Proposed Neart na Gaoithe Wind Farm:
Offshore Cable Landing Flood Risk Assessment

Mainstream Renewable Power

Kaya Consulting Limited
Phoenix House, Phoenix Crescent, Strathclyde Business Park, Bellshill, North Lanarkshire, ML4 3NJ, UK ,Tel: 01698 464190, Web: http://www.kayaconsulting.co.uk

Mainstream Renewable Power

Proposed Neart na Gaoithe Wind Farm: Offshore Cable Landing

Flood Risk Assessment

Kaya Consulting Limited Job Number: **KC444**

Date: 25th September 2012

Kaya Consulting Limited
Phoenix House
Phoenix Crescent
Strathclyde Business Park,
Bellshill
North Lanarkshire, ML4 3NJ
Tel: 01698 464190
Mobile: 0783 0298686
E-mail: yusuf.kaya@kayaconsulting.co.uk
Web : http://www.kayaconsulting.co.uk

Contents

1 Introduction

Mainstream Renewable Power is seeking consent to build and operate an offshore wind farm 15.5 km east of Fife in the Firth of Forth, Figure 1. The proposed wind farm is called Neart na Gaoithe. The scheme will connect to the existing national grid via an underground cable transporting electricity from offshore to the grid connection point within the Crystal Rig II wind farm site in East Lothian.

LUC has been commissioned to undertake the Environmental Impact Assessment (EIA) for the Onshore Works components of the project. Kaya Consulting have been sub-contracted to assess the hydrological and flooding impacts of the proposed development.

Broad scale flooding risk to the entire development has been considered in the “Water Resources, Hydrology and Flood Risk” chapter of the EIA however, this report considers flood risk at the cable landing point in more detail. The assessment considers the landing point and proposed construction compounds, and considers flood risk from Thornton Burn and coastal flood risk from extreme sea levels and waves.

Figure 1: Location map

2 National Policy Regarding Flooding, Climate Change and Return Period

2.1 National Planning Policy

Scottish Planning Policy (SPP) was published in February 2010 (and supersedes a number of Scottish Planning Policy documents, including SPP 7: Planning and Flooding and other National Planning Policy Guidance documents). SPP retains the main principle of SPP7 - that is new development should not have a significant probability of being affected by flooding and should not increase the probability of flooding elsewhere.

Some extracts from SPP are listed below:

> "*Planning authorities must take the probability of flooding from all sources – (coastal, fluvial (water course), pluvial (surface water), groundwater, sewers and blocked culverts) and the risks involved into account when preparing development plans and determining planning applications.*"

> *"Development which would have a significant probability of being affected by flooding or would increase the probability of flooding elsewhere should not be permitted."*

> *"Prospective developers should take flood risk into account before committing themselves to a site or project. The responsibility of the planning authority is to have regard to the risk of flooding when preparing development plans and determining the planning applications, but this does not affect the liability position of applicants and occupiers who have responsibilities for safeguarding their property. Planning authorities should avoid any indication that a grant of planning permission implies the absence of flood risk."*

> *"Although ultimate responsibility for avoiding and managing flood risk still lies with land and property owners, certain public bodies are expected to take a proactive role in managing and, where achievable, lowering overall flood risk. The Flood Risk Management (FRM) (Scotland) Act 2009 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 risk and undertaking structural and non-structural flood management measures."*

> *"Section 42 of the FRM (Scotland) Act 2009 will, once commenced, amend the Town and Country Planning (Development Management Procedure) Regulations (Scotland) 2009 so that planning authorities will require applicants to provide 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."*

> *"For planning purposes the functional flood plain will generally have a greater than 0.5% (1:200) probability of flooding in any year. Built development should only take place on the functional flood plains where it will not affect the ability of the flood plain to store and convey water, where the development will not be at risk of flooding and where the development will not increase the risk of flooding elsewhere. There may be exceptions for infrastructure if a specific location is essential for operational reasons or it cannot be located elsewhere."*

> *"The risks associated with rising sea levels and coastal flooding should be taken into account when identifying areas that are suitable for development."*

Similar to SPP7, SPP also proposes a Risk Framework approach which identifies flood risk in three main categories:

a. **Little or no risk area** (annual probability of flooding less than 0.1% (i.e. one in 1000 year flood). No constraints to development due to flood risk.

b. **Low to medium risk area** (annual probability between 0.1% and 0.5% (i.e. between one in 1000 and 200 year floods). Usually suitable for most development.

c. **Medium to high risk area** (annual probability greater than 0.5% (i.e. one in 200 year flood). Generally not suitable for essential civil infrastructure such as hospitals, fire stations, emergency depots etc., schools, care homes, ground-based electrical telecommunication equipment unless subject to an appropriate long term flood risk management strategy. The policy for development on functional floodplain applies. Land raising may be acceptable.

If built development is permitted, appropriate measures to manage flood risk will be required and the loss of flood storage capacity mitigated to produce a neutral or better outcome.

Residential, institutional, commercial and industrial development within built-up areas may be acceptable if flood prevention measures to the appropriate standard already exist, are under construction or are planned as part of a long term development strategy.

Undeveloped or sparsely developed areas are generally not suitable for additional development unless the location is essential for operational reasons and an alternative lower risk location is not achievable. Such infrastructure should be designed and constructed to remain operational during floods. These areas may also be suitable for some recreation, sport, amenity and nature conservation uses provided adequate evacuation procedures are in place. Job-related accommodation (e.g. caretakers and operational staff) may be acceptable. New caravan and camping sites should not be located in these areas.

