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APPENDIX 8-A FLOOD RISK ASSESSMENT

FUGRO EMU LIMITED

ABERDEEN HARBOUR EXPANSION PROJECT

FLOOD RISK ASSESSMENT

Report Reference. P1974_R3866_Rev2

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SUMMARY

Fugro EMU Limited (Fugro) is carrying out environmental investigations on behalf of Aberdeen Harbour Board (AHB) for the Aberdeen Harbour Expansion Project. These investigations have required that a Flood Risk Assessment (FRA) was carried out for the development to assess flood risk, outline potential constraints to development and make recommendations for mitigation and enhancement measures where required. Intertek Energy & Water Consultancy Services (Intertek) was engaged by Fugro to carry out this work and provide information that can be used in the Environmental Statement for the proposed development.

Nigg Bay is located 2 km to the south west of Aberdeen City Centre and is an east facing bay bordering onto the North Sea. It has a sandy foreshore and areas of marram grass and sand dunes behind. The ground level rises from 0 m Above Ordnance Datum (AOD) at the shoreline to 50 m AOD on the headlands to the north and south. The Coast Road/Greyhope Road around the bay rises above the 10 m contour but, in the centre of the bay, where it crosses the East Tullos Burn, is around 4 m (AOD). The East Tullos Burn is the principal drainage route for the catchment area to the west of the bay.

The Scottish Environment Protection Agency (SEPA) flood map for the area indicates that the proposed site is at risk of tidal flooding. The outline plans are to provide three new quay facilities in a south facing U shape with an offshore breakwater. The deck height of the west, north and east quays and the south-east breakwater will be at 6.7 m Above Chart Datum (ACD).

TIDAL FLOOD RISK

Flooding from tidal and wave action should be viewed as the primary flood risk for the site. Data were collated from SEPA flood mapping, tide gauges, historical records and coastal modelling. As the proposed site is located directly at the coast, it is within the 200 year flood zone as defined by SEPA. However, there are no recorded reports of flooding at the site. This may be because the location is generally undeveloped, limiting the potential for flooding to be reported, but there is a wastewater treatment works located at a slightly elevated position that has not reported being affected by flooding.

A review of the tide gauge data at nearby Aberdeen Harbour showed that the largest recorded water levels occurred in January 2005 with a peak level of 5.306 m ACD (3.056 m AOD) and the second largest in December 2013 of 5.229 m ACD (2.979 m AOD). A comparison with site survey data along the foreshore suggests that limited flooding of the

existing site would have occurred but that Coast Road and Greyhope Road would not have been flooded.

Modelled data were used to assess extreme tide levels and climate changes effects. If the lifetime of the proposed development is taken as 100 years, the 200 year return period flood level with a 100 year climate change allowance can be determined as 4.11 m AOD. This is below the proposed quayside level of 4.45 m AOD.

Wave modelling was also carried out to assess the 1:200 year significant wave heights both with and without the development in place to assess flood risk and the impact of the proposed construction. The presence of the breakwaters was found to result in a reduction of the wave heights within the bay. The only condition and location whereby the wave height exceeded the baseline was at the north breakwater under a 45 degree wave direction, when an increase of 0.129 m is experienced. The resulting water level at this point is significantly lower than the breakwater level, meaning that the coastal flood risk is not increased at this point. At all other locations, the significant wave height is reduced indicating a reduction of flood risk within the harbour as a result of the breakwaters. This is still the case even after a 10% allowance is made for climate change effects.

FLUVIAL FLOOD RISK

The East Tullos Burn is the only significant watercourse discharging within the bay that could pose a potential fluvial flood risk. Flood flows for the watercourse were determined both using the Flood Estimation Handbook's statistical and revitalised flood hydrograph methods, with the statistical method being used in preference due to this approach being fully adopted for Scotland. The potential for flood depths arising from the burn were assessed using simplified but conservative means. The flood flows were compared to the capacity of the watercourse's downstream throttle as it passes under Coast Road via a twin 750 mm diameter pipe culvert. The combined capacity of the pipes was found to exceed that of any flow calculated using the statistical method and all but the 1,000 year return period flow determined using the revitalised flood hydrograph method. When the culvert is clear and operating correctly, the watercourse would therefore appear to present a very low flood risk. The analysis was then repeated assuming that the culvert becomes completely blocked (there are trash screens fitted at the culvert inlet). Under this scenario, flood depths on Coast Road were determined assuming that the blocked culvert structure behaves as a broad-crested weir. Under this assumption, relatively shallow flood depths are predicted with overland flows discharging directly to the sea from this point. There is therefore a low risk of large impacts resulting even from the complete blockage the culvert.

IMPLICATIONS FOR THE PROPOSED DEVELOPMENT

Proposed finished quayside levels appear to be appropriate to mitigate most flooding scenarios. The level of the quay will be at 4.45 m AOD and this is above extreme tide levels and hence tidal flooding of the site is considered unlikely. The breakwater at 9.75 m AOD will provide protection against extreme wave heights. As the quay is to be raised above the local ground levels, the risk of flooding from storm water, sewers, highways and groundwater is considered to be low.

A safe dry escape route from the site is available to the North West which leads to higher ground and towards Aberdeen where services and facilities exist. As the quayside will be above the 2,000 year plus climate change flood level, the risk of flooding is low and there are therefore no requirements to consider or provide a flood evacuation plan.

Although the proposed development site lies inside the 200 year flood extent, as it is a coastal area, the increase in flood levels will be minimal and there is no requirement for compensatory storage as there will be no change in flood risk at adjacent sites.

The risk of tidal and fluvial flooding of the site is low, and with the quayside level raised above local ground levels for the proposed development, no part of the site will be below the 200 year plus climate change flood level. There is therefore no requirement to consider flood resistance or resilience measures.

CONCLUSIONS

The FRA reported within this document has allowed the following conclusions to be made:

- SEPA's Flood Map indicates that the proposed development is at risk of tidal flooding and an FRA is required to determine the risk of flooding to the site and to others.
- There are no anecdotal records of flooding in the immediate area of Nigg Bay. Measured tide level records indicate that tidal flooding has not occurred at the site during the record period.
- Estimates of extreme sea levels provide a 200 year sea level at Aberdeen of 3.17 m AOD and a 1,000 year level of 3.29 m AOD. These are below the proposed quayside levels.
- The anticipated rate of relative sea level rise over the next 100 years suggests tide levels are expected to increase by 0.94 m by 2115. Over the 100 year design life of the development, the 200 year tide level is expected to increase to 4.11 m AOD. The

proposed quay side level of 4.45 m AOD is therefore above the 200 year extreme still water level by 2115.

- The peak wave heights within the harbour are predicted to reduce as a result of the effects of the breakwaters, resulting in a reduction of local flood risk. At the breakwaters themselves, a modest increase in peak wave height is predicted depending upon wave direction. The forecast peak wave heights are still less than the proposed breakwater level for all but the most extreme climate change allowance.

- The main source of fluvial flooding is the East Tullos Burn which discharges into the sea within the boundary of the proposed development site. This area is not identified as at risk of fluvial flooding on SEPA's Flood Map but has been considered in this FRA based on the estimation of flood flows and conversion of flows to levels. The main constraint is the culvert below Coast Road which calculations suggest has a capacity of in excess of the 200 year flood flow for the watercourse. Even assuming a worst case that the culvert is 100% blocked, the 100 year flood flow with climate change would give a maximum depth on the road of 120 mm or 132 mm for the 1,000 year event, with overland flow discharging directly to sea. These comparatively shallow flood depths confirm that fluvial flooding will be of low magnitude and will have a smaller impact than tidal flooding. Any development should maintain at least the existing culvert capacity.

- Other potential sources of flooding have been considered which for this site may include storm water, highways, sewers, groundwater and impounded waterbodies. The proposals are to provide a new drainage system on the site which will be designed to handle extreme storm events and so the risk of flooding from these sources will be managed. Additionally, as the operational level of the quays will be raised above the local ground level, the risk of flooding from these sources is considered to be low.

- There will be a safe & dry escape route from the site to the North West which leads to an area of higher ground and towards Aberdeen where services and facilities exist.

- The proposed development site lies inside the 200 year flood extent but as this is a coastal area, the increase in flood levels due to the loss of flood storage will be minimal and there is no requirement for compensatory storage. There is also no requirement to consider flood resistance or resilience measures or a flood evacuation plan.

- Scottish Planning Policy requires that surface water runoff from a new development should be treated by a sustainable urban drainage system (SUDS) before it is discharged into the water environment. The exception to this is where the discharge is into coastal waters as in this case due to the available dilution of the receiving waterbody. As the site lies adjacent to the sea, there is no requirement or benefit in using SUDS to control peak flow and the volume of runoff. The main issue is water quality and ensuring pollution events such as spillage can be controlled. The installed drainage network should therefore include petrol interceptors and control valves to prevent any spillage of contaminants from entering the coastal environment. The final drainage scheme will be considered at the detailed design stage.

- Under the Scottish Planning Policy, the proposed land use for docks and wharves is considered to be a water compatible development which is appropriate in Flood Zone 3 (as designated by the policy). There is no requirement to consider the Exception Test and as the proposals are to provide dock and harbour facilities, this has to be located in a coastal location and there will be no reasonably available alternative locations at a lesser flood risk in the Local Planning Authority (LPA) area. Compliance with the Sequential Test is therefore demonstrated.
- The findings of this FRA do not necessitate the implementation of mitigation measures.

CONTENTS

TABLES

FIGURES

ABBREVIATIONS

ACD	Above Chart Datum
AHB	Aberdeen Harbour Board
AMAX	Annual Maximum
AOD	Above Ordnance Datum
DIA	Drainage Impact Assessment
FEH	Flood Estimation Handbook
FRA	Flood Risk Assessment
GL	Generalised Logistic
LPA	Local Planning Authority
OD	Ordnance Datum
QMED	Median Annual Flood Flow
ReFH	Revitalised Flood Hydrograph Method
SEPA	Scottish Environment Protection Agency
SSJPM	Skew Surge Joint Probability Method
SSSI	Site of Special Scientific Interest
SUDS	Sustainable Urban Drainage Systems

1 INTRODUCTION

Fugro EMU Limited (Fugro) is carrying out environmental investigations on behalf of Aberdeen Harbour Board (AHB) for the proposed expansion of Aberdeen Harbour at Nigg Bay, Aberdeen. These investigations have required that a Flood Risk Assessment (FRA) was carried out for the development to assess flood risk, outline potential constraints to development and make recommendations for mitigation and enhancement measures where required. Intertek Energy & Water Consultancy Services (Intertek) was engaged by Fugro to carry out this work and provide information that can be used in the Environmental Statement for the proposed expansion project.

