Natural Susceptibility to Coastal Erosion: Methodology and Mapping Summary

1. Introduction

The Flood Risk Management (Scotland) Act 2009 (FRM Act) introduced a co-ordinated and partnership approach to how we tackle flood risk in Scotland in a sustainable manner. To fulfil this we are considering all sources of flooding and whole river catchments when making flood risk management decisions.

As part of this approach SEPA is required to identify the most sustainable actions to manage coastal flood risk. These actions can affect and be affected by coastal erosion. To facilitate the identification of sustainable actions to manage coastal flood risk, the Natural Susceptibility to Coastal Erosion map was developed.
This summary provides information on how we developed the Natural Susceptibility to Coastal Erosion (NSCE) map and how to interpret this data. The primary purpose of this summary is to support Scottish Government, local authorities and Scottish Water in their understanding of how the map was developed, support internal/external briefings and enquiry management. This in turn will help to increase public awareness and understanding of how we are considering coastal processes and erosion as part of the Flood Risk Management Planning process.

2. Development and review

The NSCE map was funded by the Centre of Expertise for Waters (CREW) and developed by Glasgow University in partnership with SEPA and Scottish Natural Heritage. It is the first national assessment of susceptibility to coastal erosion undertaken in Scotland. The map was reviewed by leading coastal geomorphologists and coastal ecologists in Scotland.

The NSCE map is used throughout the FRM Planning process. It is one of the datasets used to produce the characterisation sections of the FRM Strategies and to help inform which actions are likely to be more sustainable to manage coastal flood risk. It will also be used to inform strategic advice provided by SEPA.

The map will be subject to review in the future and may be updated in future FRM Planning cycles as input data, methodologies and techniques change and improve. A National Coastal Change Assessment is currently being funded by CREW. This assessment will further improve our understanding of future susceptibility to coastal erosion.

3. Methodology and data

3.1. Approach

The methodology uses nationally available datasets to enable the NSCE map to cover the whole of Scotland. It is a strategic level map, consistent with the approach adopted for flood hazard and flood risk maps, and shows indicative areas that are likely to be more susceptible to coastal erosion (Appendix A).

3.2. Data

The data used to produce the NSCE map, including the direction of sediment movement arrows is listed in Appendix B, Table 3. This table also includes a description of the data, how it was used and the quality review process.

3.3. Methodology

The NSCE map is a 50m grid that was developed by combining a number of datasets. Four data layers were created from these datasets and combined using the Underlying Physical Susceptibility Model, see Table 1. This model scores each data layer for susceptibility and aggregates the score to give an overall score for each grid cell, see Table 2. This creates five categories of susceptibility to erosion from most to least susceptible. The wave exposure layer is given a half weighting in the model due to reduced levels of confidence in this dataset. Areas where sediment is known to be accumulating are then used to reduce the overall score. A reduction of three was applied at the coast, reducing to two and one moving inland.

Values below ten were deemed not susceptible to erosion at present and excluded from the NSCE map. Values greater than ten are shown on the NSCE map using five equal categories from green to red, representing low susceptibility through to high susceptibility.

Table 1: Data layers created and used in the Underlying Physical Susceptibility Model

Data layer	Rationale
Ground elevation	Low-lying coastal areas are more susceptible to coastal erosion than areas of higher topography. In these locations there is also a stronger correlation to susceptibility to coastal flooding.
Rockhead elevation	The altitude of resistant rock (i.e. rockhead elevation) relative to sea level greatly influences whether land is erodible. Where superficial deposits are present at and below sea level, land is susceptible to erosion. Where bedrock is present at and below sea level, land is less susceptible to erosion. In Scotland most types of bedrock are composed of relatively hard rock so the depth and type of superficial deposits relative to sea level is more important than the type of bedrock. Appendix C illustrates how rockhead elevation is calculated.
Distance from open coast	All other things being equal, land closer to the sea is more susceptible to coastal erosion than land further away.
Wave exposure	All other things being equal, areas exposed to high wave energy are more susceptible to coastal erosion.