> *"Landraising, which involves permanently elevating a site above the functional flood plain, may have a role in some circumstances."*

Proposals for landraising should satisfy five strict criteria (as listed in Para 208 of SPP). These include the provision and maintenance of compensatory flood storage; have a neutral or better effect on probability of flooding elsewhere; not create a need for flood prevention measures elsewhere; not create 'islands' of new development but should adjoin developed areas outwith the functional floodplain; and be set back from the bank of the watercourse.

> "*Major proposals for landraising should be promoted through the development plan."*

> *"Watercourses should not be culverted as part of a new development unless there is no practical alternative, and existing culverts should be opened where possible. If culverts are unavoidable, they should be designed to maintain or improve existing flow conditions and aquatic life. A culvert may be acceptable as part of scheme to manage flood risk or where it is used to carry a watercourse under a road or railway."*

> *"The Water Environment (Controlled Activities) (Scotland) Regulations 2005 requires all surface water from new development to be treated by a sustainable drainage system (SUDS) before it is discharged into the water environment, except for single houses or where the discharge will be made into coastal water. Surface water drainage measures proposed as part of a planning application should have a neutral or better effect on the risk*

of flooding both on and off the site. Where flooding is an issue, SUDS should be designed to mitigate the adverse effects of a storm inflow into the watercourse or sewer."

Guidance on best practice in urban drainage in Scotland is given in Planning Advice Note (PAN) 61: Planning and Sustainable Urban Drainage Systems (2001) and PAN 69: Planning and Building Standards Advice on Flooding (2004).

2.2 National Indicative River and Coastal Flood Map (Scotland)

The SEPA second generation flood map shows the likely extent of flooding for the 0.5% AEP event. Consultation of the map shows limited coastal flooding and small areas of floodplain at the area of crossing the Thornton Burn.

2.3 SEPA Technical Flood Risk Guidance

The latest version of SEPA 'Technical Flood Risk Guidance for Stakeholders' would need to be consulted when undertaking flood risk assessments (current version is 6, August 2010). In addition, SEPA's Interim Position Statement on Planning and Flooding (July 2009) would also need to be consulted. This details SEPA's role and policy position on flooding relative to land use planning and also the responsibility of the developer.

2.4 Flood Risk Management (Scotland) Act 2009

The Flood Risk Management (Scotland) Act 2009 was enacted on June 16, 2009. The Act repealed the Flood Prevention (Scotland) Act 1961 and introduces a more sustainable and streamlined approach to flood risk management, suited to present and future needs and to the impact of climate change. It encourages a more joined up and coordinated process to manage flood risk at a national and local level.

The Act brings a new approach to flood risk management including a framework for coordination and cooperation between all organisations involved in flood risk management, new responsibilities for SEPA, Scottish Water and local authorities in relation to flood risk management, a revised and streamlined process for flood protection schemes, new methods to enable stakeholders and the public to contribute to managing flood risk; and SEPA to act as a single enforcement authority for the safe operation of Scotland's reservoirs.

2.5 Controlled Activities Regulations

The Water Environment (Controlled Activities) (Scotland) Regulations 2005 (2011) (CAR) brings new controls for discharges, abstractions, impoundments and engineering works in or near inland waters. Any such work requires authorisation (licence) from the Scottish Environment Protection Agency (SEPA) who are responsible for the implementation of the Act. The Regulations include a requirement that surface water discharge must not result in pollution of the water environment. It also makes Sustainable Drainage Systems (SuDS) a requirement for new development, with the exception of runoff from a single dwelling and discharges to coastal waters.

2.6 Climate Change

SPP (2010) states that:

"The design of new development should address the causes of climate change by minimising carbon and other greenhouse gas emissions and should include features that provide effective adaptation to the predicted effects of climate change. The changing climate will increase the risk of damage to buildings and infrastructure by flood, storm, landslip and subsidence. Development should therefore normally be avoided in areas with increased vulnerability to the effects of climate change, particularly areas at significant risk of flooding, landslip and coastal erosion and highly exposed sites at significant risk from the impacts of storms."

SEPA recommend a 20% increase in peak flow for the 0.5% AEP (1:200) event, in accordance with DEFRA research. The most recent Scottish specific guidance with respect to climate change and flooding is contained in the Research Report *Climate Change: Review of Levels of Protection Offered by Flood Prevention Schemes UKCIP02 update (2003).* The UK Climate Impacts Programme (2002) (UKCIP02) on which the Scottish study is based, details a 20% and 30% increase in precipitation for the periods 2050 and 2080 respectively (based on the medium-high emissions scenario) for the east of Scotland. More recent climate change predictions (UKCP2009) are now available. However, more research is required before practical guidance can be provided as to the impact that UKCP2009 will have on extreme rainfall and flooding across Scotland.

The Climate Change (Scotland) Act 2009 also makes reference to adaptation to climate change.

It is recommended that any site drainage design considers these future estimates of increased precipitation and follows an adaptive approach.

2.7 Definition of Return Period

The concept of return period is commonly used to describe the severity of a flood event. Return period can be defined as the average number of years between the occurrences of events of a specified magnitude. A 200 year event is likely to be equalled or exceeded once in 200 years when averaged over a long period of time (hundreds of years). However, it can occur more than once or not at all in any given 200 year period.