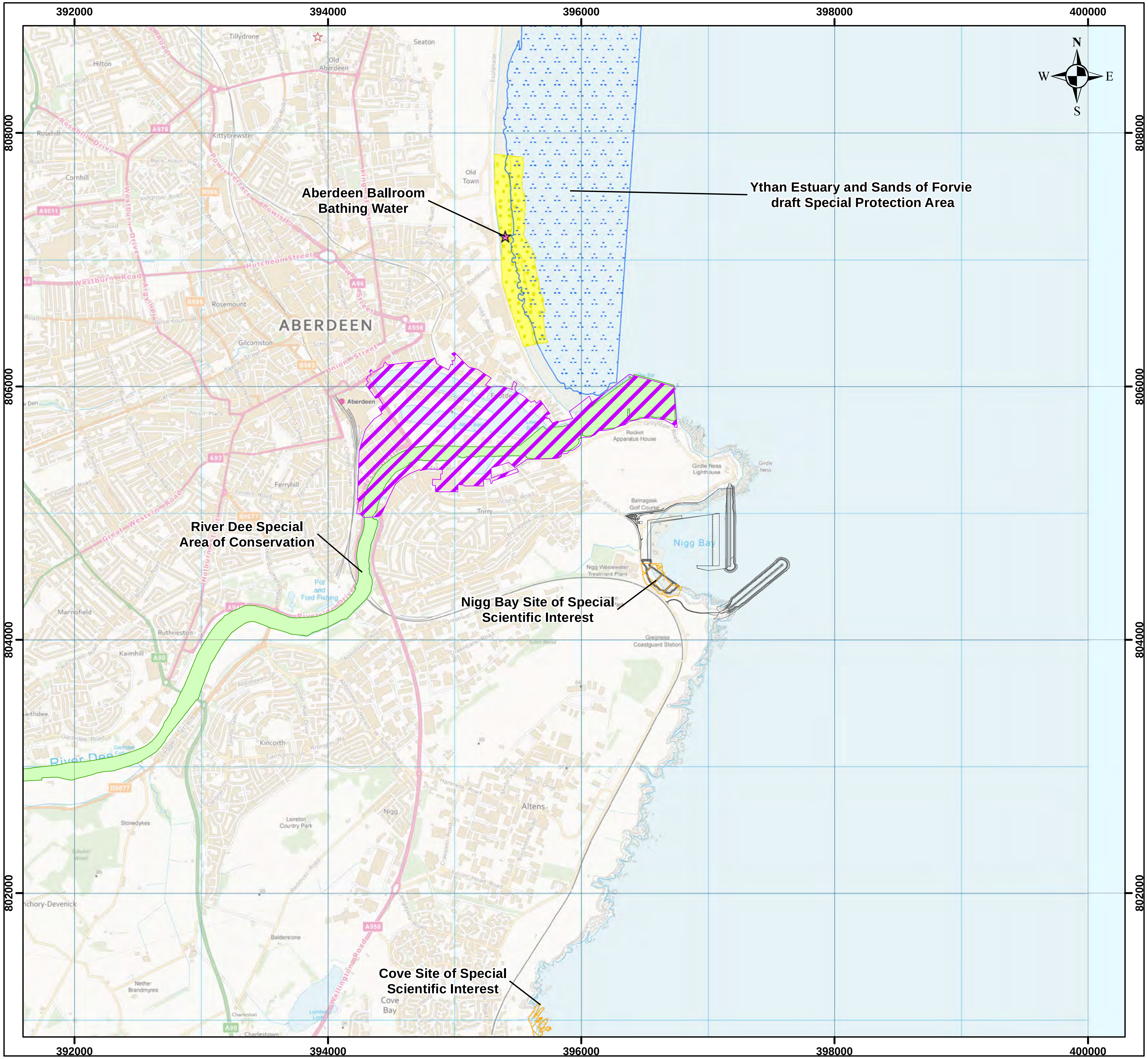
1.1 EXISTING SITE

The proposed development site of Nigg Bay is located 2 km to the south west of Aberdeen City Centre (Figure 1-1). Nigg Bay is an east facing bay bordering onto the North Sea (Figure 1-2), with a sandy foreshore and areas of marram grass and sand dunes behind as shown on an aerial photograph (Figure 1-3) and a site photograph (Figure 1-4).

The ground level rises from 0.0 m Above Ordnance Datum (AOD) at the shoreline to 50 m AOD on the headlands to the north and south (Figure 1-1). The Coast Road/Greyhope Road around the bay rises above the 10 m contour but, in the centre of the bay where it crosses the East Tullos Burn, is around 4 m AOD.

ABERDEEN HARBOUR EXPANSION PROJECT

Figure 1-1: Geographic overview of the area of interest



Legend

- Aberdeen Harbour Expansion Project area
- Existing Aberdeen Harbour Area
- Special Area of Conservation
- Site of Special Scientific Interest
- Draft Special Protection Area
- Bathing Water Monitoring Location
- Aberdeen Ballroom Bathing Water

NOTE: Not to be used for Navigation

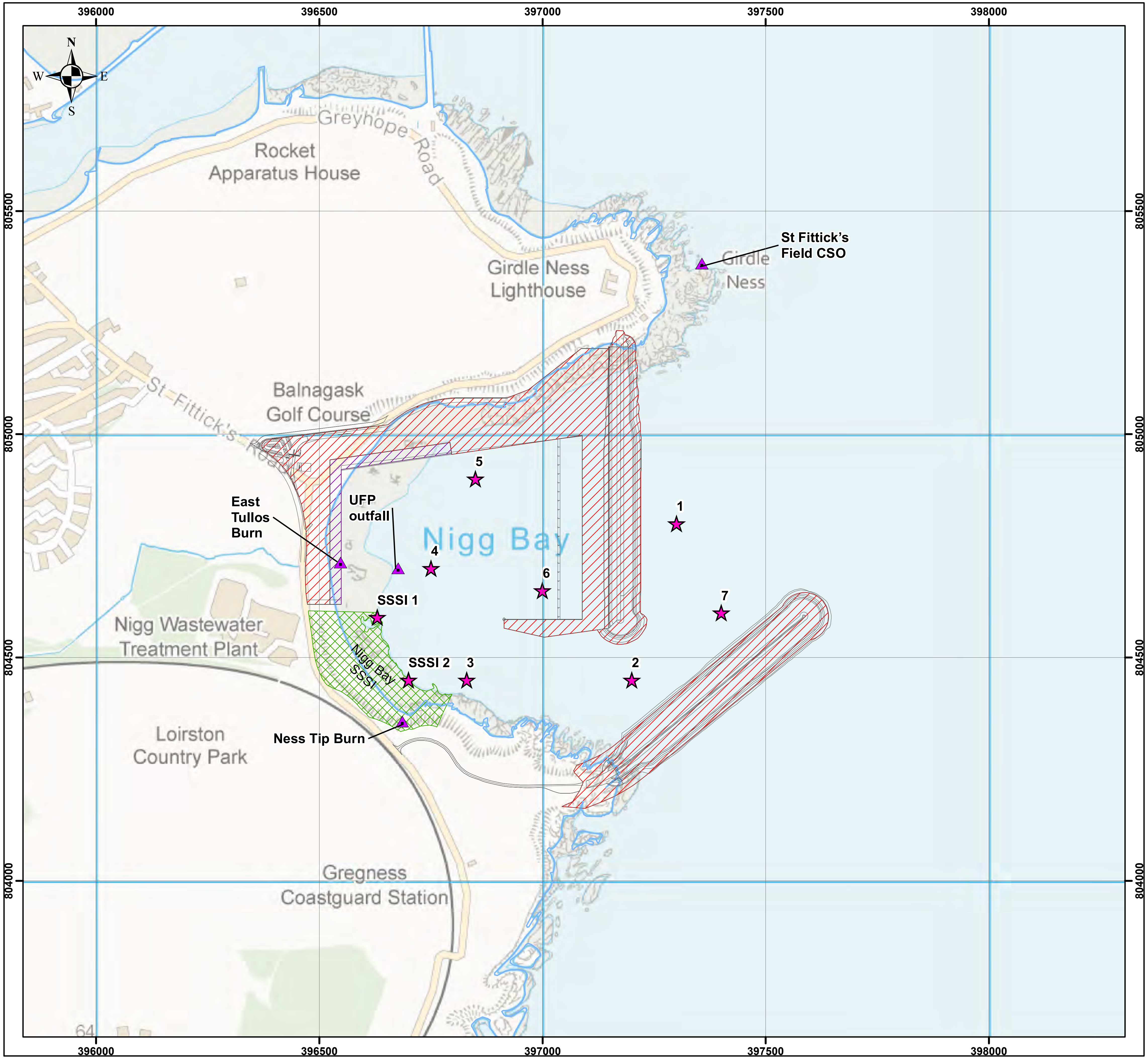
Date	Monday, September 7, 2015 09:48:11
Projection	British_National_Grid
Spheroid	Airy_1830
Datum	D_OSGB_1936
Data Source	OSOD, SNH, JNCC, SEPA
File Reference	J:\P1974\Mxd\Method_Statement\ Geographical_Overview.mxd
Created By	Emma Langley
Reviewed By	Ian Charlton
Approved By	Kevin McGovern

Valued Quality. Delivered.

0 0.2 0.4 0.8 1.2 1.6 km

ABERDEEN HARBOUR EXPANSION PROJECT

Figure 1-2: Extraction Locations



Contains Ordnance Survey data © Crown copyright and database right 2013

Legend

- Model extraction locations
- Discharge Location
- Aberdeen Harbour Expansion Project
- Suspended Deck Structure
- Site of Special Scientific Interest

NOTE: Not to be used for Navigation

Date	Thursday, September 10, 2015 17:26:32
Projection	British_National_Grid
Spheroid	Airy_1830
Datum	D_OSGB_1936
Data Source	OSOD, FUGRO
File Reference	J:\P1974\Mxd\ WQ_Extraction_Locations_v4.mxd
Created By	Ian Charlton
Reviewed By	Emma Langley
Approved By	Paul Taylor

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0 100 200 300 400 m

Figure 1-3: Aerial Photograph

Imagery ©2015 Infoterra Ltd & Bluesky, The GeoInformation Group, Data S10, NOAA, U.S. Navy, NGA, GEBCO, Map data ©2015

Figure 1-4: Site Photograph

1.2 PROPOSED DEVELOPMENT

Aberdeen Harbour Board has proposed the design and construction of a new harbour facility at Nigg Bay, immediately south of the existing harbour. The purpose of the new facility is to complement and expand the capabilities of the existing harbour, accommodate larger vessels, retain existing custom, and attract increased numbers of vessels and vessel types to Aberdeen.

The new harbour development shall include but is not limited to:

- Dredging the existing bay to accommodate vessels up to 9 m draft with additional dredge depth of 10.5 m to the east quay and entrance channel;
- Construction of new North and South breakwaters to form the harbour;
- Provision of approximately 1,500 m of new quays and associated support infrastructure. The quay will be constructed with solid quay wall construction and suspended decks over open revetment;
- Construction of areas for development by others to facilitate the provision of fuel, bulk commodities and potable water;
- Land reclamation principally through using materials recovered from dredging operations and local sources, where possible;
- Provision of ancillary accommodation for the facility;
- Off-site highway works to the extent necessary to access the facility and to satisfy statutory obligations;
- Diversions and enabling works necessary to permit the development.

The outline plans are to provide three new quay facilities in a south facing U shape with an offshore breakwater (Figure 1-2). The deck height of the west, north and east quays and the south-east breakwater will be at 6.7 m Above Chart Datum (ACD). The new quay areas will cover a surface area of approximately 20,000 m^2 (Table 1-1).

Table 1-1: Surface Area of Proposed Structures

Items	Length (m)	Width (m)	Area (m^2)
North Quay	400	15	6,000
West Quay	300	10	3,000
East Quay	400	15	6,000
Breakwater	500	10	5,000
Total			20,000

The breakwaters will be constructed of armoured units which will angle up from the sea bed in the dredged approach channel, or the natural bed level elsewhere, to the top of the structure at 12 m ACD (Table 1-2). The suspended deck structure on the West Quay and part of North Quay will be an angled revetment and rock armoured, sloping up from the dredged harbour depth of -10 m ACD to just below the deck level at 6.7 m ACD. The deck itself will sit on top of a series of piles. The south east Pier, East Quay and the east part of North Quay will all have a vertical hard face.