Table 2: Scores and weightings used in the Underlying Physical Susceptibility Model

	Most Susceptible				Least Susceptible	Weighting
	5	**4**	**3**	**2**	**1**	
Ground elevation (mAOD)	**5** (<2)	**4** (2-4)	**3** (4-6)	**2** (6-8)	**1** (>8)	1
Rockhead elevation (mAOD)	**5** (<0)	**4** (0-2)	**3** (2-4)	**2** (4-6)	**1** (>6)	1
Distance to Open Coast (m)	**5** (<100)	**4** (100-200)	**3** (200-300)	**2** (300-400)	**1** (>400)	1
Wave Exposure	**2.5** (>300)	**2** (225-300)	**1.5** (150-225)	**1** (75-150)	**0.5** (<75)	0.5
Aggregate Score	**17.5**	**14**	**10.5**	**7**	**3.5**	N/A

4. Validation and quality review

- **Peer contribution** – The methodology and map outputs were reviewed by leading coastal ecologists and geomorphologists in Scotland. Some modifications to the methodology were incorporated in accordance with the scale and purpose of the dataset.

- **Internal review** - Areas susceptible to coastal erosion is a developing research area in Scotland and the evidence base is still developing. There is currently limited field data available which inhibits the extent of validation that can be undertaken. However, seven case study areas with different environmental conditions were selected and reviewed by the project steering group where expert knowledge of the erosion susceptibility has already been established. These areas were:
    - Sanday
    - Golspie
    - St Andrews
    - Dundee
    - St Cyrus
    - Troon
    - Benbecula

  Overall the map outputs were found to correspond with field observations and expert knowledge given the national scale of the dataset.

- **Local authority and stakeholder review** – Scottish Natural Heritage was on the project steering group and heavily involved in the development of the methodology and maps. The map outputs were made available to FRM Local Advisory Groups on request and reviewed by FRM Local Advisory Groups in the North Region. Local authorities were provided with map outputs as part of the development of the FRM Strategies and the maps were made available on request throughout the consultation period of the FRM Strategies. No significant issues were identified given the scale and purpose of the dataset.

5. Interpretation

The NSCE map has been developed using nationally available datasets and a nationally applied methodology. It is a tool to support flood risk management decisions, land use planning and to help raise public awareness and understanding of coastal erosion and the interactions between coastal flooding and erosion.

The map is of a strategic nature to support flood risk management planning at a community level. It is not appropriate for property level assessment of natural susceptibility to erosion. It is not appropriate for assessing coastal erosion risk as does not take account of existing flood or coastal erosion protection structures. It also does not show areas that will erode or indicate the timescales over which erosion could occur. Coastal erosion often occurs or accelerates according to the frequency and severity of future storm events, which is not known. With any nationally consistent methodology there are assumptions and inherent uncertainly. The zoom on the map hosted on the SEPA website is set to support the use of the information at a community scale. The seaward extent of the NSCE map is clipped to the Ordnance Survey (OS) 1:10,000 scale background map. When viewed with a coarser scale background map, the model output may appear not aligned to the coastline. This is due to the difference in accuracy of the different map scales and is not an indication of actual coastal change.

The map is not licenced for commercial use and all users must agree to terms and conditions before viewing the map.

5.1. Assumptions

The outputs and underlying datasets have been produced at a 50m grid resolution. It is assumed that any loss of detail at this resolution is acceptable for a strategic, national output.

Datasets have been classified into five categories; it is assumed that any loss in detail due to this is acceptable for a strategic, national output.

5.2. Confidence and limitations in ground elevation dataset

The ground elevation Digital Terrain Model (DTM) is more vertically accurate in areas where LiDAR has been flown. The vertical accuracy of LiDAR is between 0.1-0.3m depending on when it was flown. NEXTMap is a lower resolution DTM that is available nationally. The process by which NEXTMap is collected means that canopies of dense vegetation can be incorrectly recognised as the land surface. In some areas the elevation layer may therefore categorise areas as low susceptibility (based on elevation), when in reality the area should have a higher susceptibility ranking. NEXTMap has a vertical accuracy of between 0.7-1.0m. This level of error is acceptable on a national scale, but means that areas could be incorrectly classified at a more local scale.