A better description of flood risk can be expressed in terms of probability. Statistically, there is 0.5% chance of the 200 year event occurring in any one year, 4.9% chance of occurrence in any 10 year period, 22.2% chance of occurrence in any 50 year period, and 63.3% chance of occurrence in any 200 year period. Probability of exceedance for return periods varying from 2 to 1000 year over design life periods varying from 1 to 200 years are shown below.

Probability (chance) of exceedance							
Return Period (years)	**Design Life (years)**						
	1	**10**	**30**	**50**	**60**	**100**	**200**
2	0.500	0.999	1.000	1.000	1.000	1.000	1.000
5	0.200	0.893	0.999	1.000	1.000	1.000	1.000
10	0.100	0.651	0.958	0.995	0.998	1.000	1.000
20	0.050	0.401	0.785	0.923	0.954	0.994	1.000
25	0.040	0.335	0.706	0.870	0.914	0.983	1.000
50	0.020	0.183	0.455	0.636	0.702	0.867	0.982
100	0.010	0.096	0.260	0.395	0.453	0.634	0.866
200	0.005	0.049	0.140	0.222	0.260	0.394	0.633
500	0.002	0.020	0.058	0.095	0.113	0.181	0.330
1000	0.001	0.010	0.030	0.049	0.058	0.095	0.181

It is important to note that the concept of return period in flood studies assumes that the conditions associated with flooding (catchment use, river and flood plain characteristics, hydrology, etc.) remain largely unchanged with time. In practice, this is not necessarily the case when considered over long periods of time. Therefore, return period predictions should be treated with caution, and updated regularly when additional relevant data becomes available, or significant changes take place in the catchment, or when predictive tools are improved.

3 Site Description

The proposed landing site for the offshore cable is located on the sea front to the south of Thorntonloch Farm on the East Lothian coast, Figure 2.

The offshore cables will approach the beach via underground trench or through a HDD cable boring. The cables will then pass under the beach before entering into two transition pits located out with the shoreline, to the west of the beach. From this location the cable will follow an agreed route connecting to the Crystal Rig II Wind Farm.

The cable reaches landfall at Thorntonloch Beach. The beach close to the landing point is relatively flat (approximately 1 in 100) consisting of mainly fine sandy material however, there are storm ridges of coarser (pebbles) at the back of the beach in lying in front of vegetated sand dunes. Within the Application Boundary there are no man-made sea defences; however, at the mouth of Thornton Burn (north and south of the river) and along the front of the caravan park to the north of the burn there are man-made defences comprising large rock armour and gabion baskets measuring around 0.75 m in height, Figure 1 and Photos 1 and 2.

The Thornton Burn originates from high ground to the west before passing under the A1 via a large single span masonry culvert. The burn continues east before passing under a small footbridge and discharging into the North Sea at Thornton Beach. The burn has an upstream catchment area of 14.1 km^2 at its mouth at Thornton Beach. Close to its mouth the burn main channel is around 7.5m wide with land gently sloping up towards higher ground either side of the main channel.

General ground levels considered in this report for land close to the proposed route are based on Nextmap 2 (airborne data) elevation data. The accuracy of this data generally varies between +/ -1m in the vertical direction. Ground levels at the beach front close to the mouth of the burn have been measured as 1 m OD with ground levels rising east to approximately 15 m OD.