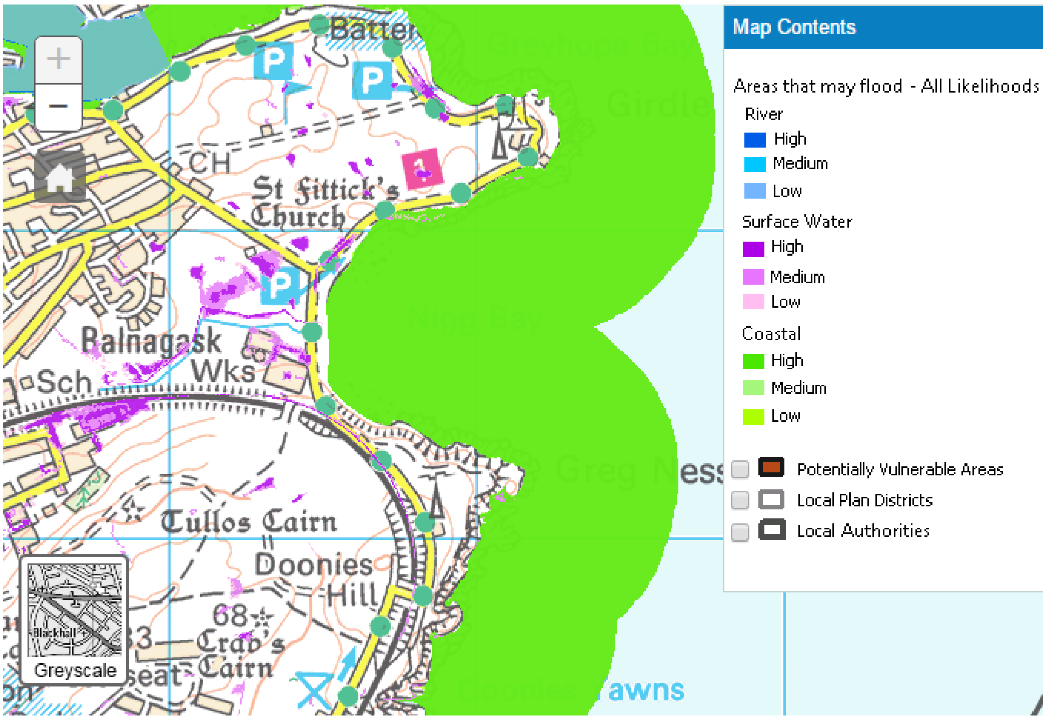
Table 1-2: Height of Structures to Chart Datum and Ordnance Datum

Items	Height (m ACD)	Height (m AOD) (CD = OD -2.25 m)
Quayside	6.7	4.45
Breakwater	12.0	9.75
Harbour Depth	-10.0	-12.25
Approach Channel Depth	-11.5	-13.75

The new harbour would be dredged to -9 m ACD for the main basin and -10.5 m ACD for the approach channel and east quay berth.

The Scottish Environment Protection Agency (SEPA) flood map for the area (Figure 1-5) indicates that the site is at risk of tidal flooding. A FRA is therefore required to determine the risk of flooding to the site and to others and identify mitigation measures to reduce flood risk, where applicable. The purpose of the FRA is to assess the flood risk, outline any potential constraints to development and make recommendations for appropriate mitigation and enhancement measures, where required. Figure 1-6 shows the surface watercourses in Nigg Bay.

Figure 1-5: SEPA Flood Map of Coastal Flooding (source http://map.sepa.org.uk/floodmap/map.htm)



ABERDEEN HARBOUR EXPANSION PROJECT

Figure 1-6: Nigg Bay Watercourses

Legend

Surface Watercourses

NOTE: Not to be used for Navigation

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Projection	British_National_Grid
Spheroid	Airy_1830
Datum	D_OSGB_1936
Data Source	OSOD,
File Reference	J:\P1974\Mxd\Method_Statement\ WFD_Waterbodies_v1.mxd
Created By	Emma Langley
Reviewed By	Ian Charlton
Approved By	Ann Saunders

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0 50 100 200 300 400 500 m

1.3 REQUIREMENTS FOR A FLOOD RISK ASSESSMENT

The methodology and requirements for an FRA are based on Scottish Planning Policy, the Flood Risk Management (Scotland) Act 2009 and the Annex to the SEPA flood risk guidance. This FRA is also based on SEPA's written response to the Scoping Opinion of 29 August 2013 (Ref PCS/128124).

1.4 SCOTTISH PLANNING POLICY

The requirements for an FRA are set out in the Scottish Planning Policy [Paragraphs 196-211] (February 2010). This requires that Local Planning Authorities (LPAs) must consider the probability and risk of flooding from all sources – tidal, fluvial, pluvial, groundwater, sewers and blocked culvert drainage and infrastructure failure when determining planning applications. Any development that would have a significant probability of being affected by flooding should not be permitted and the potential for increased flooding affecting others, such as by displacing flood water or increasing site runoff, should be also be assessed as part of the FRA.

To provide a basis for planning decision making, the flood risk framework divides flood risk into three zones and the planning policy outlines an appropriate planning response for each (Table 1-3), where the annual probability refers to the land at the time a planning application is made.

In applying the risk framework, developers and planning authorities should also take into account:

- the characteristics of the site
- the use and design of the proposed development
- the size of the area likely to flood
- depth of water, likely flow rate and path, rate of rise and duration
- existing flood prevention measures – extent, standard and maintenance regime
- the allowance for freeboard
- cumulative effects of development, especially the loss of flood storage capacity
- cross boundary effects and the need for consultation with adjacent authorities
- effects of a flood on access including by emergency services
- effects of a flood on proposed open spaces including gardens
- the extent to which the development, its materials and construction are designed to be water resistant

Table 1-3: Scottish Planning Policy Flood Risk Framework

Zone	Level of Risk	Probability of Flooding	Constraints
1	Little or None	Less than 0.1% (1,000 year)	• No constraints due to watercourse, tidal or coastal flooding.
2	Low to Medium	0.1% - 0.5% (200 to 1,000 yr)	• Areas suitable for most development. • An FRA may be required if a site is close to the 200 year limit. • Water resistant materials and construction methods may be required depending on the FRA. • These areas are generally not suitable for essential civil infrastructure such as hospitals, fire stations, emergency depots etc. Where such infrastructure must be located or extended in these areas it should be capable of remaining operational and accessible during extreme flood events.
3	Medium to High	Greater than 0.5% (200 yr)	• Generally not suitable for essential civil infrastructure (hospitals, fire stations, emergency depots etc., schools, care homes etc.) unless subject to a long term flood risk management strategy. • Land raising may be acceptable and measures to manage flood risk will be required and the loss of flood storage capacity mitigated to produce a neutral or better outcome. • In undeveloped and sparsely developed locations these areas are generally not suitable for additional development. Exceptions may arise if a location is essential for operational reasons, e.g. for navigation, transport or utility infrastructure and an alternative lower risk location is not achievable. • Infrastructure should be designed and constructed to remain operational during floods. • Measures to manage flood risk are likely to be required and the loss of flood storage capacity minimised. • Water resistant materials and construction should be used where appropriate.

Flood risk management measures should target the sources and pathways of flood waters and the impacts of flooding and should avoid or minimise detrimental effects on the ecological status of the water environment with opportunities for habitat restoration or enhancement sought.

The raising of land, above the functional flood plain may have a role in some circumstances but should include compensatory flood water storage measures to replace the lost capacity of the functional flood plain so as not to increase the risk of flooding elsewhere.

Any surface water runoff from a new development should be treated by a sustainable urban drainage system (SUDS) before it is discharged into the water environment, except where the discharge will be into coastal waters. The aim of SUDS is to mimic natural drainage, encourage infiltration and attenuate and reduce the risk of flooding both on and off the site. Planning permission should not be granted unless the proposed arrangements for surface water drainage are adequate and appropriate long term maintenance arrangements will be in place.

1.4.1 Flood Risk Management (Scotland) Act 2009

The Flood Risk Management (Scotland) Act 2009 sets in place a statutory framework for delivering a sustainable and risk-based approach to managing flooding. Although ultimate responsibility for avoiding or managing flood risk still lies with land and property owners, this act places a duty on Scottish Ministers, SEPA, local authorities, Scottish Water and other responsible authorities to exercise their functions with a view to managing and reducing flood risk and to promote sustainable flood risk management. The main elements of flood risk management relevant to the planning system are assessing flood risks and undertaking structural and non-structural flood management measures.

Section 42 of the Flood Risk Management (Scotland) Act 2009 indicates that planning authorities will require an assessment of flood risk where a development is likely to result in a material increase in the number of buildings at risk of being damaged by flooding.

1.4.2 SEPA Guidance

SEPA has advised that an FRA should consider the guidance set out in the Annex to the SEPA-Planning Authority flood risk protocol, which outlines the information required in an FRA and the appropriate methodologies for hydrological and hydraulic modelling.

SEPA's flood zone maps are used to indicate whether a site is at risk of flooding, from what source, and indicate whether an FRA is required to accompany a planning application. These indicative flood risk maps identify flood risk areas arising from fluvial, pluvial and tidal sources but the flood risk from other sources such as rising groundwater, impounded waterbodies and other drainage systems should also be considered in an FRA.

SEPA encourages surface water runoff from all developments to be treated by SUDS in line with Scottish Planning Policy (Paragraph 209), PAN 61 Planning and Sustainable Urban Drainage Systems, PAN 79 Water and Drainage and NE6 – Flooding and Drainage policy in the Aberdeen City Local Plan (2012). The FRA should include a preliminary assessment of the surface water drainage requirements including a comparison of pre- and post-development surface-water runoff, and means of treatment and attenuation and include indicative SUDS proposals and identify the location of suitable outfall points.

The level of SUDS required is dependent on the nature and size of a development, and the environmental risk posed by the development which is principally determined by the available dilution of the receiving water body. For all developments, run-off from areas subject to particularly high pollution risk (e.g. yard areas, service bays, fuelling areas, pressure washing areas, oil or chemical storage, handling and delivery areas) should be minimised and directed to the foul sewer. Where run-off from high risk areas cannot be directed to the foul sewer, SEPA can advise on the best environmental solution. Guidance on the design of SUDS systems and appropriate levels of treatment is given in CIRIA C697 (The SUDS Manual), the SEPA Guidance Note Planning advice on SUDS and on SEPA's web site. SEPA will encourage the design of SUDS to Sewers for Scotland Second Edition standards and the adoption of SUDS features by Scottish Water as this leads to better standards and maintenance.

1.5 REPORT STRUCTURE

For this FRA, the site details and flooding history are given in Section 2, including estimation of extreme tidal and fluvial flood levels and the implications for the development. Details of site runoff, with measures to control this are given in Section 3. The interpretation of planning policy guidance is given in Section 4 and the conclusions are presented in Section 5.

2 FLOOD RISK

The main source of flooding of the site is the adjacent North Sea where extreme sea levels in combination with wave heights could potentially affect the development. Details of historical flood records and estimates of extreme sea levels have therefore been used to determine the risk of flooding to the site. In addition, there is a small watercourse that enters on the west side of the bay, the East Tullos Burn, and the risk of fluvial flooding from this source is given in Section 2.2. Other potential sources of flooding are considered in Section 2.3 and the implications of all of these sources of flooding on the proposed development detailed in Section 2.4.

