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Dynamic Coast - National Coastal Change Assessment: Cell 1 - St Abb's Head to Fife Ness

Main report here

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National Coastal Change Assessment
Steering Committee

Coastal Change & Vulnerability Assessment

Dynamic Coast – Scotland's National Coastal Change Assessment

Executive Summary

- Cell 1 extends from the English border near St Abb's Head northwards to Fife Ness including the Firth of Forth.
- In Cell 1, Mean High Water Springs extends to 452 km which makes up around 2% of the Scottish coastline (excluding tidal inlets). Of this length, 41% (184 km) is categorised as hard and mixed, 36% (162 km) as artificial and 23% (105 km) as soft coast.
- Within the historical period of 1890-1970s (74 years), almost half (49%) of the soft shoreline experienced significant change with accretion (advance) dominating 42% of the area and only 8% of the coast retreating (erosion).
- The period from the 1970s to modern spans 37 years, so the historical period data has been normalised to 37 years to allow comparisons with the modern period.
- When this adjustment is applied, the extent of retreat (erosion) has increased from 4% historically to 13% post 1970s, the extent of stability has reduced from 76% to 56% and the extent of advance (accretion) has increased from 20% to 32%.
- In addition to the increases in the extents of erosion and accretion in Cell 1, there has been a substantial increase in the rate of erosion, with the fastest rates (30m+ over 37 years) now affecting 6% of the retreating shore, up from 0.5% historically.
- Accretion rates also increased although the fastest rates (30m+ over 37 years) now affected 10% of the advancing shore, a fall from 11% historically.
- Given the increase in the average rate of erosion and the changes in extent (noted above) there has been a shift toward greater mobility within Cell 1 since the 1970s.

Disclaimer

The evidence presented within the National Coastal Change Assessment (NCCA) must not be used for property level of scale investigations. Given the precision of the underlying data (including house location and roads etc.) the NCCA cannot be used to infer precise extents or timings of future erosion.

The likelihood of erosion occurring is difficult to predict given the probabilistic nature of storm events and their impact. The average erosion rates used in NCCA contain very slow periods of limited change followed by large adjustments during storms. Together with other local uncertainties, not captured by the national level data used in NCCA, detailed local assessments are unreliable unless supported by supplementary detailed investigations.

The NCCA has used broad patterns to infer indicative regional and national level assessments in order to inform policy and guide follow-up investigations. Use of these data beyond national or regional levels is not advised and the Scottish Government cannot be held responsible for misuse of the data.

Contents

Document Structure

This document outlines the Historical Change Assessments and Vulnerability Assessment for Scotland's soft coastline. The methodologies used within the NCCA are detailed in a separate report. The document is structured to conform to the Scottish coastal sediment cell and sub-cell boundaries that were first delimited by Ramsay and Brampton (2000) in a series of 11 reports. The concept of coastal cells as a science based management unit for the coast is based on a recognition that the processes that shape and alter the coast, while unrelated to administrative boundaries are related to changes in sediment availability and interruptions to that availability. As a management unit, the coastal cell can be seen to fulfil a similar function to that of a catchment area of a river for terrestrial flood management. Changes in erosion, accretion and sediment supply in one coastal cell are seen to be largely unrelated to, and unaffected by, conditions in adjacent coastal cells, and are therefore seen as self-contained in terms of their sediment movement. For example, at many sites net sediment movement is in one direction and may pass around a headland (the major cell boundaries) only in very small volumes. Within a cell, any engineering structures that interrupt alongshore sediment delivery on the updrift side of a coast may impact on the downdrift coast but not vice versa given the "one-way" nature of net sediment movement. As sediment sinks, estuaries might be suitable cell boundaries, however subdivision of an estuary where sediment may circulate freely between both banks is inconvenient and so the inner portions of major firths and estuaries have been defined as sub-cells (Ramsey and Brampton, 2000). Whilst the cell system is ideal from a scientific perspective, it remains that Local Authorities may straddle a cell boundary. The results and statistics for each Local Authority area and for Marine Planning Regions are contained in a separate report.

Commencing with a national overview, this report summarises key locations whose positions of Mean High Water Springs (MHWS) have changed between the periods 1890s to 1970s and 1970s to modern time, although the exact time of survey may vary slightly around those dates and between coasts. The locations are arranged within sub-cells, which progress around Scotland in an anticlockwise direction, followed by the Western Isles, Orkney and Shetland. A short narrative summarises the historical changes and current situation at each location, followed by a vulnerability assessment which considers the implications of assets adjacent to areas of erosion. This narrative is to allow the reader to appreciate the overall findings from the evidence on coastal changes. The report is concluded by a series of tables summarising the statistics for cell one. Each of the 11 coastal cells has a similar report to this, which sits alongside a national overview to collate the national picture and consider the implication for Scotland's coastal assets. Where appropriate, mention is made of the existence of a shoreline management plan for particular sections of the coast.

The full results of each cell are available on the webmaps (www.dynamiccoast.com) and have been designed to be highly accessible. Within the webmaps the user is able to navigate across the whole country, display various shorelines and click on each of the shorelines, to quantify the changes.

The National Context

For a full national overview of the aims, methodology, characteristics and underlying factors that control Scotland's coastline, the reader is directed to the National Overview report where a Whole Coast Assessment and results from the historical and recent changes are presented. Here only a short summary of the national changes identified are presented to place this individual coastal cell report into context.

Since the 1970s, 12% of the soft coast length across Scotland has retreated landwards (erosion), 11% has advanced seawards (accretion) and 77% stable or has shown insignificant change (Figure 1). National comparisons from the historical period (1890 to 1970) to recent period (1970-modern), accounting for the different time periods, show an increasing proportion of erosion (8% to 12%), similar stability (from 78% to 77%) and falling accretion (14% to 11%). Where coastal changes occur, they are faster than before. Nationally, average erosion rates after the 1970s have doubled to 1.0 m/yr whilst accretion has almost doubled to 1.5 m/yr.

The national pattern is an aggregation of different results from different parts of the country (Figure 2). The more exposed mainland east coast cells (1,2,3) and Solway Firth (7) have greater proportions of soft coast erosion and accretion (i.e. significant change) and lower proportions of stability. On the rock-dominated cells (for example cells 8,9,10, 11), soft coast stability is far higher and the extent of erosion and accretion lower. Whilst the natural level of protection offered to the soft sections of coast by the surrounding rocky coast has not changed through time, the proportion of soft coast experiencing erosion and accretion has. Considering the changes through time, the exposed coastal cells of the east coast have seen greater increases in change, with more modest changes occurring on the rock-dominated cells.