Figure 2: Detailed location map

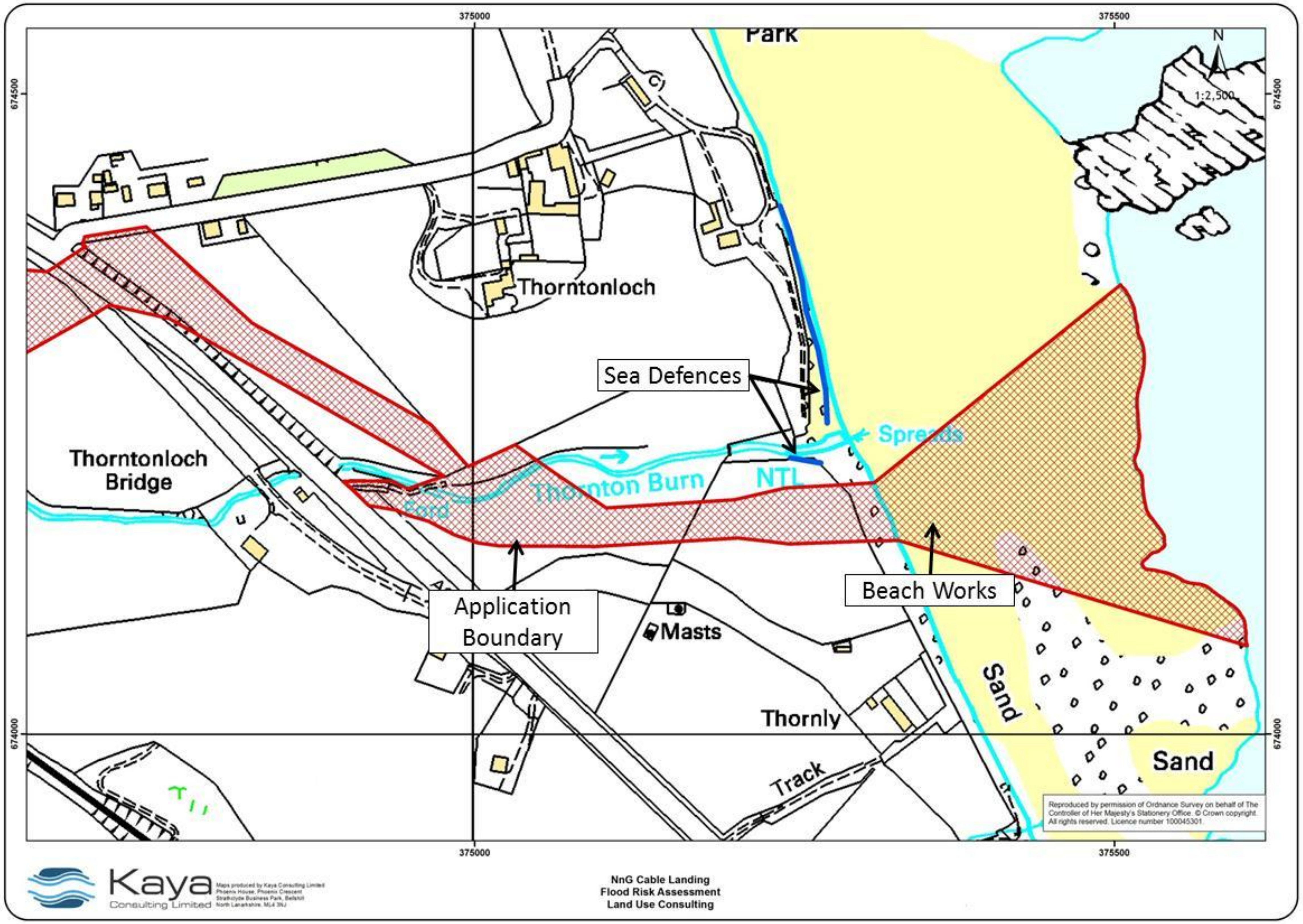


Photo 1: View of beach from north of Thornton Burn looking south

Photo 2: Mouth of Thornton Burn and sea defences

4 Hydrological Assessment

A hydrological assessment was undertaken for the Thornton Burn in the vicinity of the cable site.

4.1 Thornton Burn

The catchment area at the mouth of the Thornton Burn was calculated to be 14.1 km^2, extracted from the Flood Estimation Handbook (FEH) CD-Rom Version 3. Other catchment characteristics are shown in Table 1.

Table 1: Catchment characteristics for Thornton Burn

Parameter	Thornton Burn
Easting (m)	375250
Northing (m)	674200
AREA (km^2)	14.1
ALTBAR (m)	197
ASPBAR (^{o})	30
ASPVAR	0.4
BFIHOST	0.681
DPLBAR	6.93
DPSBAR	156.3
FARL	1
FPEXT	0.0089
PROPWET	0.43
SAAR (mm)	741
SAAR4170 (mm)	764
SPRHOST	30.32
URBEXT1990	0
URBEXT2000	0.0003

Thornton Burn is an ungauged watercourse and as a result estimation of return period flows is based on standard methods suitable for such catchments. Three methods are considered; FEH Rainfall-Runoff Method; Institute of Hydrology (IH) small catchment method (Report124) and Revitalised Flood Hydrograph (ReFH) method.

The catchment is below the lower end of the range of suitable catchment sizes for the application of the FEH Pooling Group method, due to the limited number of small gauged catchments within the national data set. Hence, this method is not considered.

In addition, the ReFH method has not been fully calibrated for Scottish catchments and as a result this method is not normally approved by SEPA and is used here for comparison purposes only.

The results of the three methods are provided in Table 2. Scottish Government guidelines suggest that the magnitude of extreme flood events will increase by 25% in eastern Scotland in the next 50 to 75 years. Hence, values for 1 in 200 year flow + 25% are also provided in Table 2.

Table 2: Return period flow estimates for Thornton Burn at mouth

Method	Q_{200} (m^3/s)	Q_{200} + climate change (m^3/s)	Comment
FEH Rainfall-Runoff	11.9	14.9	Known to provide high estimates for some small catchments
[a]IH124	12.9	16.1	-
ReFH	6.5	8.1	Not calibrate for Scottish catchments

a. Area = 14.1km^2, SAAR = 741mm, Urban Correction = 0, SOIL = 0.43

Given the size of the catchment the FEH Rainfall-Runoff and IH124 methods would appear the most appropriate. Taking the most conservative (highest) flow predictions from these two methods gives a 1 in 200 year peak flow estimate of 12.9 m^3/s and a 1 in 200 year + climate change estimate of 16.1 m^3/s (based on IH124).

5 Hydraulic Assessment of Thornton Burn

This section presents a mathematical modelling assessment of Thornton Burn which flows close to the north of and crossed by the preferred cable route. The model was set up to translate the estimated design flows in Section 4 to water levels so that the areas of the cable route affected by such flows can be predicted.

5.1 Model Set-up

A HEC-RAS model was set-up based on cross section data which was interpolated from Nextmap 2 elevation data of land surrounding the burn. This may be considered conservative as the Nextmap 2 data would not include the main channel of the burn and hence it would give higher bed level across the channel and this would result in higher water level predictions. Extent of the modelled reach of the watercourses and the location of model cross-sections are shown in Figure 3. In total, approximately 350 m of the Thornton Burn has been modelled.

In total 6 channel crossings have been extracted from the Nextmap 2 data and included in the model, see Figure 3. The burn passes under the A1 via a large masonry arch culvert, details of the structure were not included in the model due to lack of relevant survey information about the structure. The downstream boundary of the model stops at known tidal limit (as shown on OS maps).

Bed roughness (Manning's n) values throughout the model have been set to 0.045 for the main channel and 0.065 for floodplains and vegetated banks based on visual observations made during site walkover.

