that the Scheme is at risk of flooding during 5% AEP event and greater, and therefore there will also be a flood risk to the site during construction. Construction of the Scheme will be undertaken over a period of two years as shown in Chapter 6 of the ES. The construction within Lake Lothing is programmed to last approximately ten months. Although there is a low probability (≤ 5% AEP) of a flood occurring to the site during this time, it is prudent to consider the impacts of such an event.

8.1.2 Due to the relatively short lifespan of the construction phase, a flood management plan should be prepared for the site as part of the full CoCP. Measures will be put in place for the site to minimise flood damage during large return period events. It is expected that in most instances there will be sufficient warning due to tide level predictions to implement the measures outlined in the CoCP. This includes time for removal of plant and equipment from the site to higher ground upon receiving a flood warning. This will limit damage and ensure that any hazardous materials with the potential to float will be moved.

8.1.3 As identified in Chapter 5 of the ES, coffer dams will be used for approximately ten months to construct the bridge piers. The coffer dams will displace water within Lake Lothing and reduce the amount of storage available within the channel temporarily and will be significantly larger than the fully constructed piers. The cofferdam will be constructed using a two zone approach; an outer removable cofferdam extending from the harbour wall to the location of the piers and an inner cofferdam built around the piers themselves. Using this approach, a large section of the construction cofferdam can be removed in preparation for an extreme event which could exceed the height of the quay wall. A smaller inner cofferdam will remain to protect critical components sensitive to flooding. This will lead to negligible net loss of storage within Lake Lothing during such an event. For further information regarding the cofferdam see Chapter 5 of the ES.

8.1.4 A short hydraulic modelling assessment has been carried out to assess the worst case impact of the cofferdam on the expected water levels in the Lowestoft.

8.2 Modelling Approach

8.2.1 The construction sequence for the support piers is to create two sheet pile cofferdams from the north and south quays. The cofferdams will be de-watered allowing the central pier foundations to be constructed. It has been assumed that the height of the cofferdam will be the same as the quay wall levels, although the inner cofferdam will be kept higher than the flood water level. This is to maintain essential equipment during the construction phase.

8.2.2 Within the model, z-lines are used to represent the cofferdams and set at the same height at the quay wall. This represents the worst case scenario where the large cofferdam is not demounted prior to an extreme tide. This sufficiently simulations the blockage caused by the cofferdams and allows water to cascade into the de-watered section only when they are overtopped.

8.3 Results

8.3.1 Table 8-1 shows the modelled water levels for the cofferdam simulation compared to the baseline simulation. The water levels at the comparison points (shown in Figure 6.3) for the 5% AEP, 0.5% AEP, 0.5% AEP+CC and 0.5% AEP+ H++ events are presented to two decimal places.

Table 8-1 - Cofferdam Simulation Results

	Baseline				Difference: Cofferdam - Baseline			
	5% AEP	0.5% AEP	0.5% CC	0.5% H++	5% AEP	0.5% AEP	0.5% CC	0.5% H++
P1	2.74	3.39	4.93	6.51	0.00	0.00	0.00	0.00
P2	2.74	3.39	4.92	6.49	0.00	0.00	0.00	0.00
P3	2.74	3.39	4.93	6.52	0.00	0.00	0.00	0.00
P4	2.74	3.39	4.93	6.57	0.00	0.00	0.00	-0.01
P5	2.73	3.35	4.75	6.32	0.00	-0.01	0.00	0.00
P6	2.73	3.33	4.63	6.20	0.00	0.00	0.01	0.00
P7	2.74	3.34	4.56	5.96	0.00	0.00	0.01	0.01
P8	2.74	3.34	4.57	5.95	0.00	0.00	0.01	0.01
P9	2.74	3.34	4.57	5.95	0.00	0.00	0.01	0.01
P10	2.74	3.34	4.58	5.95	0.00	0.00	0.02	0.09
P11	2.74	3.34	4.57	5.95	-0.01	-0.03	-0.01	-0.02
P12	2.74	3.34	4.58	5.95	-0.01	-0.03	-0.01	0.00
P13	2.74	3.34	4.57	5.95	-0.01	-0.05	-0.04	-0.15
P14	2.74	3.34	4.57	5.94	-0.01	-0.03	-0.01	-0.01
P15	2.74	3.32	4.52	5.85	-0.01	-0.02	-0.01	-0.01
P16	2.73	3.28	4.27	5.22	0.00	-0.03	-0.01	-0.01

8.3.2 The construction method using two cofferdams from the North and South quays has been explicitly simulated in the 2D flood model. This represents a worst case construction scenario as both the cofferdams are assumed to be in place at the same time, and a maximum sized cofferdam has been assumed. The results have shown the maximum change in water level is an increase of 0.09m in the 0.5% AEP + H++ event as a result of a localised reduction in velocity.

8.3.3 The maximum increase in water level in the 0.5% AEP + CC event is 0.02m, this is in the channel near the cofferdam and is considered negligible. This increase has been attributed to a localised reduction in velocity. A negligible impact on water levels is also seen on the floodplain.