2.1 TIDAL SOURCES OF FLOODING

The SEPA flood map (Figure 1-5) shows the 200 year and 1,000 year tidal flood extent and indicates that the site is at risk from extreme tidal flooding, which given its coastal location is not unexpected. The site lies inside the 200 year flood zone and is therefore in Flood Zone 3 according to the Scottish Planning Policy Flood Risk Framework (Table 1-3). There are currently no formal flood defences to protect the existing, undeveloped site.

2.1.1 Anecdotal Records

A search of anecdotal records of flooding in the immediate area of Nigg Bay revealed that there is no available documentary evidence of flooding near the site. This should be considered unsurprising given its rural and coastal location, which means that there is a high likelihood that any flooding would go unreported. The British Hydrological Society's "Chronology of British Hydrological Events" also provides no evidence of historical flood events at this location.

2.1.2 Tide Level Data

Measured tide level records are available from the tide gauge operated by the National Oceanography Centre (formerly the Proudman Oceanographic Laboratory) at Aberdeen Harbour. The gauge was originally located at Pocra Quay pier leg (NJ 9559 0582) but was relocated to its present location at the entrance to Victoria Dock (NJ 9525 0591) in 1973. The records from this gauge extend over 85 years from 1930 to 2015, although there are gaps in the record for the following issues:

- a 19 year spell with no data returned (1937 to 1945 inclusive)
- 13 years have records that are less than 50% complete
- when the gauge was moved in 1973

The levels are recorded as ACD (2.25 m below AOD), and the annual maximum series is given in Appendix A.

A summary of the largest peaks in the annual maximum data (Table 2-1) shows that the largest recorded water levels occurred in January 2005 with a peak level of 5.306 m ACD (3.056 m AOD) and the second largest in December 2013 of 5.229 m ACD (2.979 m AOD). Comparison with the site survey and the ground level of 0 m to 5 m along the foreshore suggests that flooding of the existing site would have occurred at these tide levels but that Coast Road/Greyhope Road would not have been flooded. There are no records of any property or infrastructure flooding at Nigg Bay on these dates as this is a rural location.

Table 2-1: Largest Annual Maximum Water Levels at Aberdeen Tide Gauge

Rank	Date and Time	Height (m ACD)	OD (CD – 2.25m)
1	12/01/2005 14:30	5.306	3.056
2	05/12/2013 15:00	5.229	2.979
3	11/01/1993 02:45	5.175	2.925
4	09/02/1997 14:15	5.143	2.893
5	27/11/2011 14:15	5.140	2.890

2.1.3 Modelled Extreme Tide Levels

Where measured tide level data records are less that the return period of interest, which is the case at many if not all coastal development sites, estimates of extreme sea levels are based on a joint SEPA and Environment Agency report[i]. This project used the results from a continental shelf tide-surge model and tide level data from 40 Class A gauge sites around the UK. A joint probability statistical analysis was then used to generate predicted high tide with surge and combining these two elements gives the overall design sea level for different probabilities based on the Skew Surge Joint Probability Method (SSJPM). An interpolation method is then used to determine extreme sea levels between the primary gauge sites.

The model results are corrected so they agree with values obtained from a statistical analysis of the primary gauge records and also checked against design sea levels at secondary tide gauge sites. This report provides extreme sea levels using the best available data and the latest techniques commonly adopted to provide the required design tide levels. Table 2-2 shows a 200 year sea level for Aberdeen of 3.17 m AOD and a 1,000 year level of 3.29 m AOD. This does not take into account the potential effects of climate change or wave heights which are considered in more detail in Sections 2.1.4 and 2.1.5 below.

Table 2-2: Extreme Sea Levels near Aberdeen (m OD)

Site	1	2	5	10	20	50	100	200	500	1,000
Moray Firth	2.85	2.91	3.00	3.07	3.13	3.22	3.29	3.35	3.44	3.51
Aberdeen	2.68	2.75	2.84	2.91	2.97	3.05	3.11	3.17	3.24	3.29
Leith	3.37	3.44	3.54	3.61	3.69	3.80	3.88	3.97	4.10	4.20

2.1.4 Climate Change

It is anticipated that global sea levels will rise over the next 100 years. The degree of this change will depend on the level of future greenhouse gas emissions and the sensitivity of the climate system. The accepted allowances for the rate of relative sea level rise (Table 2-3) should be used when considering flooding from the sea into the future, over the design life of a development. This is usually taken as 60 years for commercial development or 100 year for residential or larger scale projects.

A study of sea level data from the north east of England and around Scotland has shown that Aberdeen has been subject to comparative sea level rises since 1980[ii]. This confirms the need at a local level for considering sea level rises.

These anticipated rates of relative sea level rise over the next 100 years, are based on the Department for Environment, Food and Rural Affairs *FCDPAG3 Economic Appraisal Supplementary Note to Operating Authorities – Climate Change Impacts,* October 2006.

Table 2-3: Anticipated Rates of Sea Level Rise Relative to 1990 for NW England, NE England & Scotland

Parameter	1990 to 2025	2025 to 2055	2055 to 2085	2085 to 2115
Sea level Rise (mm/yr)	2.5	7.0	10.0	13.0

This suggests tide levels are expected to increase by 0.94 m by 2115 (Table 2-4). These increases should be used to dictate design levels over the design life of the development.

Table 2-4: Estimated Tide Levels with Climate Change

Year	No Yrs	Rate (mm/yr)	200yr	1,000yr
2008	-	-	3.17	3.29
2025	17	2.5	3.21	3.33
2055	30	7.0	3.42	3.54
2085	30	10	3.72	3.84
2115	30	13	4.11	4.23

If the lifetime of the proposed development is taken as 100 years, the 200 year plus climate change estimated flood level can be taken as 4.11 m AOD. As detailed in Table 1-2, this is below the proposed quay side level of 4.45 m AOD.

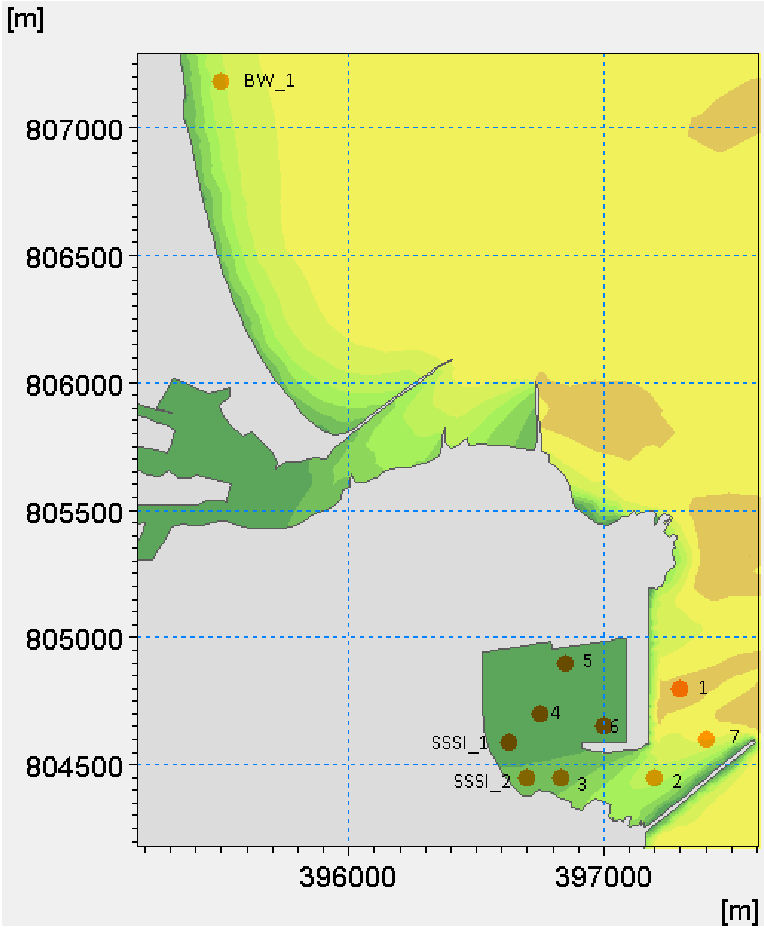
2.1.5 Wave Heights

As part of the overall assessment of the site, a detailed hydrodynamic coastal model has been developed which incorporates the effects of wave action and local bathymetry. The results of this hydrodynamic study, particularly wave heights, were used in this FRA.

Simulations were carried out to assess the impact of the development on average, annual and extreme significant wave heights. As the extreme wave heights are the most pertinent to this FRA, only these 1:200 year return period events will be discussed further.

The model was used to determine wave heights both before and after the development to gauge the impact of the development and also allow a comparison of these heights to be made against ground levels and the levels of the proposed harbour facilities and breakwater. The points used to represent the conditions in and around Nigg Bay are shown in Figure 2-1.

Figure 2-1: Wave Modelling Extraction Locations



Note: SSSI = Site of Special Scientific Interest

Table 2-5: 1:200 Year Significant Wave Heights

	Wave Angle	Significant Wave Height at Each Location Above Mean Sea Level (m)									
		1	2	3	4	5	6	7	BW_1	SSSI_1	SSSI_2
Baseline	45 deg	6.560	6.372	4.349	4.256	3.994	5.806	6.718	3.213	3.136	3.194
	90 deg	7.626	7.776	3.959	4.517	5.012	6.150	8.479	3.244	3.156	2.842
	135 deg	7.286	7.252	3.143	4.254	5.086	5.706	7.935	3.161	2.904	2.354
Developed	45 deg	6.688	3.679	1.483	0.229	0.079	0.036	5.277	3.214	0.582	1.238
	90 deg	7.298	2.092	0.997	0.165	0.057	0.026	3.845	3.244	0.395	0.844
	135 deg	5.015	0.853	0.462	0.082	0.029	0.013	1.845	3.161	0.188	0.396
Difference	45 deg	0.129	-2.693	-2.866	-4.028	-3.915	-5.771	-1.441	0.000	-2.554	-1.956
	90 deg	-0.328	-5.684	-2.962	-4.352	-4.954	-6.124	-4.634	0.000	-2.761	-1.998
	135 deg	-2.271	-6.399	-2.681	-4.172	-5.057	-5.693	-6.090	0.000	-2.716	-1.958

Table 2-5 shows the significant wave heights generated by the model for the pre and post development scenarios, along with the difference between these predictions. As can be seen, the presence of the breakwaters results in a reduction of the wave heights within the harbour. The only condition and location whereby the wave height exceeds the baseline is at the north breakwater under a 45 degree wave direction, when an increase of 0.129 m is experienced. The resulting water level at this point is significantly lower than the breakwater level, meaning that the coastal flood risk is not increased at this point. At all other locations, the significant wave height is reduced indicating a reduction of flood risk within the harbour as a result of the breakwaters.

At the bathing water to the north, there is unsurprisingly no change to the wave heights as a result of the development.

Even when considering peak wave heights rather than the significant wave height, a similar picture emerges, with reductions in level within the harbour. The peak wave height in the analysis was found to be 9.175 m at assessment point 1. This is still lower than the breakwater level of 9.75 m OD and is a minor 3 mm reduction over the peak water level at the same point for the baseline scenario.

Figures showing the changes in wave height as a consequence of the construction of the harbour are provided in Appendix B.