The model was run under steady state and dynamic conditions, with a downstream model boundary set as a 'Normal' boundary with a boundary slope of 0.02, consistent with the channel gradient.

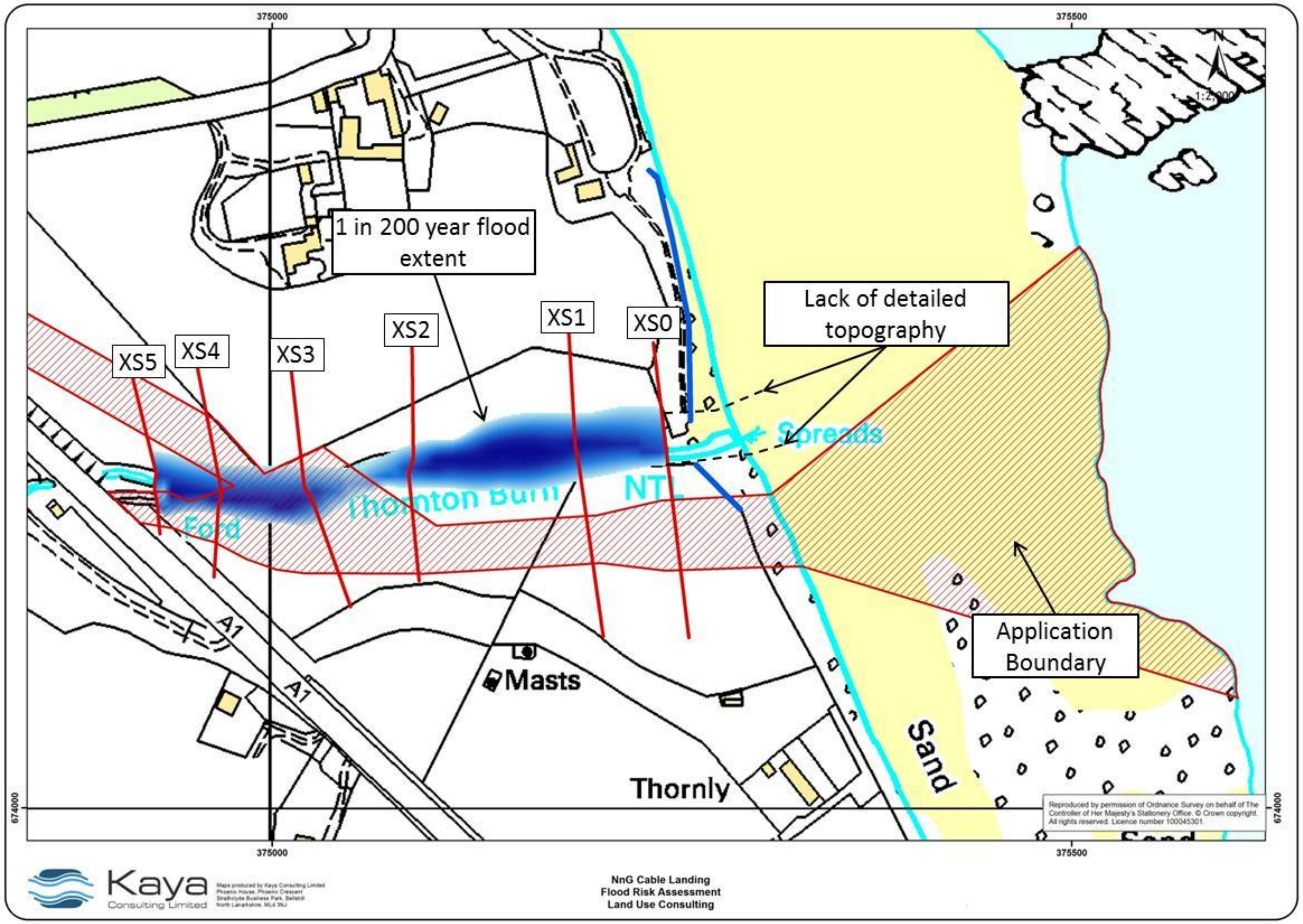
5.2 Model Results

The predicted water levels for the 1 in 200 and 1 in 200 year plus climate change flows are shown in Table 3. The predicted 1 in 200 year flood extent based on Nextmap 2 elevation data is also illustrated in Figure 3.

Table 3: Model results for Thornton Burn

Cross-sections	1 in 200 year flood level (m OD)	1 in 200 year + climate change flood level (m OD)
5	10.27	10.38
4	9.04	9.16
3	7.94	8.04
2	6.22	6.32
1	3.93	4.04
0	2.98	3.07

Figure 3: 1 in 200 year flood map for Thornton Burn



5.3 Model Sensitivity

A model sensitivity analysis provides an illustration of the effect of changing key model parameters on the important model outputs (in our case flood levels). By re-running the model for a range of scenarios and changing one input parameter for each model run, the effect of each input on the model results can be isolated. If model parameters are varied within the range of possible input values, then a sensitivity analysis can also provide an indication of uncertainty associated with the model predictions.

A sensitivity analysis was undertaken considering the following parameters;

- Manning's n of the channel and floodplains varied from design values by 20%
- Downstream boundary set to 200 year extreme sea level

Increasing Manning's n by 20% caused peak water levels along the modelled reach to increase by an average of 0.15 m.