5.3. Confidence and limitations in rockhead elevation dataset

The British Geological Society Superficial Deposits Thickness model is based on borehole data and exposures which are generally better in more developed areas of the country. The density of boreholes and other survey data (and therefore the quality of this dataset) is less good in more remote locations.

The model uses the depth and altitude of superficial Quaternary deposits (generally unconsolidated sediments laid down during the last ice age) to inform susceptibility to coastal erosion. The type of superficial deposit is also important to inform susceptibility to coastal erosion e.g. whether it is glacial till or windblown sands. Inclusion of type of superficial deposit would improve the maps but is not supported by nationally available datasets.

5.4. Confidence and limitations in distance from open coast dataset

This was generated using OS Boundary Mean High Water Springs 2009 (MHWS). This dataset is not updated regularly so in dynamic areas of coastline, this distance may not be accurate. However, this is viewed to be acceptable for a national level assessment.

There are several areas of coast (inlets and estuaries) where MHWS extends far inland and in reality waves would be attenuated to an extent that coastal erosion susceptibility would be significantly reduced. To compensate for this, where a distance across an inlet or estuary was less than 500m, they were excluded. 'Distance from open coast' was measured from the start of the 500m stretch.

5.5. Confidence and limitations in wave exposure dataset

The wave exposure dataset uses fetch and wind exposure as a proxy for wave exposure. This was the best nationally available dataset to indicate wave energy. The original format of the dataset was incompatible with the other data layers and required extensive processing before it could be incorporated into the model. This increases uncertainty in the data, however, expert knowledge of the coast was used to ensure known sheltered areas had a low wave exposure index and more exposed areas of coast had a high wave exposure index.

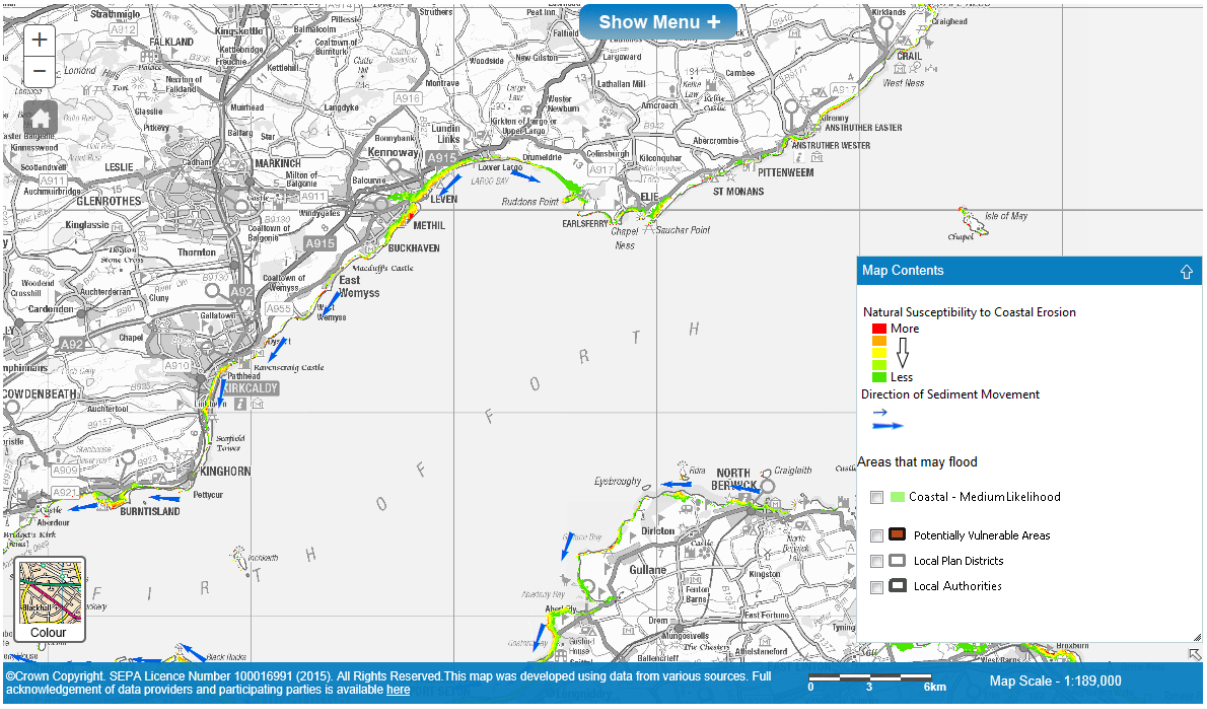
The uncertainties associated with this dataset are greater than the others so it was weighted 0.5 to reduce its relative influence on the final output.