The anticipated impact of climate change is for an increase in the frequency of high water levels (as detailed above) and also for an increase in storminess. This will result in a change in wave heights due to increased water depths and in the frequency, duration and severity of storm events and wind speed. The latest guidance suggests that a 10% sensitivity allowance should be added to offshore wind speeds and wave heights by 2115[iii] (Table 2-6). The proposed quayside level of 4.45 m OD is above the 200 year extreme still water levels and this is further protected from significant wave heights by the breakwater to 2115 and from the peak wave height to 2055.

Table 2-6: Anticipated Increase in Wind Speed and Wave Height for NW England, NE England & Scotland

Parameter	1990 to 2025	2025 to 2055	2055 to 2085	2085 to 2115
Offshore wind speed	+5%		+10%	
Extreme wave height	+5%		+10%	

2.2 FLUVIAL FLOODING

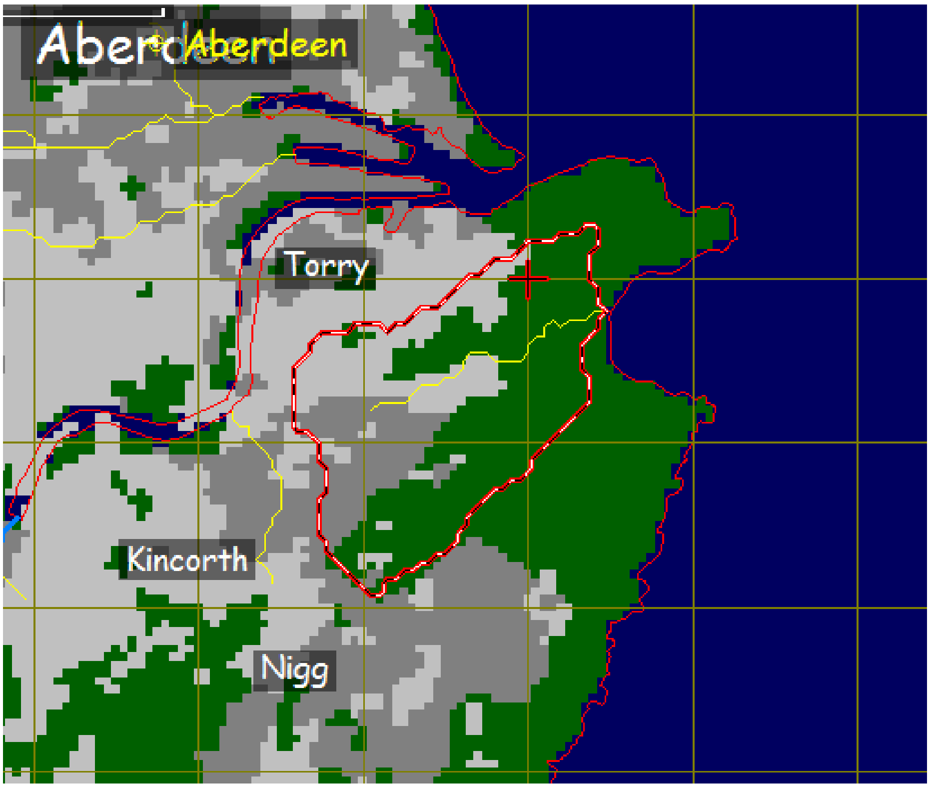
The main potential source of fluvial flooding for the site is the East Tullos Burn which discharges into the sea within the boundary of the proposed development. This watercourse passes through a number of culverts upstream of the site and has recently undergone some improvement works. Although this area is not identified as at risk of flooding on the SEPA Flood Map (Figure 2-2) it is usual that an FRA should determine the risk of flooding from fluvial sources and include hydraulic modelling if this is necessary. The FRA should include an assessment to ensure all new and existing culverts have sufficient capacity to convey storm flows, in compliance with SEPA and Scottish Planning Policy requirements. The risk of fluvial flooding is based on the estimation of flood flows and conversion of flows to levels and this is considered below.

Figure 2-2: SEPA Flood Map of Fluvial Flooding (source http://map.sepa.org.uk/floodmap/map.htm)

2.2.1 Flood Flows

The assessment of the impact of fluvial flows requires the derivation of extreme flood flows for a range of return periods from the 2 year to the 1,000 year event. This is based on methods detailed in the Flood Estimation Handbook (FEH)[iv], using the Revised Statistical Method[v] and the Revitalised Flood Hydrograph Method (ReFH) for comparison. Flow estimates are provided at the downstream boundary of the East Tullos Burn where it crosses the Coast Road at the entrance of the bay. The FEH catchment delineation at this location is provided (Figure 2-3).

Figure 2-3: FEH Catchment Map (source FEH Vol. 3[iii])



The FEH catchment descriptors (Table 2-7) indicate that this watercourse has a small catchment area (2.41 km^2) and is partly urban (URBEXT1990 = 0.27), with no lakes or reservoirs (FARL = 1.0) and a low percentage runoff (SPRHOST = 18.1%). The FEH methods are believed to be appropriate for the site, with the small catchment area of the watercourse still above the FEH recommended minimum of 0.5 km^2.

The FEH calculations are based on the latest FEH CD version 3 which is provided as Figure 2-3. The creation of wetlands adjacent to the East Tullos Burn would reduce the estimated peak flows in which case flood risk would be reduced. The FRA therefore considers a conservative scenario and it is not necessary to change the assessment.

A full definition of the parameters in Table 2-7 is given in the FEH Volume 5.

Table 2-7: FEH Catchment Descriptors at Flow Estimation Point

FEH Parameter	Description	Value
Grid Ref	OS Grid Reference	NJ 96450 04800
AREA	Catchment Area (km^2)	2.41
ALTBAR	Mean Altitude (m OD)	30
BFIHOST	Baseflow index based on hydrology of soil types	0.828
DPLBAR	Average drainage path length (km)	1.64
DPSBAR	Average drainage path slope (m/km)	70.6
FARL	Flood attenuation index due to reservoirs and lakes	1
PROPWET	Proportion of time the catchment is wet	0.42
SAAR	Average Annual Rainfall (mm)	716

FEH Parameter	Description	Value
SPRHOST	Percentage runoff based on hydrology of soil types	18.14
URBEXT1990	Urban extent in 1990	0.2596
URBEXT2000	Urban extent in 2000	0.3104

The flow estimation process requires that the empirically derived flows from the FEH are adjusted using recorded flow data at one or more nearby flow measurement stations. However, SEPA does not operate any such stations within 10 km of the East Tullos Burn and a local adjustment is therefore not possible. Using more distant stations would result in similar flows as the empirical method.

2.2.1.1 FEH Statistical Method

As the site of interest is ungauged, as a first approach it is appropriate to use the FEH Statistical method. This is based on a two stage approach:

- Calculation of the index flood (the median annual flood flow- QMED) which at an ungauged site is derived from catchment descriptors, but can be adjusted using the ratio of QMED from catchment descriptors and flow data at a nearby (donor) gauging station if available.
- The fitting of various extreme value distributions to a pooled group of annual maximum flow data from hydrologically similar sites (pooling group) to estimate flows at different return periods.

The FEH catchment descriptors for the subject site are used to derive QMED (Table 2-8) using the Revised Statistical Method QMED equation [v].

Table 2-8: QMED from Catchment Descriptors

Site	Rural QMED (m^3/s)	Urban QMED (m^3/s)
East Tullos Burn at Nigg Bay	0.16	0.27

FEH recommends the use of an urban adjusted QMED which for the East Tullos Burn is 0.27 m^3/s.

The calculation of a flood frequency curve and peak flows for extreme return periods is then based on the construction of a pooling group and the fitting of an extreme value distribution to the pooled group of Annual Maximum (AMAX) data from hydrologically similar stations using WINFAP software. The initial pooling group contains 14 stations and has 516 station years of record. No stations were removed for having less than the required 8 years of data.

Examination of the pooling group indicates it is strongly heterogeneous and a review considered essential (H2 = 4.318). However, a review of the pooling group provided no valid reason to remove any of the component stations and the pooling group was considered acceptable. The stations in the pooling group (Table 2-9) include a mixture of stations with both relatively steep and flat growth curves (Figure 2-4); hence some discordancy may be expected.

Figure 2-4: WINFAP Component Stations

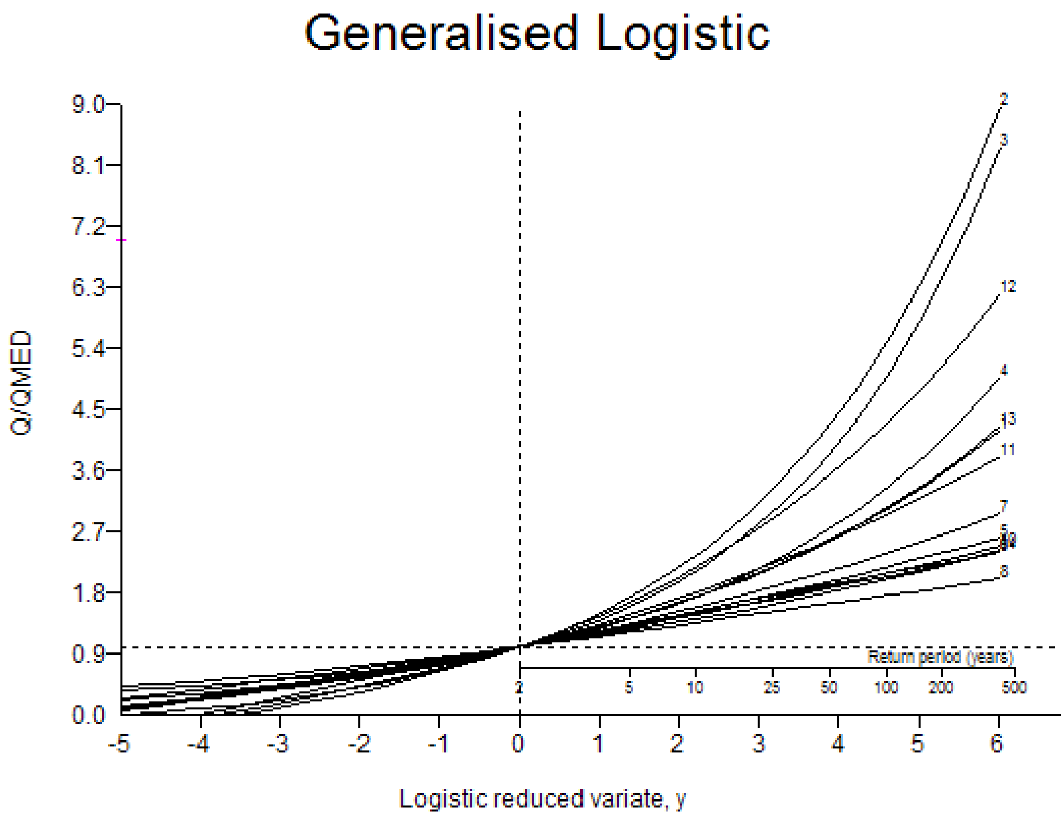


Table 2-9: Component Stations of Pooling Group

Station	No Yrs	L-CV	L-skew	L-kurt	Discordancy	Skewness
26802 (Gypsey Race @ Kirby Grindalythe)	14	0.253	0.216	0.254	0.439	1.331
44008 (South Winterborne @ Winterbourne Steepleton)	33	0.395	0.332	0.221	1.301	1.449
39033 (Winterbourne @ Bagnor)	50	0.336	0.369	0.363	1.816	1.603
40033 (Dour @ Crabble Mill)	31	0.246	0.292	0.318	1.222	1.653
33054 (Babingley @ Castle Rising)	36	0.214	0.069	0.151	0.416	1.671
26003 (Foston Beck @ Foston Mill)	52	0.243	-0.015	0.080	1.557	1.728
39089 (Gade @ Hemel Hempstead Bury Mill)	39	0.232	0.099	0.131	0.074	1.762
42011 (Hamble @ Frog Mill)	40	0.159	0.013	0.129	0.822	1.790
39042 (Leach @ Lechlade)	40	0.199	0.050	0.120	0.316	1.850
43014 (Avon @ Upavon East)	41	0.206	0.051	0.074	0.416	1.903
33032 (Heacham @ Heacham)	46	0.312	0.112	0.064	0.883	1.909
43806 (Wylye @ Brixton Deverill)	21	0.383	0.222	0.113	1.526	1.914
44003 (Asker @ East Bridge Bridport)	30	0.253	0.221	0.154	0.969	1.932
42007 (Alre @ Drove Total)	43	0.158	0.128	0.107	2.241	1.961

WINFAP indicates that the Generalised Logistic (GL) distribution provides the best fit extreme value distribution for this site. Extreme floods up to the 1,000 year event are calculated using an extension of the 100 year pooling group using the same GL distribution. The adopted flood estimates are therefore based on a QMED donor adjustment ratio of 1.0 and a pooled group growth curve (Table 2-10).