The downstream boundary of the model was set to estimate 200 year still water level at the mouth of the burn. This was extracted from the Coastal Flood Boundary Conditions around the UK coastline. This indicated a 200 year still water level (tide + storm surge) of 3.83 m OD. This resulted in an increase of around 0.9 m in peak water level at the downstream reach of the model.

6 Assessment of Extreme Sea Levels, including Effects of Climate Change

Extreme water levels are determined by a combination of astronomical tides and storm surges caused by weather conditions offshore. Astronomical tides are created largely by the attraction of the moon and are accurately predictable in advance. Storm surges are caused by the meteorological factors such as winds acting on sea surface and variation in atmospheric pressure.

6.1 Present Day Extreme Sea Levels

A recent EA (2011) report and associated data sets have updated the standard POL (1997) method for estimation extreme sea levels around the UK coast (Coastal Flood Boundary Conditions around the UK Coastline). Extreme sea levels for a range of return periods based on EA (2011) at Thorntonloch are provided in Table 4.

Table 4: Extreme sea levels at Thorntonloch

Return Period	Extreme Sea Level (m AOD)[a]	Confidence Interval (m)
1 year	3.23	0.2
2 year	3.31	0.2
5 year	3.40	0.2
10 year	3.47	0.2
25 year	3.58	0.2
50 year	3.66	0.3
100 year	3.74	0.3
200 year	3.83	0.4
500 year	3.95	0.6

a Values for EA(2011) Point 1070

The extent of flooding for 200 year extreme sea level is shown in Figure 4.

6.2 Impact of Climate Change on Sea Levels

There are a number of methods for the estimation of the effect of climate change on sea levels.

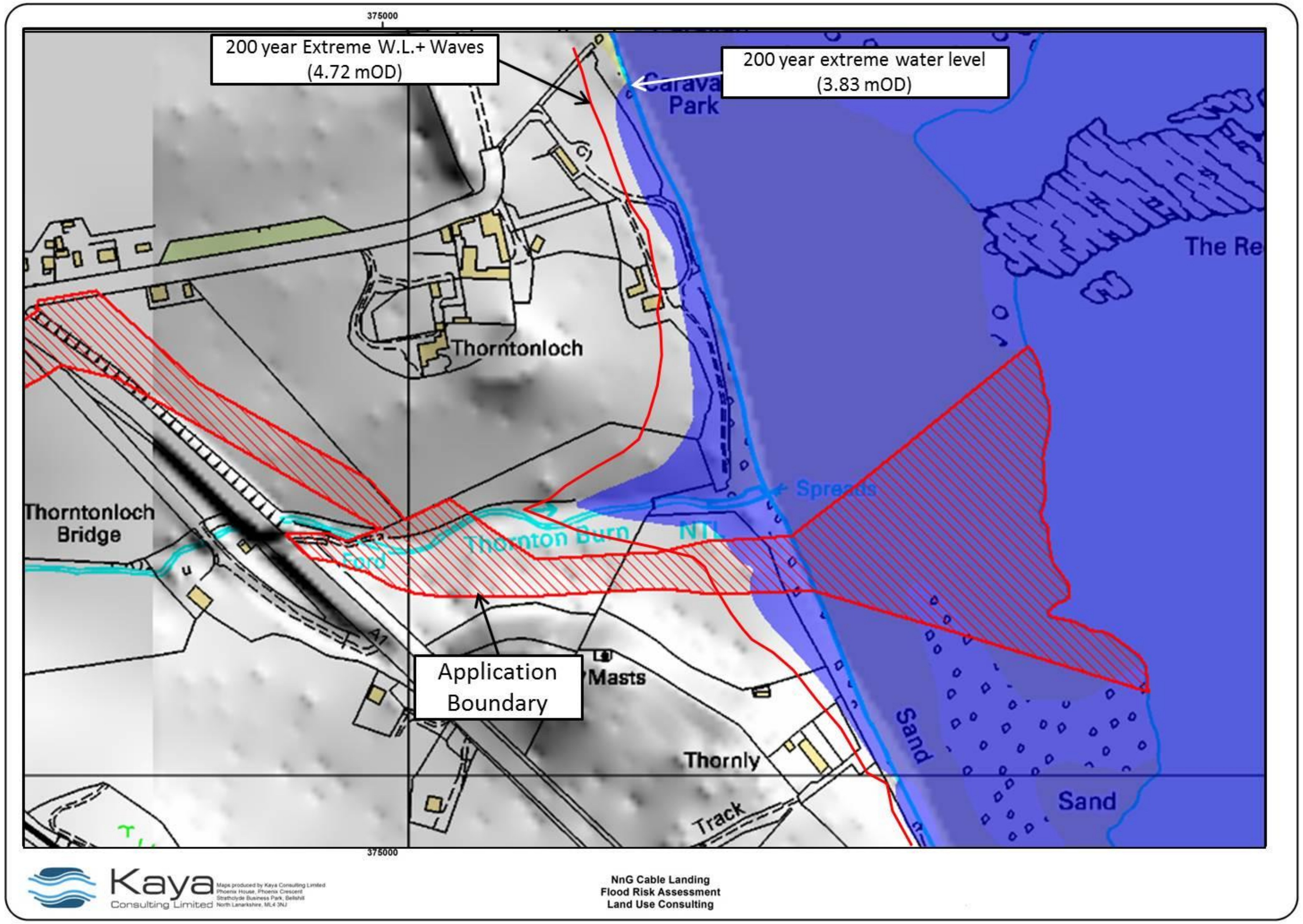
DEFRA guidance (2006) provides estimates of the likely effect of climate change on sea water levels over the next century for areas around the UK coastline, Table 5. Between 2010 and 2085 the DEFRA guidance would indicate a sea level rise of around 0.55 m at Thorntonloch.