8.3.4 However, embedded mitigation in the form of removable walls to the cofferdam will be employed that will sacrificially flood the cofferdam in the event of a flood event that would exceed the height of the quay wall. This would lead to a negligible loss of storage within Lake Lothing during such an event.

8.3.5 Given the low likelihood of a significant flood event occurring during the two year construction phase, the implementation of a flood management plan is sufficient mitigation and will be provided within the full CoCP.

8.3.6 The during construction measures should be developed in consultation with the EA, the Port Authority, and SCC. The EA has produced a guidance document[10] for businesses detailing what a flood management plan should contain and this should be used to develop the flood management plan for the construction phase once the specific details of the construction are known. Information that will be of use when developing the flood management plan is provided in the interim Code of Construction Practice (CoCP) in Appendix 5A to the ES.

[10] https://www.gov.uk/government/publications/preparing-your-business-for-flooding

9 Conclusions

9.1 Conclusions

9.1.1 This FRA has been prepared for the Scheme in line with the NPPF, the PPG and in consultation with the EA. The Scheme has been designated a NSIP and therefore this FRA has been undertaken in accordance with the requirements of the National Policy Statement for National Networks in terms of flood risk. Guidance within the DMRB and the CIRIA SuDS Manual has also informed the FRA.

9.1.2 The following documents have been reviewed to gather information for this study;

- The Suffolk Coastal and Waveney District Strategic Flood Risk Assessment;
- The Broadland Rivers Catchment Flood Management Plan;
- The Suffolk SMP2 Sub-cell 3c;
- The Suffolk Preliminary Flood Risk Assessment;
- The Suffolk Flood Risk Management Strategy; and
- The Lowestoft Flood Risk Management Strategy.

9.1.3 The Scheme covers 19.18 hectares and includes the proposed bascule bridge and new road layout associated with it. The design for the Scheme consists of a central bascule bridge supported by a total six concrete piers with piled foundations, approximately 0.8km upstream of the existing A47 Bascule Bridge. The Scheme is considered a NSIP and deemed 'Safety Critical'. Safety critical is defined as any development that is required to remain accessible/functional in an emergency event.

9.1.4 The Scheme is located within Flood Zone 3 (3a), which means there is a 0.5% AEP of flooding from the sea or a 1% AEP chance of flooding from fluvial sources in any given year. The Scheme is classified as essential infrastructure and therefore the Exception Test is required for the Scheme. This FRA has addressed part two of the Exception Test (part one is addressed in the Case for the Scheme (document reference 7.1).

9.1.5 As part of the FRA, it was necessary to carry out a detailed hydraulic assessment of tidal flood risk from Lake Lothing to the Scheme and the impact of the Scheme on flood risk elsewhere. Sensitivity testing using the model developed for this assessment showed that fluvial flows have a negligible impact on peak flood water levels in Lowestoft and the town is most at risk from tidal flooding.

9.1.6 A 2D TUFLOW model of Lake Lothing and the outer harbour has been developed for this assessment. A baseline model was developed to represent the existing flood risk within Lowestoft. The baseline model was subject to sensitivity testing to ensure the model was robust and could be used to undertake hydraulic assessments as part of the FRA process. It was not possible to fully calibrate the hydraulic model due to a lack of suitable data as discussed in the Hydraulic Modelling Report (refer to Annex B). The 2013 storm surge event has been modelled and the predicted flooding checked against historic flood extents for Lowestoft and photos/anecdotal evidence to verify the model results. These are discussed in full in the Hydraulic Modelling Report (refer to Annex B).

9.1.7 The model has been used to investigate the risk of flooding in Lowestoft for the present day scenario and, in order to consider the impact of and resilience to future flooding, the model has also been used to simulate future flood events with an allowance for climate change included (based on allowances for the year 2140, 120 years in the future). Due to the designation of the Scheme as a NSIP and safety critical infrastructure, the EA have requested that the low probability, high risk flood event (H++) within the UK Climate Projections 2009 (UKCP09) predictions is also modelled to assess a credible maximum scenario. It has been agreed with the EA that the Scheme does not have to include mitigation for the impacts predicted by the model for the high risk, low probability H++ event.

9.1.8 Once the baseline model had been developed and verified, a version of the model was developed to represent Lowestoft post-development of the Scheme and understand the flood risk to the Scheme. The results from the baseline and Scheme scenarios have been compared in order to ascertain the impact of the Scheme on flooding elsewhere.

9.1.9 The modelling undertaken shows that the Scheme has a negligible impact on predicted flood levels for events up to and including the 0.5% AEP climate change event. A moderate impact in terms of flood risk is predicted for the 0.1% AEP climate change event and each of the H++ scenarios modelled. The increase in predicted water levels within Lake Lothing as a result of the Scheme can be attributed to afflux at the proposed bascule bridge rather than the displacement of water by the bascule bridge piers in the channel as there is a reduction in water levels predicted for most events to the west of the proposed bascule bridge.