Table 2-10: Stats Method Flood Frequency Estimates (m^3/s)

Site	Return Period (Years)							
	2	10	20	50	100	100+CC	200	1,000
East Tullos Burn	0.27	0.36	0.40	0.46	0.51	0.62	0.57	0.72

Due to the uncertainties in flood estimation and expected climate change impacts, it is usually required that flood flows should include an allowance for increased river flow due to climate change. SEPA suggests a 20% increase in river flows by 2110 and the 100 year peak flow is therefore adjusted by increasing peak flows by 20% (Table 2-10).

2.2.1.2 Revitalised Flood Hydrograph Method

An alternative approach to flood estimation is given by the flood hydrograph methods, and although this is not yet adopted in Scotland it is included in this FRA for comparison with the statistical method results. The original FEH rainfall runoff method underwent significant modification in 2006, as it was shown to overestimate measured flows at gauging stations, and now takes advantage of new data and more advanced hydrological modelling techniques since the original method was developed. The improved or Revitalised Flood Hydrograph model (ReFH) retains the overall structure of the earlier FEH approach but with various improvements and ReFH is now preferred to rainfall runoff.

ReFH is also used to derive peak flows for the specified design events based on a critical storm duration of 1.3 hours. The flows at the East Tullos Burn (Table 2-11) are slightly higher than those from the FEH statistical method

Table 2-11: ReFH Flood Frequency Curves (m^3/s)

Site	Return Period (Years)							
	2	10	20	50	100	100+CC	200	1,000
East Tullos Burn	0.22	0.35	0.40	0.48	0.55	0.66	0.64	0.93

This arises as the ReFH growth curve is steeper than the statistical method (Table 2-12) and this may be due to errors in the extreme rainfall data set, which is the subject of current research.

Table 2-12: Flood Growth Curves

Site	Return Period (Years)						
	2	10	20	50	100	200	1,000
Stats	1.00	1.33	1.48	1.70	1.89	2.11	2.67
ReFH	1.00	1.57	1.79	2.15	2.48	2.88	4.19

The ReFH flood estimates are used to confirm that the statistical method estimates are reasonable but the statistical method results are preferred as they are considered to be more robust and hence are adopted in this study.

2.2.2 Fluvial Flood Levels

The conversion of flood flows to level can be based on a hydraulic model if available. However, without a topographic survey of the channel and flood plain upstream, it is not possible to construct a model of the watercourse. The catchment area and hence the flood flows are very small and it is likely that fluvial flood risk will be small compared to tidal extreme flood levels, therefore a simplified approach was adopted.

The main constraint to flows is the culvert taking the watercourse under the Coast Road. This is made up by two 750 mm diameter pipes that are approximately 10 m in length. This is assumed to have a fall of 0.2 m over its length and with an equivalent sand toughness (k) of 10 mm. A silt depth of approximately 50 mm was observed in the base of the culvert during a site visit. This arrangement has a total culvert capacity of 2.24 m^3/s litres per second (l/s) (Table 2-13).

Table 2-13: Pipe Capacity Calculations

Parameter	Value
Diameter (mm)	2 x 750
Length (m)	10.0
US invert (m OD)	5.2
DS Invert (m OD)	5.0
Slope	0.025
Clean Pipe Area (m^2)	0.884
Total Pipe Perimeter (m)	4.712
Culvert Hydraulic Radius (m)	0.0875
Silt depth (mm)	50
Equivalent sand roughness (mm)	10
Total Flow Capacity (m^3/s)	2.24

Any excess flood flow above this pipe capacity would flow over the road and flood depths can be determined assuming this road acts as a 10 m wide broad crested weir. However, the culvert has a capacity in excess of the 1,000 year flood flow meaning that flooding should not be an issue for any of the return period events considered as part of this FRA (Table 2-14). The design of the development should ensure that the existing culvert capacity is not reduced to ensure that this performance is maintained.

Table 2-14: Flow Over Road with Culvert

	Return Period (years)							
	2	10	20	50	100	100+CC	200	1,000
Flow (m^3/s)	0.27	0.36	0.4	0.46	0.51	0.62	0.57	0.72
Culvert Capacity (m^3/s)	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24
Road Flow (m^3/s)	0	0	0	0	0	0	0	0
Water Depth(mm)	0	0	0	0	0	0	0	0

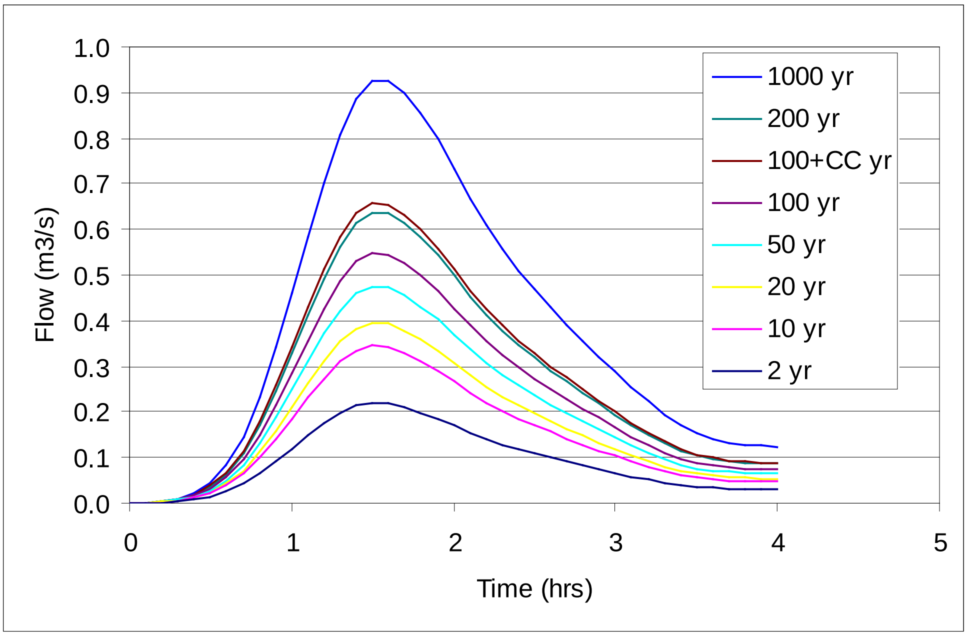
In the worst case, and assuming the culvert is 100% blocked, the 100 year flood flow with climate change would give a maximum depth over the road of 120 mm or 132 mm for the 1,000 year event. In this situation, the flood waters would locally overtop the road and small dunes to flow directly onto the beach. These very shallow flood depths and simple overland flow paths confirm that fluvial flooding will be of low magnitude and will have a smaller impact than tidal flooding.

Table 2-15: Flow Over Road Assuming Blocked Culvert

	Return Period (Years)							
	2	10	20	50	100	100+CC	200	10,000
Flow (m^3/s)	0.27	0.36	0.4	0.46	0.51	0.62	0.57	0.72
Pipe Flow (m^3/s)	0	0	0	0	0	0	0	0
Road Flow (m^3/s)	0.27	0.36	0.4	0.46	0.51	0.62	0.57	0.72
Water Depth (mm)	68.7	83.2	89.3	98.0	105.0	119.5	113.0	132.1

The ReFH flood hydrographs show the small catchment area would provide small flood flows and of limited duration (Figure 2-5). The very shallow depths confirm that fluvial flooding will be of low risk and a smaller risk than tidal flooding.

Figure 2-5: ReFH Flood Hydrographs (source ReFH 2 – WHS Software)



2.3 OTHER SOURCES OF FLOODING

The Scottish Planning Policy emphasises the need to consider other potential sources of flooding when planning a development and for this site these may include:

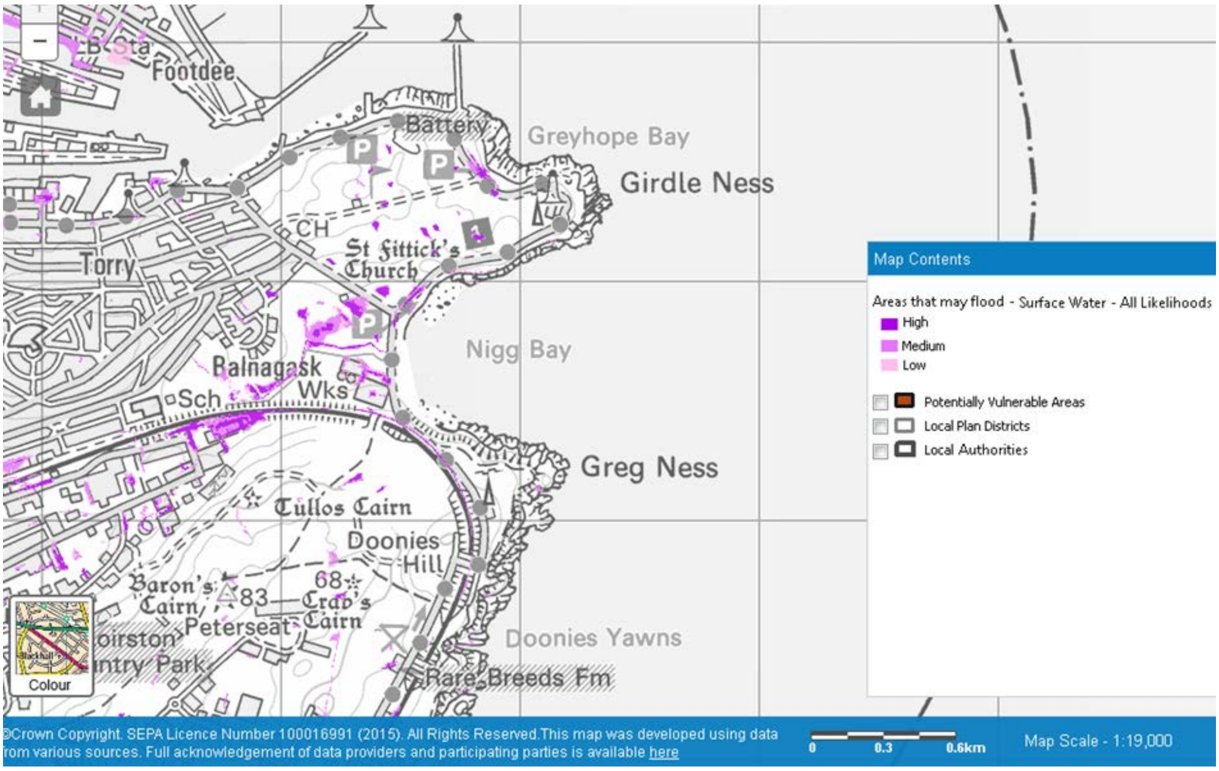
- Storm Water Flooding. This can occur when excess water runs off the surface of a site or adjacent land particularly during short but intense storms. Flooding occurs because the ground is unable to absorb the high volume of rainwater or because the amount of water is greater than the capacity of the drainage system to take it away. This can occur on developed impermeable sites with tarmac or buildings or where the soils are impermeable. SEPA pluvial flood maps show those areas likely to experience surface water flooding during heavy rain storms (Figure 2-6) and suggest the site is at low risk. The proposals are to provide a new drainage system on the site which will be designed to handle extreme storm events and so the risk of flooding from this source will be managed. Additionally, the operational floor level of the quays will be raised above the local ground level and this will prevent stormwater ponding from entering the site or any new buildings. The risk of storm water flooding will therefore be low.
- Highway flooding can occur from intense rain storms on road surfaces when the amount of water arriving on the road is greater than the capacity of the drainage facilities that take it away. Exceptional rainfall, a road being in a low lying area or changes in runoff from adjacent areas are situations that can lead to the road flooding or being waterlogged even when drains are in good working order. Material carried into the drains by floods can also lead to them becoming blocked when materials like mud are deposited on the road or when there is a heavy fall of leaves. This type of flooding is difficult to predict but as the site is higher than the local road and raised above the local ground levels, the risk of flooding from this source is considered to be low.
- Sewer flooding. This can occur when a storm or combined sewer network becomes overwhelmed and its maximum capacity is exceeded. Higher flows are likely to occur during periods of prolonged rainfall when the capacity of the sewer system is most likely to be reached. During summer periods sewers can become susceptible to blockage as the low flows are unable to transport solids. This can lead to the gradual build-up of solid debris. There are no recorded incidents in the vicinity of the site. Issues such as local blockage are difficult to predict with any certainty but the raised quayside levels will provide protection and the risk of flooding from this source is considered to be low.
- Groundwater flooding is most likely to occur in low-lying areas underlain by permeable rocks (e.g. Chalk or Sandstone) and results from water rising up or from water flowing from abnormal springs. This tends to occur after long periods of sustained high rainfall which can cause the water table to rise above normal levels, particularly in lower lying areas. The risk of groundwater flooding is highly variable and depends on local conditions at any particular time and it is not possible to accurately assess the risk. There are no records of the area having been affected. If groundwater is close to the ground surface then rising groundwater and flooding due to impeded drainage could occur and this may require further

consideration. However, as the new development will be raised above the local ground level the risk from groundwater flooding to the quays and buildings is likely to be low.

- Flooding from impounded waterbodies should also be considered. There are no lakes, reservoirs, canals or other waterbodies in the local area whose failure would have an impact on flooding the site.

The above indicates that the risk of flooding from other sources is low or can be managed.

Figure 2-6: SEPA Flood Map of Storm Water Flooding (source http://map.sepa.org.uk/floodmap/map.htm)



2.4 IMPLICATIONS FOR THE PROPOSED DEVELOPMENT

The FRA should outline specific development control recommendations to minimise damage to new properties and the risk to life in case of flooding and these are considered below.

2.4.1 Floor Levels

There are no flood defences to provide protection against the 200 and 1,000 year tide level of 3.17 m and 3.29 m AOD, or with climate change by 2115 of 4.11 m and 4.23 m AOD respectively (Table 2-4). However, the level of the quay will be at 4.45 m AOD (Table 1-1) and is above these extreme tide levels and hence tidal flooding of the site is considered unlikely. The breakwater at 9.75 m AOD will provide protection against extreme wave heights. As the quay is to be raised above the local ground levels the risk of flooding from storm water, sewers, highways and groundwater is considered to be low.

2.4.2 Safe Escape

A safe dry route should be available to allow users of the development to escape during an extreme flood event. A shallow depth of water on an escape route is permissible if velocities are low. For this site there will be a safe dry or low depth of flood water route on the road from the site to the North West which leads to higher ground and towards Aberdeen (Figure 1-1) where services and facilities exist. SEPA's flood map (Figure 1-5) shows this road would not be affected by the 200 year event and this can be considered to be a safe route.

2.4.3 Volume of Displacement

The volume of water which would be displaced from the site, before and after development, is usually compared to determine the need for compensatory storage. Although the proposed development site lies inside the 200 year flood extent, as it is a coastal area, the increase in flood levels will be minimal and there is no requirement for compensatory storage as there will be no change in flood risk at adjacent sites.

Similarly, as the proposals are at the coast, as long as the capacity of the East Tullos Burn is maintained there should be no cumulative effect on any other development proposals in the catchment area.

2.4.4 Flood Resilience and Resistance

The risk of tidal and fluvial flooding of the site is low and with the quayside level raised above local ground levels no part of the site is below the 200 year + climate change flood level. There is therefore no requirement to consider flood resistance or resilience measures.

2.4.5 Flood Evacuation Plan

As the quay side will be above the 200 year + climate change flood level, the risk of flooding is low and there are no requirements to consider or provide a flood evacuation plan.

3 PLANNING POLICY GUIDANCE

3.1 APPROPRIATE DEVELOPMENT

Under panning policy the proposed land use for docks and wharves is considered to be a water compatible development which is appropriate in Flood Zone 3 (Table 3-1).

Table 3-1: Appropriate Land Use by Flood Zone

Classification	Zone			
	1	2	3a	3b
Essential Infrastructure	Appropriate	Appropriate	Exception test	Exception test
Highly Vulnerable	Appropriate	Exception test	Not permitted	Not permitted
More Vulnerable	Appropriate	Appropriate	Exception test	Not permitted
Less Vulnerable	Appropriate	Appropriate	Appropriate	Not permitted
Water Compatible	Appropriate	Appropriate	Appropriate	If it has to be there

SEPA's flood map shows the site lies in Flood Zone 3 and for the proposed development the Exception Test is not required. For sites in Zone 3 the Sequential Test is usually considered.

3.2 THE SEQUENTIAL TEST

The Sequential Test requires a search for reasonably available alternative locations for the proposed development at a lesser flood risk in the LPA area. As the proposed development is to provide dock and wharves, this has to be at a coastal location and must be located in Flood Zone 3 hence there will be no alternative locations at a lower flood risk. Compliance with the Sequential Test is therefore demonstrated.

4 CONCLUSIONS

The FRA reported within this document has allowed the following conclusions to be made:

- SEPA's Flood Map indicates that the proposed development is in Zone 3 and at risk of tidal flooding and an FRA is required to determine the risk of flooding to the site and to others.
- There are no anecdotal records of flooding in the immediate area of Nigg Bay. Measured tide level records indicate that tidal flooding has not occurred at the site during the period of records.
- Estimates of extreme sea levels provide a 200 year sea level at Aberdeen of 3.17 m OD and a 1,000 year level of 3.29 m OD. These are below the proposed quayside levels.
- The anticipated rate of relative sea level rise over the next 100 years suggests tide levels are expected to increase by 0.94 m by 2115. Over the 100 year design life of the development, the 200 year tide level is expected to increase to 4.11 m AOD. The proposed quay side level of 4.45 m AOD is therefore above the 200 year extreme still water level by 2115.
- The peak wave heights within the harbour are predicted to reduce as a result of the effects of the breakwaters, resulting in a reduction of local flood risk. At the breakwaters themselves, a modest increase in peak wave height is predicted depending upon wave direction. The forecast peak wave heights are still less than the proposed breakwater level for all but the most extreme climate change allowance.
- The main source of potential fluvial flooding is the East Tullos Burn which discharges into the sea within the boundary of the proposed development site. This area is not identified as at risk of fluvial flooding on SEPA's flood map but has been considered in this FRA. The main constraint is the culvert below Coast Road which calculations suggest has a capacity in excess of the 200 year flood flow for the watercourse. Even assuming a worst case that the culvert is 100% blocked, the 100 year flood flow with climate change would give a maximum depth on the road of 120 mm or 132 mm for the 1,000 year event, with overland flow discharging directly to sea. These comparatively shallow flood depths confirm that fluvial flooding will be of low magnitude and will have a smaller impact than tidal flooding.
- Other potential sources of flooding have been considered which for this site may include stormwater, highways, sewers, groundwater and impounded waterbodies. The proposals are to provide a new drainage system on the site which will be designed to handle extreme storm events and so the risk of flooding from these sources will be managed. Additionally as the operational level of the quays will be raised above the local ground level, the risk of flooding from these sources is considered to be low.
- There will be a safe dry escape route from the site to the north west which leads to an area of higher ground and towards Aberdeen where services and facilities exist.

- The proposed development site lies inside the 200 year flood extent but as this is a coastal area, the increase in flood levels due to the loss of flood storage will be minimal and there is no requirement for compensatory storage. There is also no requirement to consider flood resistance or resilience measures or a flood evacuation plan.
- Scottish Planning Policy requires that surface water runoff from a new development should be treated by sustainable drainage systems (SUDS) before it is discharged into the water environment. The exception is where the discharge will be into coastal waters as in this case due to the available dilution of the receiving waterbody. As the site lies adjacent to the sea there is no benefit in using SUDS to control peak flow and the volume of runoff. The main issue is water quality and ensuring pollution events such as spillage can be controlled. The installed drainage network should therefore include petrol interceptors and control valves to prevent any spillage of contaminants from entering the coastal environment. The final drainage scheme will be considered at the detailed design stage.
- Under planning policy, the proposed land use for docks and wharves is considered to be a water compatible development which is appropriate in Flood Zone 3. There is no requirement to consider the Exception Test and as the proposals are to provide dock and harbour facilities, this has to be located in a coastal location and there will be no reasonably available alternative locations at a lesser flood risk in the LPA area. Compliance with the Sequential Test is therefore demonstrated.
- The findings of this FRA do not necessitate the implementation of mitigation measures.

5 REFERENCES

i Coastal flood boundary conditions for UK mainland and islands, Project: SC060064/TR2: Design sea levels (February 2001).

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iii Flood and Coastal Defence Appraisal Guidance FCDPAG3 Economic Appraisal Supplementary Note to Operating Authorities – Climate Change Impacts, October 2006.

iv Flood Estimation Handbook Volume 3, Centre for \Ecology and Hydrology, 1999.