SNIFFER (2008) provides a review of available research on the effect of climate change on sea levels, storm surges and wave heights around the Scottish coast. The report does not give guidance on estimates to be used for design, but indicates that sea level rise near the site might be expected to be of the order of 1.6 – 35 cm by 2080 depending on the climate change model scenario used.

Table 5: Adjustments due to climate change, DEFRA (2006)

Component	1990 - 2025	2025 - 2055	2055 - 2085	2085 - 2115
New sea level rise (mm/yr)	2.5	7.0	10.0	13.0
Increase in extreme wave height	+ 5 %	+ 5 %	+ 10 %	+ 10 %

Figure 4: Flood extent for 200 year extreme sea level predictions



UKCP09 provide the latest climate change predictions for a range of parameters, including sea level. The UKCP09 provides predictions for a range of emissions scenarios (High, Medium and Low) and provides results as a probability distribution. Values near Thorntonloch are provided in Table 6. At present, there is no guidance as to the most appropriate emissions scenario and exceedance percentile to use for flood risk assessments in Scotland.

Based on the available sea level rise estimates, values ranging from 0.04 – 0.53 m are available. Given the uncertainty this assessment considers a value of around 0.34 m is likely to provide the current 'best estimate' (UKCP09, High Emissions, 50%ile), which is the value that is thought appropriate for derivation of the 1 in 200 year + climate change flood envelope.

Table 6: UKCP09 sea level rise estimates (m) for Thorntonloch (2008 to 2085)

Emissions Scenario	Net Sea Level Rise (m)		
	5% probability	50% probability	95% probability
Low	+0.07	+0.23	+0.39
Medium	+0.08	+0.29	+0.50
High	+0.10	+0.34	+0.64

Based on raw data output from UKCP09 user interface

7 Estimation of Wave Heights and Joint Probability of Waves and Extreme Sea Levels

Joint probability describes the likelihood that two events will occur at the same time. In this report we are interested in the joint probability of an extreme still water level occurring at the same time as an extreme wave. There has been much research into this issue and the estimation of joint probabilities is covered by many publications including EA (2005). An extreme, 1 in 200 year high tide level has a 0.5 % chance of occurring once during any year and when it occurs it will have a duration of only a couple of hours or so. In a similar way a 1 in 200 year wave also has a 0.5 % chance of occurring once during any year and will also have a similar or shorter duration. Hence, the likelihood that both events will occur at the same time is small. However, in the case of waves and high sea levels, they are dependent on one another to some extent in that high winds will produce both phenomena. The degree of dependency affects the joint probability of the two events and EA (2005) attempts to derive joint probabilities based on assumed or estimated degrees of dependency between the two variables.

Calculations in this report were undertaken using methods outlined in EA (2005) and assuming that waves and extreme still water levels were modestly dependent (CF = 20). This is based on results for the correlation of waves and water levels along the east coast of the UK as presented in Figure 4.2 of EA (2005). Using CF=20 and methods outlined in EA (2005) different combinations of wave and water level return periods are presented, all which produce a joint probability of 1 in 200 years, Table 7.

Table 7: Probabilities of input variables to provide a joint probability of 1 in 200 years

Variable 1 (Still water level) Return Period (years)	Variable 2 (Wave height) Return Period (years)	Joint probability Return Period (years)
0.02	200	200
1	7	200
2	3	200
10	0.7	200
20	0.3	200
50	0.1	200
100	0.07	200
200	0.03	200

Data is taken from Table 3.5 in EA (2005), rounded up to integer years. A value of CF=20 is considered, based on data for east coast of Scotland, shown in Figure 4.2 of EA (2005)

7.1 Estimation of Significant Wave Height

There are many definitions of the significant wave height that approaches a structure. One commonly used definition is the average of the highest third of the waves ($H_{1/3}$). The Eurotop Manual uses the spectral wave height (H_{mo}) and this is the value that is used in this assessment.

The value of the significant wave height required for this assessment is that at the toe of the structure, once the waves have been impacted by shallow water effects. Hence, two stages are required in the prediction;

- Estimate deep water significant wave height for different return period wind conditions
- Estimate shallow water wave height

The calculations were undertaken using standard equations.

Predictions of the deep water significant wave height are based on estimated return period wind speeds, fetch lengths that the winds act over and the wind duration. Estimates of return period wind conditions were made using the methods outlined in British Standard No. 1699. Wind speeds for different return periods were then estimated using the scaling relationship provided in BS 1699. Wind speeds for different wind directions were predicted using ‘Direction Factors’ also provided within BS 1699.

Maximum fetch lengths for the site exceed 500 km. Over this distance wind durations in excess of 12 hours would be required to produce fully developed wave conditions. A detailed analysis of deep water wave conditions would require wind duration frequency data from the Met Office. Such an assessment was beyond the scope of this study. However, as wave heights impacting the shoreline at the site will be strongly influenced by depth limiting conditions it is not thought that a more detailed assessment is required at this stage. As waves approach shallow water near the coast, wave heights will be strongly affected by local water depth and foreshore slope conditions rather than conditions in deep water offshore.

As waves approach the shore they can shoal and break as the water depth decreases and the wave interacts with the bed. Breaking of waves will tend to limit the maximum wave height that will impact a sea defence.