5.6. Confidence and limitations in sediment accumulation dataset

Expert knowledge was used to quality check areas known to be accumulating or accreting sediment. However, sediment movement is dynamic and influenced by developments and other anthropogenic influences at the coastline. It is likely that areas accumulating sediment will change over time and therefore the susceptibility to coastal erosion could change from that represented in the NSCE map. There are also many areas of the coastline where sediment supply is less well understood and there could be gaps in this dataset.

Appendix A

Figure 1: Example of Natural Susceptibility to Coastal Erosion (NSCE) Map



Appendix B

Table 3: Data used as an input to the Natural Susceptibility to Coastal Erosion map

Data	Description	How the data was used	Quality check
Ordnance Survey Boundary Mean High Water Springs (2009)	Mean High Water Springs polyline.	• To derive distance from open coast (Inlets with a mouth of less than 500m were removed). • To derive wave exposure.	No additional quality checks were carried out on this dataset.
SEPA's Digital Terrain Model (DTM)	A composite Digital Terrain Model (DTM) comprising LiDAR and Intermap's NEXTMap DTM with a horizontal resolution of 5m and a vertical accuracy of between 0.1 to 1m.	• To derive ground elevation. • The raster was resampled to 50m using cubic convolution assignment method. • Elevations were ranked according to susceptibility to erosion.	Checks were undertaken at the boundary of NEXTMap and LIDAR data to ensure there were no jumps in ground level.
British Geological Society Superficial Deposits Thickness Model (Advanced Superficial Thickness Model)	Thickness of superficial deposits based on borehole records and map data with a horizontal resolution of 50m.	• To derive rockhead elevation.	No additional quality checks were carried out on this dataset.
Intermap's NEXTMap Digital Terrain Model (DTM)	DTM with a horizontal resolution of 5m and a vertical accuracy of between 0.7 to 1m. NEXTmap is derived from airborne Interferometric Synthetic Aperture Radar (IFSAR).	• To derive rockhead elevation. • The raster was resampled to 50m using cubic convolution assignment method.	No additional quality checks were carried out on this dataset.
SNIFFER's Fetch dataset	200m raster along the Scottish coastline with a non-dimensional index value (range from 2 to 800) that takes into account wave fetch and wind exposure, based on a methodology devised by Burrows et al, 2008 (Marine Ecology Progress Series).	• To derive wave exposure. • Raster cells were converted to points and Thiessen polygons which were clipped to a 400m coastal buffer.	No additional quality checks were carried out on this dataset. Expert knowledge was used to quality check wave exposure derived from this dataset.

EUrosion's Coastal Sediment Supply	The following polygons were used from Coastal Evolution Category: • **6** Aggregation probable, but not documented; • **70** Aggregation confirmed (available data) along parts of the segment; • **71** Aggregation confirmed (available data) almost the whole length of the segment	To derive areas of accretion and reduce the susceptibility to erosion score where there are known areas of accretion.	Expert knowledge and academic literature was used to review and adjust areas of accretion
Sediment Drift Direction	The predominant direction of longshore drift or sediment movement (where known) based on Ramsay and Brampton, 2000 (Coastal Cell Reports)	To display 'Direction of Sediment Movement' on the NSCE map	No additional quality checks were carried out on this dataset.