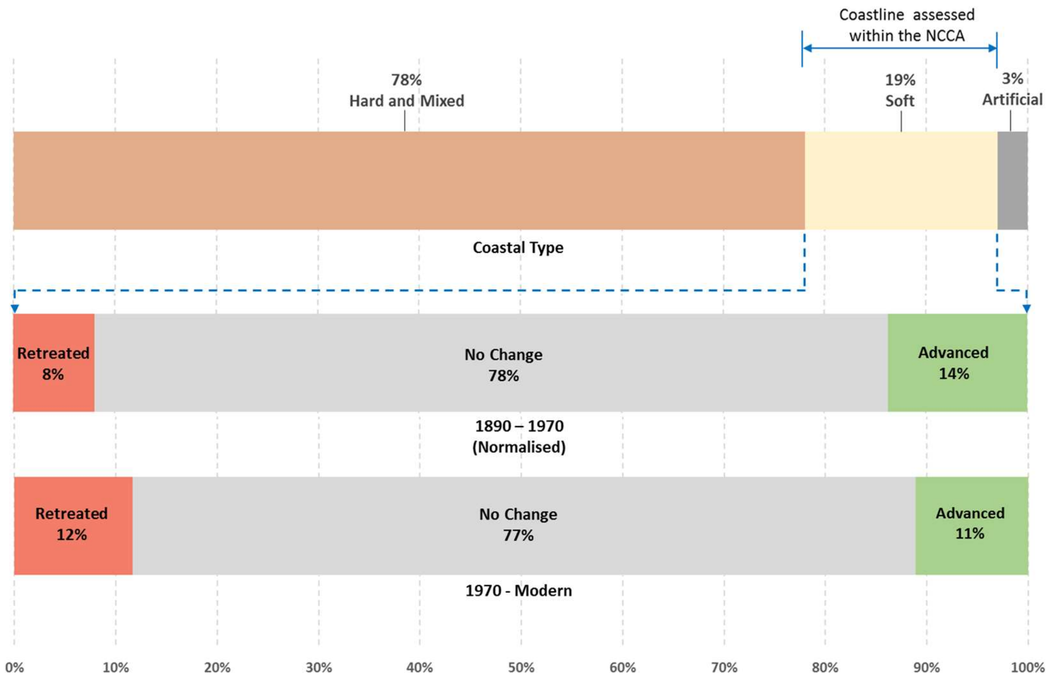

Figure 1: National coastal change results showing the proportion of soft coast retreating, stable and advancing within each change category in the historical (ca. 1890-1970 normalised for time period) and recent (ca. 1970-Present) time periods.

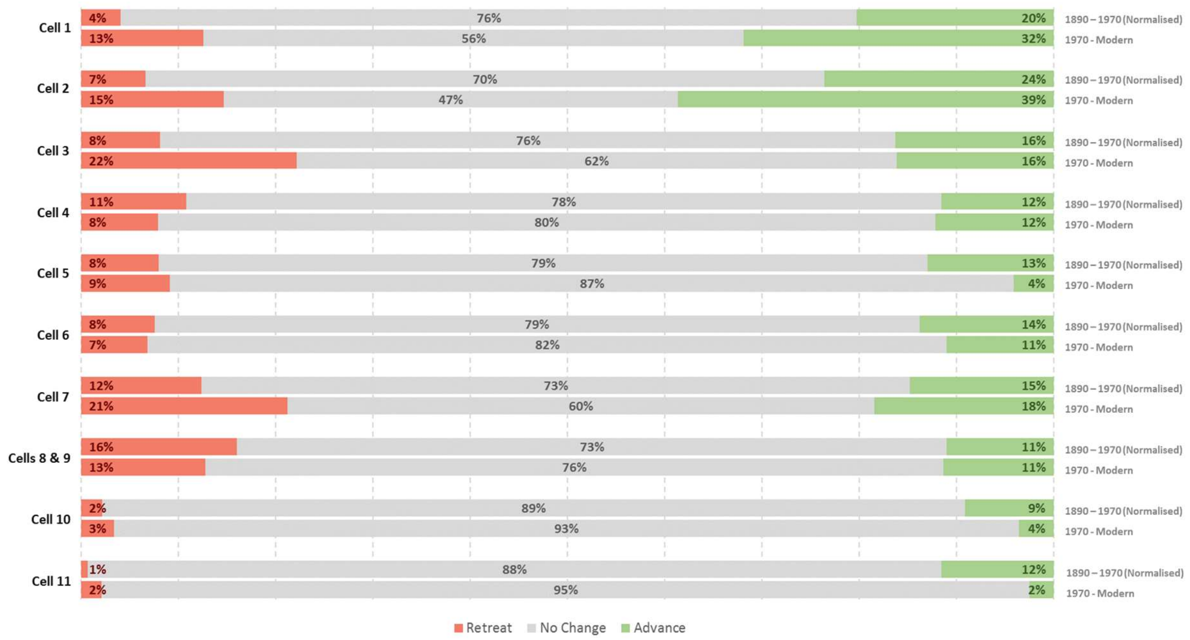

Figure 2: National coastal change results showing historical (ca. 1890-1970, normalised for time period) and recent (ca. 1970 Present.) % of coastal cell showing retreat (red), stability (grey) and advance (green) for soft coast within each cell.

Two other trends are worthy of mention here. The first relates to the propensity for the outer coast to be more exposed to wave impact than the inlets, bays and firths of the inner coast and so the potential for wave-driven erosion is greater along the outer coast. This is exacerbated by a reduction in sediment supply to the outer coast from the higher levels experienced a few thousand years ago. These outer coasts constantly lose sediments to inlet infilling via longshore drift (currents that transport sediment from a source area updrift to an accepting area downdrift). As such, erosion has progressively become the dominant trend on the outer coast in all places except where the import of longshore drift sediments feeds downdrift beaches. Conversely inlets, embayments and firths are sediment sinks that accept soft coastal sediments derived from erosion of the outer coast (the sediment sources) in addition to sediment freshly delivered by rivers. The result is that whilst the inner coast has a bias toward accretion, the outer coast, hard or soft, has a bias toward erosion.

A second trend is the close coincidence between coastal defences and erosion of the adjacent coast. Unsurprisingly, the insertion of defences is in response to a coastal erosion or flooding event, yet there are many instances where the defences themselves have exacerbated the pre-existing erosional condition, either on-site or on adjacent coastline downdrift. The reasons are three-fold. First, a defence structure is aimed at halting or slowing an existing erosion condition and so a successful structure not only halts erosion but also the supply of eroded sediment that had previously reached the fronting beach. The result is a reduced sediment supply and beach lowering. Second, most structures reflect wave energy and, indirectly, sediment leading to beach lowering. Third, the insertion of a defence structure on a coast that is affected by longshore currents not only prevents the supply of sediment to the fronting beach, it also reduces the supply of sediment previously exported leading to downdrift beach lowering and erosion.

Cell 1 - St Abb's Head to Fife Ness

Cell 1 extends from the English border near St Abb's Head northwards to Fife Ness including the Firth of Forth. The sub cell boundaries are shown in Figure 1.1 below. Further contextual information about the processes operating in Cell 1 can be found in Ramsay & Brampton (2000). Cell 1 benefits from the existence of Shoreline Management Plans for both East Lothian and Fife coastlines.