9.1.10 Hazard mapping has shown the impact of the Scheme on the hazard is small and found to be close to the Scheme. There is a slight change in hazard to port areas close to the Scheme within the port infrastructure, however no buildings are at increased risk due to the Scheme in the 0.5% AEP present day event. The 0.5% AEP climate change event shows there are some areas within the port near the Scheme that experience an increase in risk caused by the change in flow patterns however no buildings are affected. There are no other changes in hazard across the domain. Due to the wide spread significant/extreme hazard shown in the baseline category, emergency procedures will already be in place therefore it was deemed that no additional assessment is required due to the Scheme.

9.1.11 The assessment has shown that there is no increase in flood extent due to the Scheme. Consequently, no additional properties are at risk of flooding because of the Scheme.

9.1.12 In terms of the safety and operability of the Scheme, the bascule bridge deck itself is not predicted to flood in any of the events modelled for this assessment. Parts of the approach roads leading to the bascule bridge are predicted to flood during the operational phase of the Scheme, however this flooding is also predicted for the baseline scenario. As the impacts of the Scheme on flood risk are negligible, the relative level of flood risk during flood events remains the same as for the baseline scenario.

9.1.13 Based on the results of the hydraulic modelling undertaken for this FRA, mitigation is not required for the Scheme as the impact on tidal flooding is negligible up to and including the 0.5% AEP climate change event. It is noted that although Table 6-3 states that mitigation is required for a negligible increase in flood depth to highly vulnerable and essential infrastructure, using professional judgement, it is deemed impractical to provide mitigation for this in this scenario. In the baseline scenario for the 0.5% AEP climate change event flood depths on the floodplain are over 2m, therefore the negligible increase as a result of the Scheme does not alter the scale of risk during this event. As the flood risk to the site is tidal, the mitigation in order to prevent the negligible increase during the 0.5% AEP climate change event would be substantial and given the baseline scenario flood depths, receptors would still be at high risk of significant flooding even with the mitigation in place.

9.1.14 A Scheme Worst Case scenario has been modelled for the 0.5% AEP event to understand the impact of an increase in bridge pier size underneath the bridge deck compared to the current design. The increase in blockage underneath the bridge deck (from 10% to 15%) between the Scheme and Scheme Worst Case scenario has a negligible impact on the model results even in the 0.5 % AEP H++ event and the only negative impact is shown within the outer harbour (0.01m increase in Scheme Worst Case scenario compared to the Scheme scenario).

9.1.15 A high level assessment of surface water runoff from the Scheme has been undertaken as part of this assessment. Runoff from the site will be restricted to the greenfield runoff rate even though the site is currently brownfield in order to limit the impact of the Scheme on surface water flooding elsewhere. In order to restrict runoff from the site to the greenfield runoff rate, 16,100m^3 of storage for the 1% AEP plus climate change allowance (upper end) event for the six hour storm duration is required.

9.1.16 The Scheme will result in an increase in impermeable area compared to the existing site and in turn will lead to an increase in the surface water runoff for the site post-development. The EA in general promotes the use of SuDS to attenuate peak flows, provide water quality improvements and environment enhancements where ground conditions are suitable. There is a range of SuDS options available to the designers which will be considered during the detailed design and implemented where appropriate. The Drainage Strategy (Appendix 18B to the ES) document considers this in detail and discusses the proposed embedded mitigation for surface water runoff.

9.1.17 The risk of flooding during the construction phase of the Scheme has been considered in this FRA. Construction of the Scheme will be undertaken over a period of two years as shown in Chapter 5 of the ES. The construction within Lake Lothing is programmed to last approximately ten months. During this time there is low likelihood of a significant flooding event, however it is prudent to consider the impacts of such an event. Due to the relatively short lifespan of the construction phase and the small localised impacts predicted by modelling, a flood management plan will be implemented to reduce flood damage during large return period events. It is likely that in most instances there will be sufficient warning due to tide level predictions to implement the plan. A flood management plan will be put in place for the site to minimise flood damage during large return period events, this will be the responsibility of the site management team and will be finalised through consultation with SCC. The requirement for this plan is contained within the interim CoCP.

9.2 Mitigation

9.2.1 Mitigation for tidal flooding is not required as this FRA has shown that the Scheme will have a negligible impact on flooding for events up to and including the 0.5% AEP climate change event.

9.2.2 The Scheme will increase the impermeable area within the red line boundary, therefore SuDS will be used to attenuate surface water runoff and ensure that discharge from the site is limited to greenfield runoff rate. The Drainage Strategy (Appendix 18B to the ES) for the Scheme includes the details of the SuDS features that will be incorporated in the Scheme.

9.2.3 The risk of flooding during the construction phase of the Scheme is considered to be low and the impact of the construction on flood risk in Lowestoft is negligible. A suitable flood management plan will be prepared based upon the Interim CoCP (Appendix 5A of the ES) and will adopted by the Contractor prior to construction commencing.

Annex A – EA Correspondence

Annex B – Hydraulic Modelling Report

Annex C – Figures