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Appendix A Annual Maximum Tide Levels at Aberdeen Tide Gauge

Table A-1: Annual Maximum Tide Levels at Aberdeen Tide Gauge

Year	Maximum Level (m OD)	Expected No Values	No Values	Missing Values	% Complete
1930	4.8521	8760	5175	3585	59.1
1931	4.8825	8760	4656	4104	53.2
1932	4.7301	8784	695	8089	7.9
1933	4.4253	8760	312	8448	3.6
1934	4.9435	8760	311	8449	3.6
1935	4.8825	8760	1033	7727	11.8
1936	4.7911	8784	1224	7560	13.9
1937	-99	8760	0	8760	0.0
1938	-99	8760	0	8760	0.0
1939	-99	8760	0	8760	0.0
1940	-99	8784	0	8784	0.0
1941	-99	8760	0	8760	0.0
1942	-99	8760	0	8760	0.0
1943	-99	8760	0	8760	0.0
1944	-99	8784	0	8784	0.0
1945	-99	8760	0	8760	0.0
1946	4.6387	8760	8712	48	99.5
1947	4.7911	8760	8231	529	94.0
1948	4.7911	8784	7226	1558	82.3
1949	4.9435	8760	7533	1227	86.0
1950	4.0596	8760	287	8473	3.3
1951	4.6702	8760	844	7916	9.6
1952	4.8521	8784	792	7992	9.0
1953	4.7911	8760	360	8400	4.1
1954	-99	8760	288	8472	3.3
1955	4.2729	8760	576	8184	6.6
1956	3.9681	8784	8783	1	100.0
1957	5.0349	8760	8712	48	99.5
1958	4.731	8760	8760	0	100.0
1959	-99	8760	0	8760	0.0
1960	-99	8784	0	8784	0.0
1961	-99	8760	0	8760	0.0
1962	4.0901	8760	8759	1	100.0
1963	-99	8760	0	8760	0.0
1964	4.8216	8784	7509	1275	85.5
1965	4.7941	8760	8735	25	99.7
1966	-99	8760	0	8760	0.0
1967	5.0997	8760	7992	768	91.2
1968	4.8224	8784	8784	0	100.0
1969	5.0997	8760	8522	238	97.3
1970	4.9778	8760	8546	214	97.6
1971	4.7644	8760	8610	150	98.3

Year	Maximum Level (m OD)	Expected No Values	No Values	Missing Values	% Complete
1972	4.7035	8784	8423	361	95.9
1973	4.8	8760	8760	0	100.0
1974	-99	8760	0	8760	0.0
1975	-99	8760	0	8760	0.0
1976	-99	8784	0	8784	0.0
1977	-99	8760	0	8760	0.0
1978	-99	8760	0	8760	0.0
1979	-99	8760	0	8760	0.0
1980	4.759	8784	8679	105	98.8
1981	4.957	8760	7785	975	88.9
1982	4.679	8760	8396	364	95.8
1983	4.943	8760	7647	1113	87.3
1984	5.106	8784	8753	31	99.6
1985	4.88	8760	8760	0	100.0
1986	4.88	8760	8760	0	100.0
1987	4.844	8760	8760	0	100.0
1988	5.025	8784	8784	0	100.0
1989	4.976	8760	8760	0	100.0
1990	5.132	8760	8760	0	100.0
1991	5.032	8760	8760	0	100.0
1992	4.866	8784	8784	0	100.0
1993	5.175	35040	30624	4416	87.4
1994	5.009	35040	29698	5342	84.8
1995	5.097	35040	35040	0	100.0
1996	4.934	35136	35136	0	100.0
1997	5.143	35040	35040	0	100.0
1998	4.969	35040	34984	56	99.8
1999	5.071	35040	33964	1076	96.9
2000	4.979	35136	34517	619	98.2
2001	4.928	35040	34717	323	99.1
2002	5.064	35040	33611	1429	95.9
2003	4.808	35040	34281	759	97.8
2004	4.714	35136	35136	0	100.0
2005	5.306	35040	35040	0	100.0
2006	4.984	35040	35040	0	100.0
2007	4.975	35040	35040	0	100.0
2008	4.907	35136	35136	0	100.0
2009	5.074	35040	33898	1142	96.7
2010	4.88	35040	35040	0	100.0
2011	5.14	35040	34989	51	99.9
2012	4.856	35136	35130	6	100.0
2013	5.229	35040	35040	0	100.0
2014	5.049	35040	35040	0	100.0
2015	4.862	35040	35040	0	100.0

Appendix B Change in Significant Wave Height Figures

Figure B-1: Change in Wave Height for 45 Degree Wave

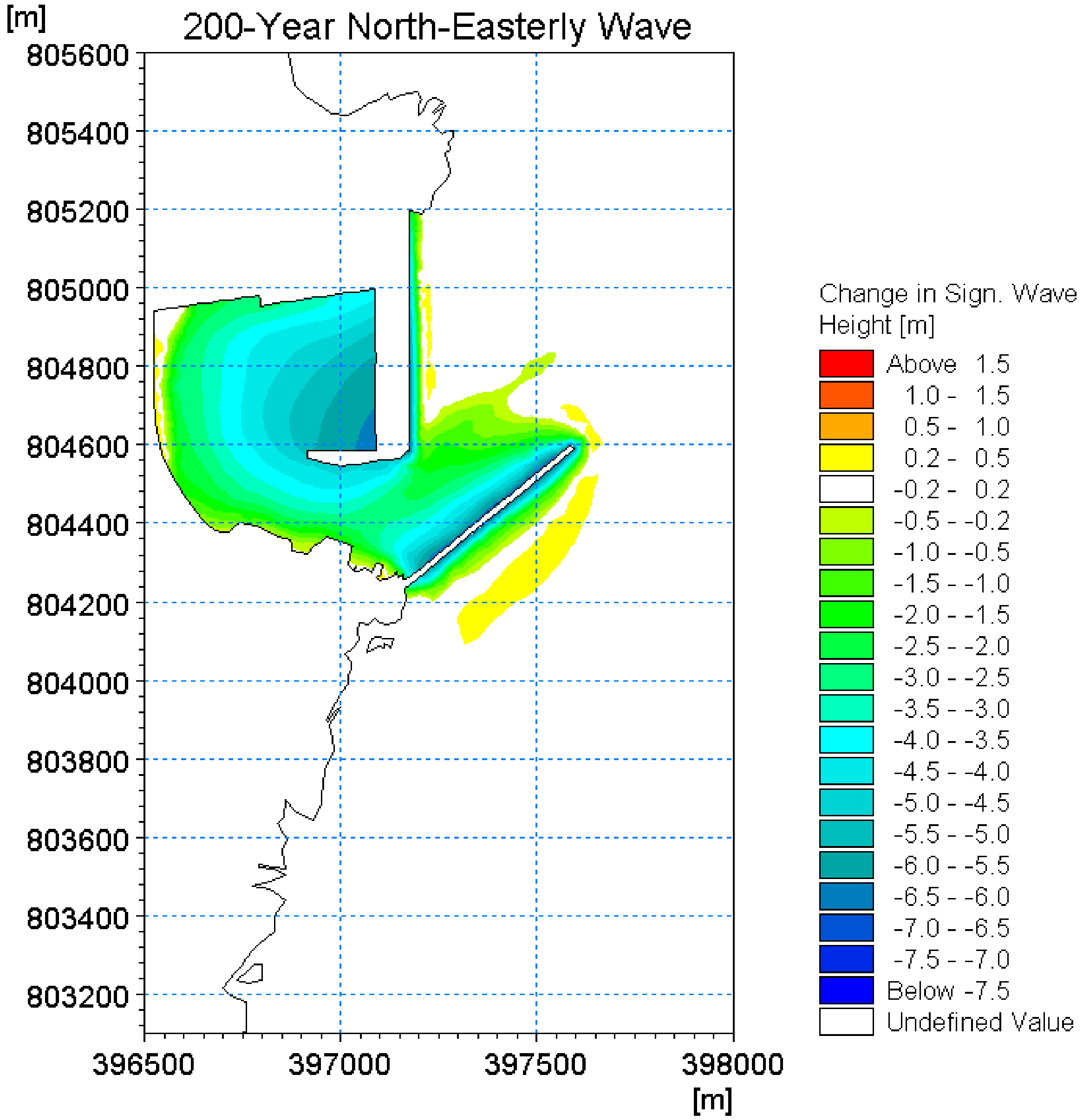

Figure B-2: Change in Wave Height for 90 Degree Wave

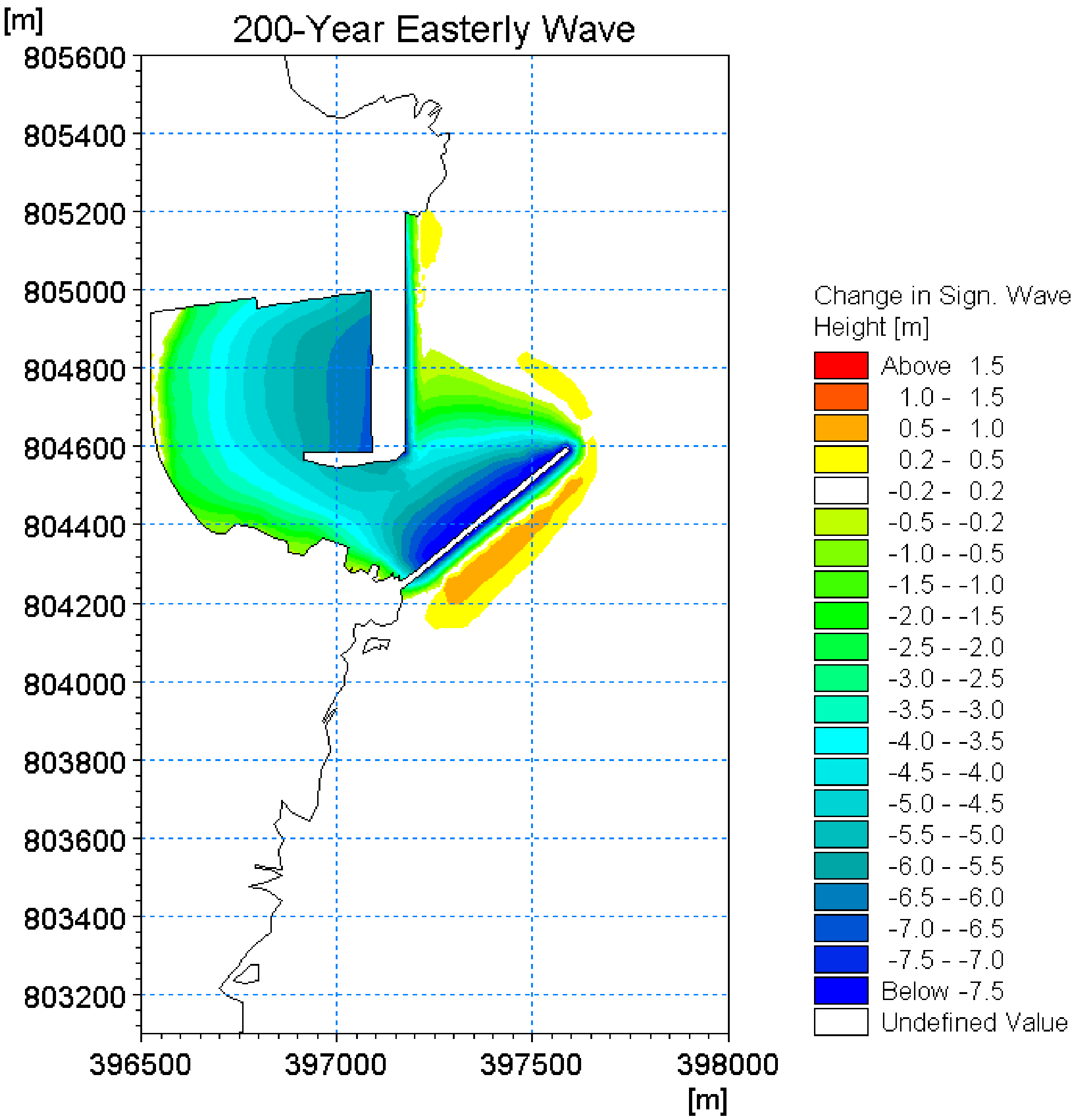

Figure B-3: Change in Wave Height for 135 Degree Wave