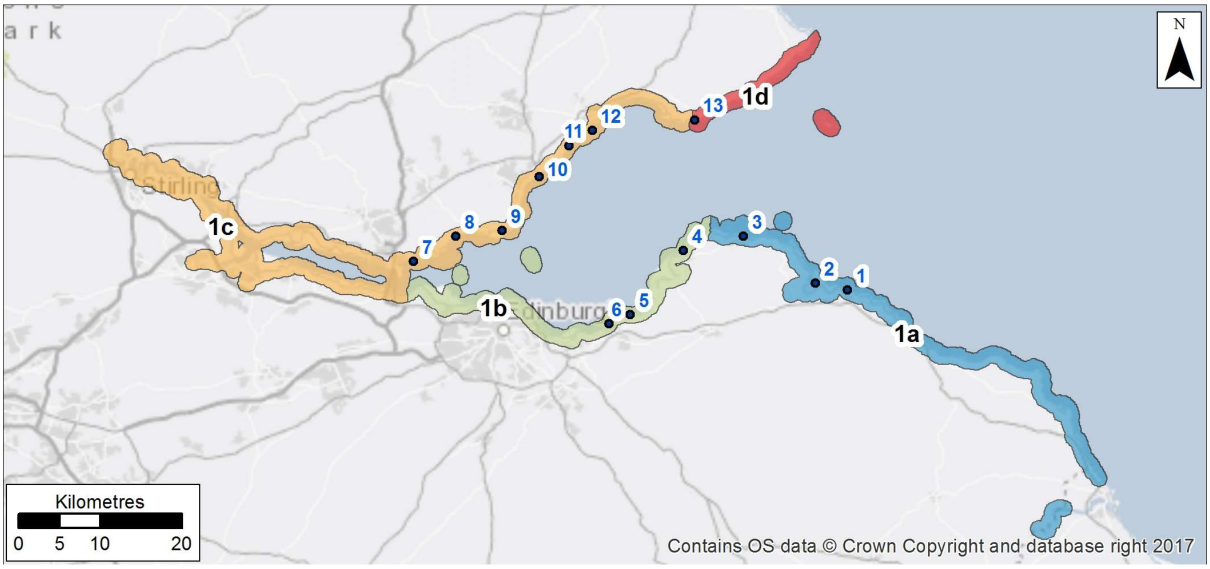

Figure 1.1: The sub-cell boundaries of Cell 1 and locations of sites discussed in this report (blue numbers).

Physical Overview

In Cell 1, Mean High Water Springs (MHWS) extends to 452 km which makes up around 2% of the Scottish coastline (excluding tidal inlets). Of this length, 41% (184 km) is categorised as hard and mixed, 36% (162 km) as artificial and 23% (105 km) as soft coast (Table 1.1). Within the historical period of 1890-1970s (74 years), almost half (49%) of the soft shoreline experienced significant change with accretion (advance) dominating 42% of the area and only 8% of the coast retreating (erosion). The period from the 1970s to modern spans 37 years, so the historical period data has been normalised to 37 years to allow comparisons with the modern period.

When this adjustment is applied the extent of erosion increased from 4% historically to 13% post 1970s, the extent of stability reduced from 76% to 56% and the extent of accretion increased from 20% to 32%. In addition to the increases in the extents of erosion and accretion in Cell 1, there has been a substantial increase in the rate of erosion, with the fastest rates (30m+ over 37 years) now affecting 6% of the retreating shore, up from 0.5% historically. Accretion rates also increased although the fastest rates (30m+ over 37 years) now affect 10% of the advancing shore, a fall from 11% historically (Figure 1.2).

This trend is consistent with a move from accretion (reducing), through a transitional condition of no change (increasing), toward erosion (increasing) with the average rate of erosion increasing from the historical to the recent period. Further statistics for Cell 1 can be found in Table 1.2 and Table 1.3 at the end of this report.

Table 1.1: Proportion of each coastal type within Cell 1.

Modern Coastal Type	Length	
	km	%
Soft	105.2	23%
Artificial	162.8	36%
Hard and Mixed	184.1	41%
Total Length (excluding tidally influenced inlets)	452.2	100%

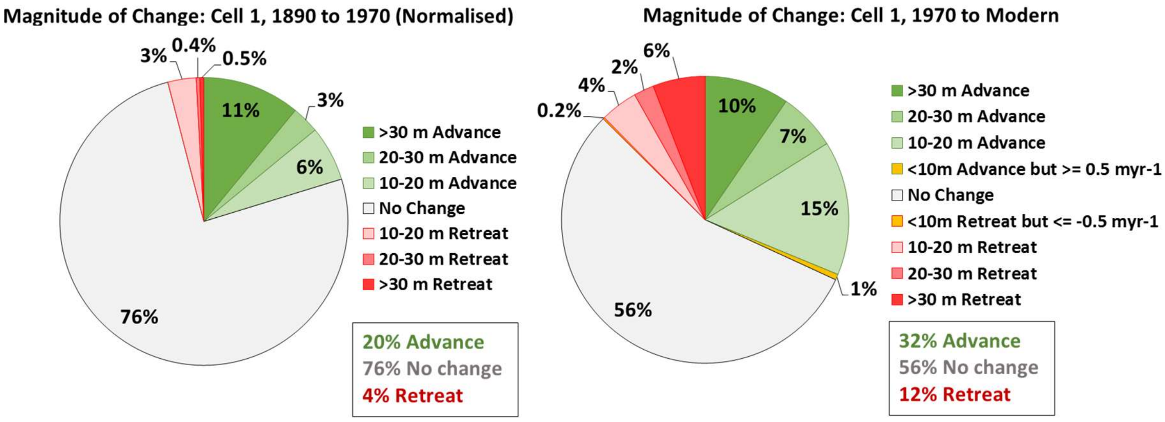

Figure 1.2: Coastal change results for Cell 1 showing the proportional amount of change in the historical (ca. 1890-1970 normalised) and recent (ca. 1970-Present) periods. Rounding errors may produce small % differences between Figure 2 and Figure 1.2.

Asset Vulnerability Overview

The Vulnerability Assessment methodology serves to project the known past erosion rates forward into the future to the year 2050 and is viewable on the online webmaps at www.dynamiccoast.com. Within Cell 1 a total land area of 17.9Ha, which supports various assets, is anticipated to be lost by 2050, this includes 20 residential and non-residential properties. When areas that erosion may influence are included then a further eight residential and non-residential properties are anticipated to be affected by 2050. For a full summary of vulnerable assets see Table 1.4 at the end of this report.

Sub-cell Summaries

Subcell 1a - St Abb's Head to North Berwick

1a.1 Dunbar (Site 1)

Historical Change: Whilst much of the shoreline has remained stable, to the east of Dunbar, at the site where the Torness Power station is now located, there has been 300 m of land claim over 800 m of coast. This section of coast is now stable and protected by an artificial boulder embankment so that no change is detectable between 1970 and modern. Dunbar east beach, to the southeast of Dunbar harbour, is backed by an assortment of old masonry seawalls and has seen significant seaward movement in MHWS between 1983 and 2011 (Figure 1.3). More recently however, the beach levels were anecdotally reported by the Dunbar Beach Action Group as having dropped following storm events in winter 2013/2014. A proposal (2016) is in place to feed the beach with sediment to restore its recreational and protective potential. Immediately to the west of the harbour, the first embayment has experienced between 16 m (east end) and 48 m (west end) coastal retreat between 1983 and 2011. The rocky intertidal foreshore and high bluffs to the rear will likely limit future retreat rates. This is also the case for the coastline to the west that fronts the golf course as far as the entrance to Belhaven Bay.