The significant wave height in shallow water depends on a number of parameters including the water depth at the base of the sea defences and the foreshore slope. The foreshore slope of 0.01 (1 in 100) was estimated based on local photographs and a visual inspection made during the site visit.

Estimates of wave heights for depth-limited situations were made using methods in the Eurotop Manual, which are based on modelling by Van der Meer (1988). Results for 1 in 200 year joint probability of extreme still water and wave heights scenarios are illustrated in Table 8.

It should be noted that the wave heights are affected by the water depth and as we are considering joint probability, extreme return period (i.e., 200 year) waves are associated with lower water depths (e.g., Scenario 1). As a result, large offshore waves will be more strongly affected than more common waves (i.e., 0.03 year) that occur associated with extreme sea levels (e.g., Scenario 8). Hence, there is not as much difference between extreme return period (i.e., 500 year) and common (i.e., 0.03 year) waves as might be expected.

Table 8: 1 in 200 year estimated depth-limited, shallow water wave heights – Present Day

	Still Water		Shallow Waves		[a]Combined Water Level (m)
Scenario	Return Period (years)	[a]Water Level (m)	Return Period (years)	H_{m0} (m)	
1	0.02	2.90	200	2.35	4.04
2	1	3.23	7	2.03	4.25
3	2	3.31	3	1.91	4.27
4	10	3.47	0.7	1.90	4.42
5	20	3.55	0.3	1.89	4.50
6	50	3.66	0.1	1.85	4.57
7	100	3.74	0.07	1.82	4.65
8	200	3.83	0.03	1.78	4.72

[a] Still Water Level + half of shallow wave height

The values illustrated in the above Table 8 are based on several conservative assumptions which provide an outline assessment of the potential wave effects at the site. Due to the nature of the development (underground power line), it is not thought that a more detailed assessment is required.

8 Flood Risk Assessment

The Thornton Burn flows east, parallel with the proposed cable route. The model results indicated that peak flows would be confined within an area of low lying ground surrounding the channel for flows up to and including 200 year plus climate change. It was also shown that a narrow area of low-lying land would be affected by coastal flooding. This is consistent with the SEPA 200 year indicative flood map.

The extreme 200 year still water level (tide + surge) prediction for the area is 3.83 m AOD. Conservative calculations undertaken indicate that combined water levels including waves could reach around 4.72 m OD. Existing beach defences are around 1 m high and it is likely that even during a storm event with a 2 year still water return period (4.25 m OD) water would overtop the defences and inundate low lying areas upslope of the beach. However, only a narrow strip of low-lying land is predicted to be affected by coastal flooding in the vicinity of proposed cable landing.

The predictions indicate that the proposed route of the cable is outwith the predicted floodplain, except at the coastline and where it crosses the Thornton Burn. Where ground levels are lower than 5 m OD along the coastline there is the risk of flooding during high tides and storm surges and wave effects. Therefore, this will need to be taken into account in the design of the scheme. For example, the cable will need to be buried at a sufficient depth so that it does not become exposed in future during extreme events.

At the point where the proposed cable will cross the burn, there is the risk of flood waters affecting the crossing whether it was over the burn or under the channel bed. However the Thornton Burn is crossed via a trenchless crossing, for example Horizontal Directional Drilling, therefore the works would not be expected to be affected by extreme storm events.

It was noted during the site walkover that existing channel bank eroded in some places. It appears that the course of the lower part of the burn migrates. Although this would not necessarily affect the proposed cable line, it is clear that the channel is active and that cognisance should be made of beach erosion when designing the cable route upon landfall. There is also a risk of channel bank erosion at the location of the proposed channel crossing. This will need to be taken into account in the design of the trenchless crossing to ensure that the line of the cable is located significantly under the bed of the channel.

If any part of the floodplain on the east side of the A1 were to be raised as part of the proposed development (whether it be during construction or operation), this will have no adverse effect on any properties nearby. Any small increase this may cause to peak flows will have no adverse effects elsewhere, as flood waters discharge into the sea after a short distance. The main issue is to protect the cable line and associated infrastructure from damage during high flows and extreme tides/storm surges and waves.

The Application Boundary crosses the coast at a location where there are no man-made sea defences, although there are defences to the north of the Boundary. Hence, the development would not be expected to impact these defences and it should be noted that this study did not undertake an engineering assessment of the sea defences, with descriptions provided above based on a visual site inspection. The Application Boundary crosses coastal dunes and potential environmental impacts of the development on the dunes are considered within the Environmental Impact Assessment for the Project.

9 Summary and Conclusions

This report describes a flood risk assessment for a proposed offshore cable landing at the sea front close to Thorntonloch in East Lothian.

Parts of the proposed cable corridor and onshore works are predicted to lie within the 200 year floodplain of Thornton Burn and the sea. However, given the extent of the proposed works (underground cable, including stream crossing by way of directional drilling under the burn) and the location of the development (adjacent to the coast) it is not expected that the development would result in any change in ground levels or change in flood risk to others.

The risk of flooding will need to be considered during construction activities. However, it is anticipated that this risk will be low due to short time scale of construction work. In addition, if required, work on the beach will be undertaken during low tide. Care will need to be taken to be aware of Met Office and SEPA flood warnings during construction activities and emergency responses to flood risk be addresses in construction management plans.

The Application Boundary crosses coastal dunes and potential environmental impacts of the development on the dunes are considered within the Environmental Impact Assessment for the Project.