Appendix C

How rockhead is calculated

The NEXTMap Digital Terrain Model (DTM) is used in this calculation instead of SEPA's DTM. This ensures greater compatibility with British Geological Survey (BGS)'s Advanced Superficial Thickness Model (ASTM), as it was used by BGS within the processing of the ASTM. To establish rockhead elevation, the following calculation is performed:

Rockhead data layer (50m raster) = NEXTMap (50m raster) – ASTM (50m raster)

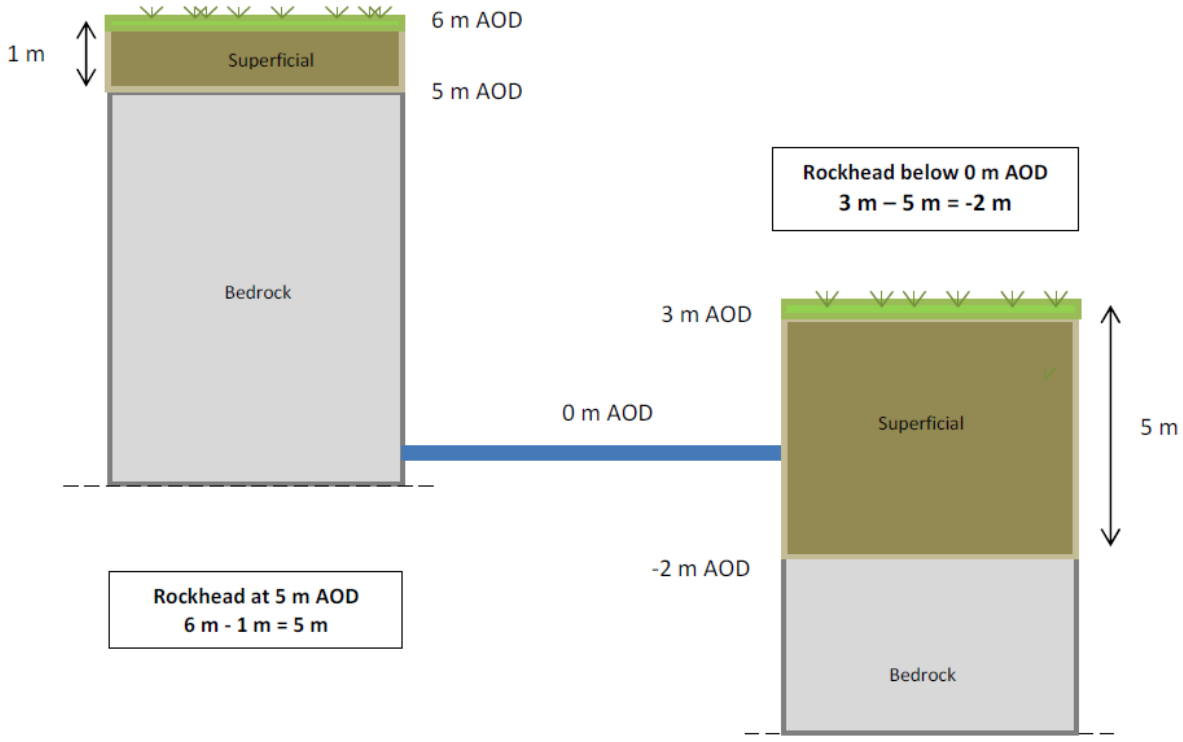


Figure 2: Hypothetical scenarios detailing the method to derive rockhead elevation using NEXTMap DTM and the BGS Superficial Thickness Model. An elevation of 0 mAOD was assumed to equal mean sea level. A negative value of rockhead elevation indicates superficial deposits are present at or below sea level, increasing susceptibility to coastal erosion. The scenario on the left would have low susceptibility to coastal erosion, whereas the scenario on the right would have high susceptibility as soft deposits are present at sea level.