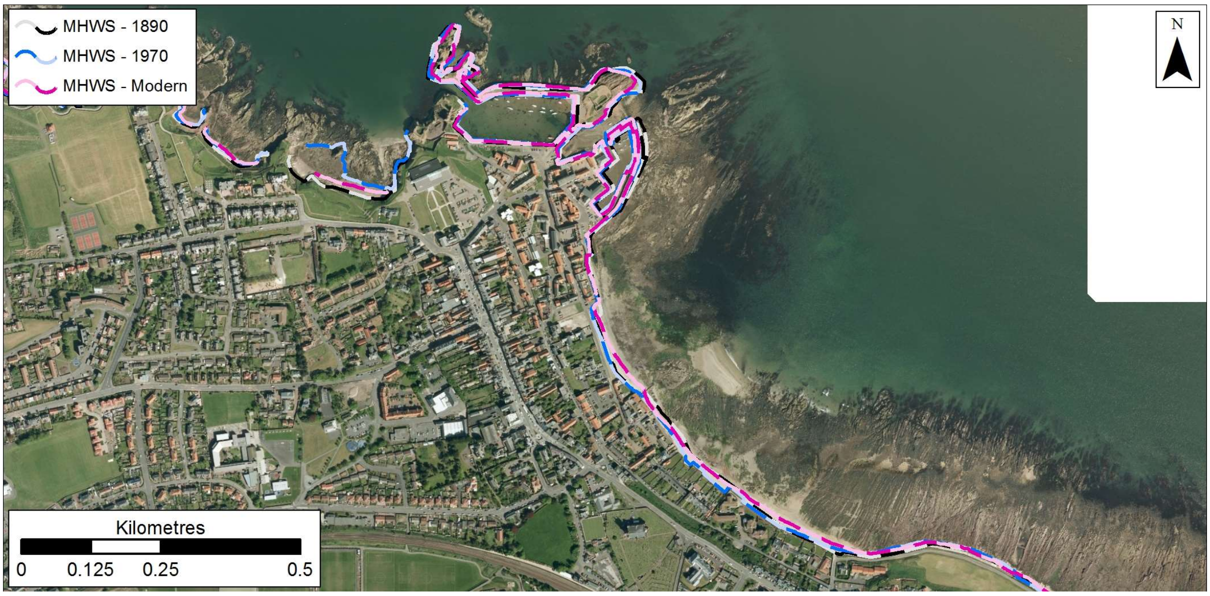

Figure 1.3: MHWS position in 1890, 1970s, and Modern datasets at Dunbar. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

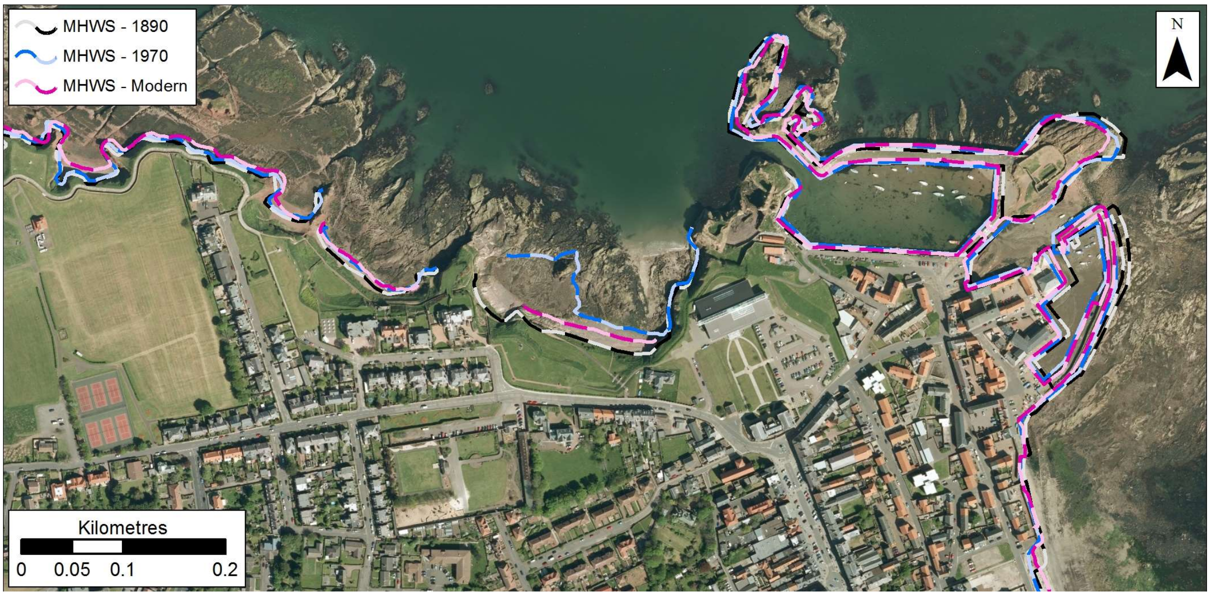

Figure 1.4: MHWS position in the 1970s, and Modern datasets at Dunbar Harbour. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: The area west of Dunbar Harbour is anticipated to experience erosion by 2050 (Figure 1.4 and Figure 1.5). The assets affected are environmental (nature conservation sites in the Firth of Forth) in the first instance. Further landward and within the erosion vicinity polygon, a 90 m (0.09 km) section of road and at least three properties lie within the potentially erodible area. This location also includes a Potentially Vulnerable Areas (PVA), the Battle of Dunbar Battlefield, the Firth of Forth Special Protected Areas (SPA) and Site of Special Scientific Interest.

Figure 1.5: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

1a.2 John Muir Country Park at Dunbar (Site 2)

Historic Change: The Belhaven Bay shoreline at John Muir Country Park has seen considerable changes since the 1890s (Figure 1.6). The central section of beach, dunes and backing salt marshes have built up and extended seawards by over 350 m between 1893 and 1970 and extended northwest by 580 m. Since 1970, the beach and dunes have continued to extend but rather than seawards they have extended alongshore towards the north east by 450 m and to the south west by 250 m. Some erosion has occurred within the River Tyne exit, most likely due to the movement of the main river channel, which in turn is in response to a modest extension of the inner spit of Sandy Hurst. The position of Sandy Hurst has not changed substantially since 1893. However, the 2011 position of MHWS on the salt marshes on the northern shore (area within the white box in Figure 1.6) appears to coincide with the position plotted in 1893. In the 1970s, it is depicted as being located some 160 m to the southeast (seaward) of the 1893 and 2011 position. Such a major retreat of MHWS across the salt marsh contrasts with the apparent extent of marsh shown on aerial imagery and it is likely that the method of survey of the saltmarsh edge differs from that used in 1893 and that used now. As a result, the 1970 position is subject to some doubt and this point is discussed in the National Overview Report. This location also includes the Firth of Forth SPA and SSSI.

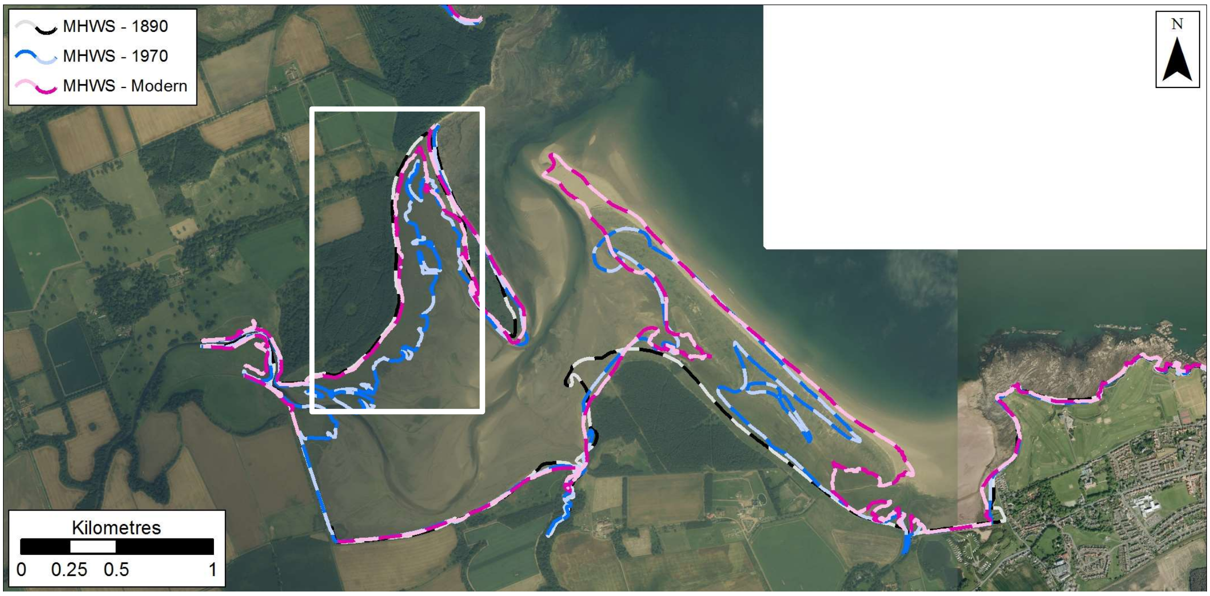

Figure 1.6: MHWS position in 1890, 1970s, and Modern datasets at John Muir Country Park. The white box delineates the area of saltmarsh referred to in the text. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: The Vulnerability Assessment anticipates that past accretion will continue, extending the beach and dunes to the north and south (as well as building in height) rather than seawards to the north (Figure 1.7). If past erosion trends continue within the Tyne estuary then substantial lengths of both the south and north estuary shores, including areas of beach, dune and salt marsh, may be affected by 2050 since the topography is low lying and composed of sandy sediments. The assets within this area are mainly natural heritage sites and their loss may increase the areas of flood risk. One limit to the northwards extension of future erosion vulnerability into the rear of the outer spit is that this area is also likely to accrete and gain in height from sand feed along the outer coast. The integrity of this section of the spit will depend on the relative balance of sand loss on the inner face versus sand gain on the outer face.

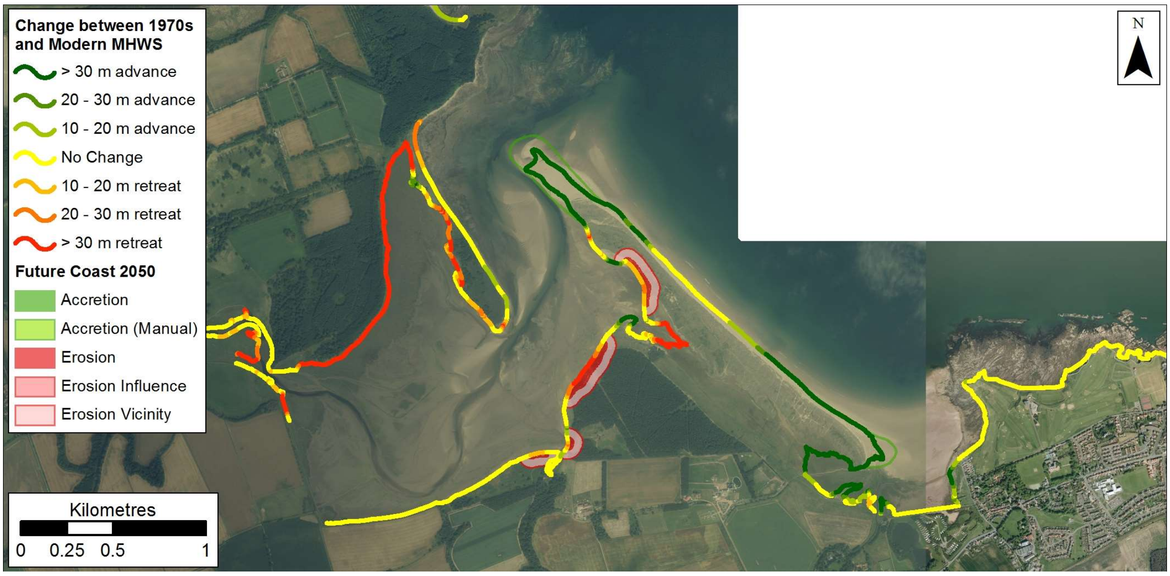

Figure 1.7: The change between the 1970s and Modern MHWS position, and the future coastal position extrapolated to 2050 in John Muir Country Park. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

1a.3 North Berwick (Site 3)

Historic Change: To the east of the harbour along the seafront of North Berwick, the position of MHWS has either remained stable or shown minor advance between 1893 and 1992 although the 8 m of advance is below the threshold (10 m) of significant change. Between 1992 and 2011 there has been seaward advance of some 18 m (i.e. 0.9 m/yr) along much of the eastern beachfront. To the west of the harbour, between 1890 and 1970 the shoreline remained largely stable although immediately to the south of the harbour the beach advanced some 9m (0.1 m/yr). This trend was reversed between 1991 and 2011 with 12 m (0.5 m/yr) of erosion occurring immediately south of the harbour wall and 15m of accretion at the western end of the beach (0.6 m/yr) (Figure 1.8). The foreshore at North Berwick is designated as part of the Firth of Forth SPA and SSSI.

Figure 1.8: MHWS position in the 1970s, and Modern datasets at North Berwick. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: The Vulnerability Assessment used the current erosion and accretion rates and projects them forward to 2050. Since much of the beachfront either side of the harbour shows accretion then these are predicted to continue to 2050 and are depicted via the green accretion area bars on Figure 1.9. However, in the area immediately adjacent and south of the harbour the predicted erosion by 2050 area impinges on one building with the erosion influenced area capturing a further four buildings and residences. The area of erosion vicinity includes a further 34 buildings and residences as well as significant length of Victoria Road and Melbourne Road, the only access routes to the harbour.

Figure 1.9: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at North Berwick. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Subcell 1b - North Berwick to the Inner Firth of Forth

1b.1 Gullane and Aberlady (Site 4)

Historic Change: Much of the shoreline east of Gullane is characterised by cliffs with pocket or cliff-foot beaches that have remained stable or have shown minor accretion between 1890, 1970 and modern (Figure 1.10). A minor amount of erosion has occurred between 1970 and modern at the western edge of a north-east facing beach to the north of Muirfield Golf Course and west of Dirleton. At Gullane, the beach has undergone a substantial amount of reshaping between 1890 and modern with erosion of 40 m (1890-1970) and up to 35 m (1970-modern) at the northern and central sections, and accretion of 25 m (1890-1970) and 15 m (1970-modern) in the western end. The accretion trend continues toward the headland to the west but at much reduced amounts.

Further west, substantial accretion dominates within Aberlady Bay, particularly on the eastern side where 100 m accreted between 1980 -1970 (ca 1 m/yr) and a further 330 m 1990-2011 (ca 15 m/yr). The south side of the bay has seen only minor accretion or stability over the same time spans as above. Aberlady Bay is part of the Firth of Forth SPA.

Figure 1.10: MHWS position in 1890, 1970s, and Modern datasets at Gullane Bay. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: The Vulnerability Assessment used the current erosion and accretion rates and projects them forward to 2050. Because of past erosional trends in the northern part of Gullane beach, the future look of vulnerability depicts a significant length of shoreline (600 m) to be potentially erosion-affected by 2050, with the erosion zone extending 50 m inland and the erosion influenced zone at 60 m inland (Figure 1.11). There are no built assets within this zone with the nearest residential properties a further 200 m inland and situated on top of a cliffline.

Figure 1.11: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Gullane Bay. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

1b.2 Port Seton (Site 5)

Future Vulnerability: Much of the foreshore at Port Seton has a veneer of sediments partially covering a rocky foreshore. The shoreline has retreated between 1890 and 1970, however to the eastern half of Figure 1.12, recent advances can be seen of up to 17 m and up to 12 m towards the west. There is little recent change adjacent and to the west of the coast protection in front of a small collection of buildings in the middle of the map. Such a location would not normally merit inclusion; however aerial photography clearly shows the undermining of a grassed area landward of the seawall. So, whilst no damage is known to have occurred to property, this demonstrates the fallibility of seawalls in some situations.

Figure 1.12: MHWS position in 1890, 1970s, and Modern datasets at Port Seton. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Figure 1.13: Aerial photography from 2009-05-11 showing the initial situation, with the grassed area behind seawall unaffected, see Figure 1.14 for comparison. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

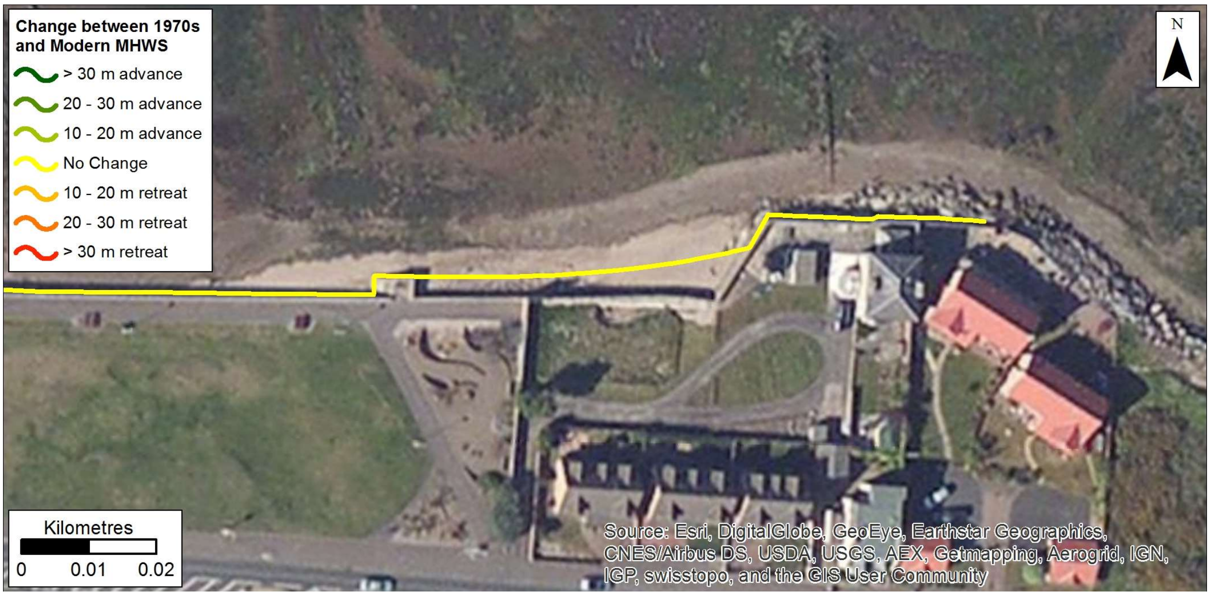

Figure 1.14: Esri default air photography taken on 2011-05-01 showing an area of undermining landward of the sea wall, see Figure 1.13 for comparison.

1b.3 Prestonpans (Site 6)

Historic Change: Much of the shoreline between Cockenzie and Prestonpans has either accreted or been subject to land claim after 1890 to house Cockenzie Power Station (Figure 1.15) and so the shoreline has since been protected with hard defences over much of its length. The one exception to this is along the urban frontage of Prestonpans itself where a 450m section of the beach is unprotected and has undergone erosion of ca 14m along its length between 1970 and modern. The western part of the town is protected by various generations of sea wall but beyond that the shore is unprotected north of Musselburgh Golf Course (Figure 1.16). It is possible that the coastline here once had coastal defences but these have now failed and bypassed. The shoreline is substantially seawards of the 1890 position suggesting land claim. However, there has been landward movement of MHWS between 1970 and modern of 15-25 m along the northern shore and accretion of up to 50m on the west facing shore. Prestonpans is a Potentially Vulnerable Area, is home to the Battle of Pinkie Battlefield and the Firth of Forth Special Protection Area along its foreshore.

Figure 1.15: MHWS position in 1890, 1970s, and Modern datasets at Prestonpans. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

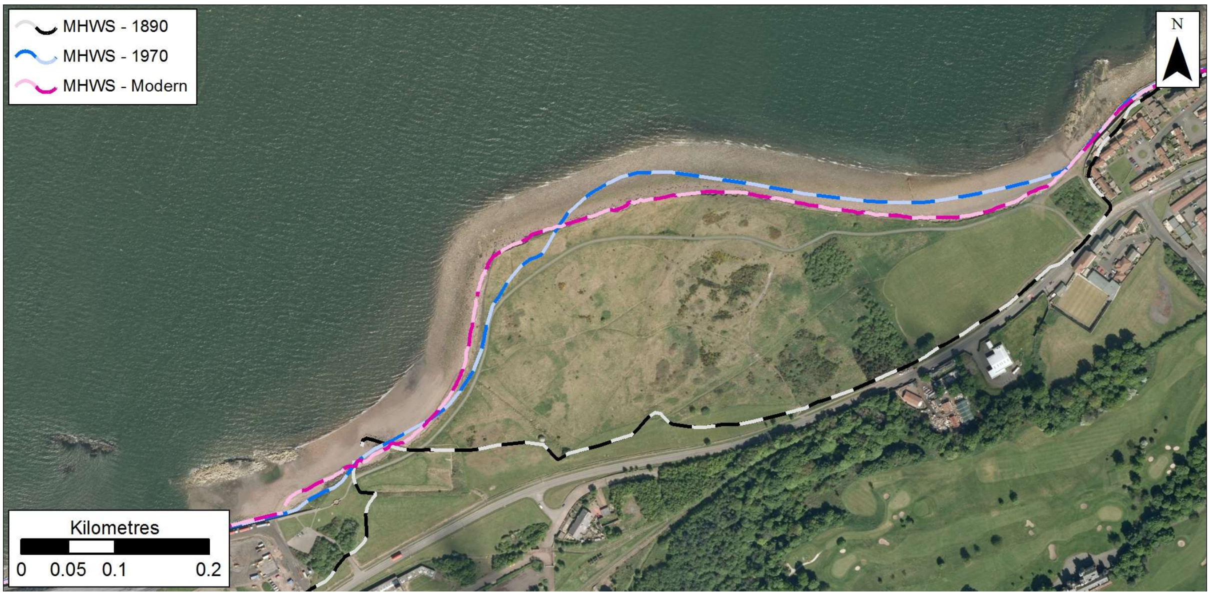

Figure 1.16: MHWS position in 1890, 1970s, and Modern datasets at east of Prestonpans. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: The Vulnerability Assessment used the current erosion and accretion rates and projects them forward to 2050. At the present rate of erosion of the unprotected shoreline at Musselburgh, the future area of vulnerability (Figure 1.17) spans 380 m of linear coast and extends 23 m inland affecting three commercial properties and one residential property. The erosion influenced area captures another four properties whilst the vicinity influences a further 21 properties, the High Street and an electricity substation. To the west of Musselburgh, future erosional vulnerability affects 500 m of linear shore and extends 25 m inland. This erosion affected area is mainly undeveloped land, though the erosion vicinity does impinge on a short stretch of the western extension of the High Street.

Figure 1.17: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data in Prestonpans. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Figure 1.18: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data east of Prestonpans. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Subcell 1c - Inner Firth of Forth to Elie Ness

1c.1 Dalgety Bay (Site 7)

Historic Change: The coastline at Dalgety Bay is now mostly protected or is rocky along its length and shows only minor fluctuations in the positions of MHWS over time (1890-modern). The one exception occurs at Harbour Place where the 1890 and 1970 shore positions show an inlet that once may have been a small harbour. The modern shore shows this inlet to have been removed, probably the subject of land claim post 1970 and the shoreline is now artificially protected. The foreshore at Dalgety Bay is part of the Firth of Forth Special Protection Area.

Future Vulnerability: The Vulnerability Assessment used the current erosion and accretion rates and projects them forward to 2050. No issues of past significant erosion are noted at Dalgety Bay and so the future vulnerability map shows no areas of concern.

Figure 1.19: MHWS position in 1890, 1970s, and Modern datasets at Dalgety Bay. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Subcell 1d - Elie Ness to Fife Ness

1d.1 Aberdour to Burntisland (Site 8)

Historic Change: The coastline between Aberdour and Burntisland is backed by a rock cliff that falls to a low platform along which the rail line to Kirkcaldy runs. Between 1970 and modern, the shoreline has receded by 10-20 m with most erosion occurring in the east. Similar amounts of erosion have occurred in the past in the west but this section is now protected by a boulder revetment.

Figure 1.20: MHWS position in 1890, 1970s, and Modern datasets at Aberdour and Burntisland. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: This section of shoreline has been categorised as hard and mixed in large part due to the steepness of the slope. Nevertheless, there may be pockets which are more erodible than this overall classification suggests. Future coastline has not been projected forward as this is a 'hard and mixed' shoreline.

1d.2 Kinghorn (Site 9)

Historic Change: To the west of Kinghorn the coast has shown minor erosion of up to 10m between 1970 and modern along the length of coast where the rail line runs, although the 1890 MHWS now coincides with the modern line. East of this there has been significant accretion beyond the end of the boulder revetment that protects the rail line. However, at the end of the revetment some 24m of erosion has occurred (1970-modern) that will continue unless the revetment is extended. East of this at Kinghorn itself, between 1970 and modern there has been 12 m of erosion over 120 m of the eastern end of Pettycur Bay. Accretion has characterised the western end of the bay. The foreshore at Kinghorn is notified as a part of the Firth of Forth Special Protection Area and a Site of Special Scientific Interest.

Figure 1.21: MHWS position in 1890, 1970s, and Modern datasets at Kinghorn. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: The Vulnerability Assessment used the current erosion and accretion rates and projects them forward to 2050. In the west, the area of erosion impacts mainly beach and dune but the erosion influenced area captures 30 m of rail line with a further 50 m within the erosion vicinity footprint. Moving east to Pettycur Bay, a continuation of the erosion trend produces erosion of the beach and dune area over 30m at the eastern end of the bay and with the erosion vicinity impinging on 16 residential properties and their suburban access road.

Figure 1.22: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Kinghorn. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

1d.3 Dysart (Site 10)

Historic Change: The shoreline at Ravenscraig Park underwent significant accretion between 1890 and 1970 that was substantially reversed from 1970 to modern so that some 39 m has been eroded from the centre of the bay with the mean erosion being 15 m or so. The east limit of the bay is constrained by a rocky shore and so minimal change has occurred over these time frames. To the north of the park at Howard Place, The Walk and Edington Place, the shoreline has moved seaward substantially (by up to 130 m) from its 1890 position to 1970, very likely resulting from coal waste being tipped onto the foreshore, as was the practice from nearby collieries. Between 1970 and modern this has reversed with up to 90m of erosion in places, although the average amount is lower. This is the likely outcome of the cessation of colliery waste tipping and the closure of the Fife collieries post 1970. There is a Potentially Vulnerable Area at Dysart, the Dysart House Garden of Designed Landscape, Ravenscraig Property in Care and the Firth of Forth Special Protection Area.

Figure 1.23: MHWS position in 1890, 1970s, and Modern datasets at Dysart. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Figure 1.24: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data in Dysart. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: The Vulnerability Assessment used the current erosion and accretion rates and projects them forward to 2050. At Ravenscraig Park the future erosion vulnerability footprint largely affects beach and parkland but within the vicinity of erosion area lie six residential properties, part of the Kyles Road and a small section of the A955 (Figure 1.24). To the north of this section lie two areas of future vulnerability. The southernmost of which affects a section of Howard Place and The Walk and includes eight residential properties within the erosion vicinity footprint. The northern area lies close to Edington Place affecting 100 m of shore and 50 m inland but no properties at risk. It is likely that this area is made ground composed of coal waste.

1d.4 West and East Wemyss (Site 11)

Historic Change: Substantial amounts of accretion occurred along this stretch of coast as a direct result of colliery waste tipping directly onto the intertidal zone at Buckhaven to the north. Up to 86 m of coastal advance occurred at West Wemyss (Figure 1.25) and 50 m at East Wemyss (Figure 1.26). This was reversed following the closure of the Francis Mine in Buckhaven with rapid erosion following between 1970 and modern, necessitating the construction of coastal defences at East Wemyss to protect houses built on the ground gained earlier. Up to 86 m has been lost at West Wemyss along substantial stretches of coast, with 16 m of loss at East Wemyss, increasing to 50 m in the north toward Buckhaven. There is a Potentially Vulnerable Area along this coastline along with Wemyss Castle Garden of Designed Landscape and the Firth of Forth Special Protection Area.

Figure 1.25: MHWS position in 1890, 1970s, and Modern datasets at West Wemyss. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: The Vulnerability Assessment used the current erosion and accretion rates and projects them forward to 2050. Much of the rapidly eroding area that starts at the south end of East Wemyss (at Back Dykes road) affects undeveloped ground characterised by bluffs of easily eroded glacial till (Figure 1.27), although one non-residential property lies within the erosion vicinity area. Since the frontage of East Wemyss itself is now protected by a boulder revetment, there are no extant future vulnerability issues noted. The area to the north and closer to Buckhaven has a 600 m long erosion footprint that affects mainly undeveloped land.

Figure 1.26: MHWS position in 1890, 1970s, and Modern datasets at East Wemyss. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Figure 1.27: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at East Wemyss. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

1d.5 Buckhaven (Site 12)

Historic Change: Although protected by hard defences to the limit of the developed and built up area of Buckhaven at Lady Wynd, the shoreline north of this point has shown considerable change since 1890 resulting from up to 300 m of accretion associated with land claim and colliery waste. Between 1970 and modern this has reversed by up to 50 m of erosion over 100 m in the central area north of Lady Wynd (Figure 1.28). The total area affected by erosion is about 650 m of coast. This shoreline is a Potentially Vulnerable Area and part of the Firth of Forth Special Protection Area.

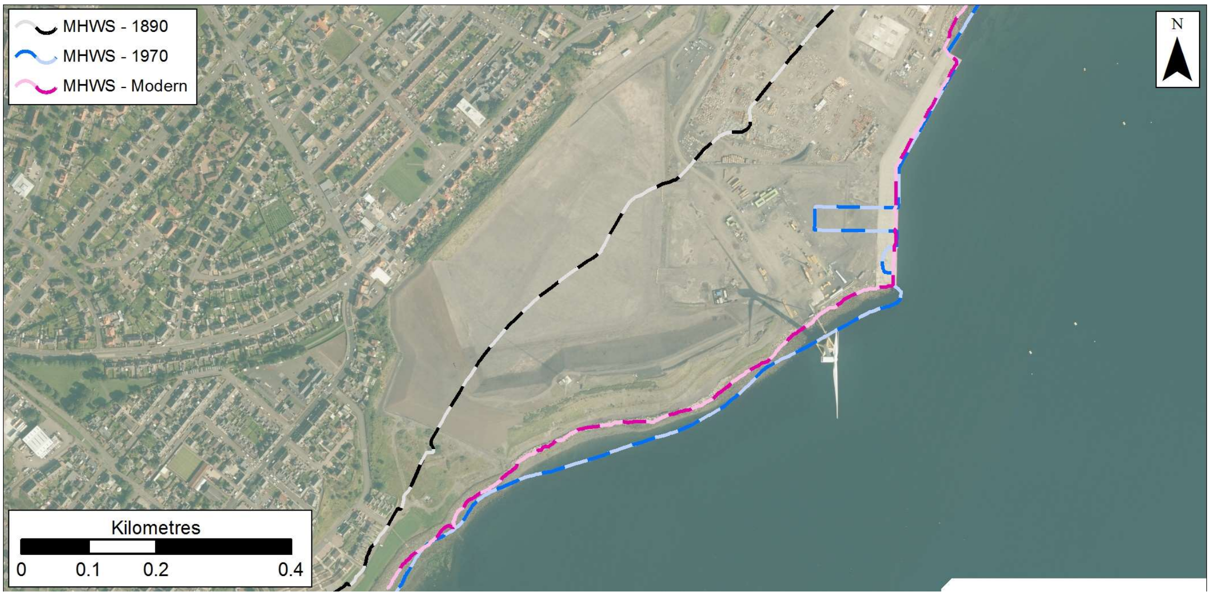

Figure 1.28: MHWS position in 1890, 1970s, and Modern datasets at Buckhaven. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: The Vulnerability Assessment used the current erosion and accretion rates and projects them forward to 2050. Some 650 m of coast is vulnerable but much of this in the north affects made ground (Figure 1.29), likely of colliery waste. In the south however, at Shore Street and Lady Wynd, some 50 m of shore is vulnerable with the footprint of erosion vulnerability extending 100 m inland and affecting 11 residential properties and an electricity substation as well as some 130 m of Shore Street roadway.

Figure 1.29: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS at Buckhaven. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

1d.6 Elie and Earlsferry (Site 13)

Historic Change: At Elie the accretion that occurred between 1890 and 1970 was reversed from 1970 to modern and the MHWS line migrated landward to reoccupy its 1890 position. Since then much of the shoreline has been subject to various protection measures that have halted any further landward excursion, other than a very small area of shore at The Terrace where some 10 m has been lost since 1970. To the east of Elie, the beach and dune frontage has moved landward by up to 20 m over much of the foreshore between 1970 and modern, a trend that has accelerated since the 1890 position (Figure 1.30). East of Sauchar Point the foreshore and dunes are part of the Firth of Forth Site of Special Scientific Interest.

Figure 1.30: MHWS position in 1890, 1970s, and Modern datasets at Earlsferry. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: The Vulnerability Assessment used the current erosion and accretion rates and projects them forward to 2050. The erosion of over 400 m of linear coast to the east of Elie affects beach and dune land with no built assets located in the area (Figure 1.31). However, the vulnerability of the urban area within Elie at The Terrace and Stenton Row places 15 properties at risk as well as the roadways leading south from the High Street.

Figure 1.31: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Earlsferry. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Coastal Change Statistics for Cell 1

Within the soft sections of Cell 1, **42% has been advancing** between **1890 and 1970**; compared with **32%** between **1970 and modern data**.
Within the soft sections of Cell 1, **8% has been retreating** between **1890 and 1970**; compared with **13%** between **1970 and modern data**.
Within the soft sections of Cell 1, the **average rate of advance** is **0.9 m/yr** between **1890 and 1970**, and **2.3 m/yr** between **1970 and modern data**.
Within the soft sections of Cell 1, the **average rate of retreat** is **-0.2m/yr** between **1890 and 1970**, and **-1.3 m/yr** between **1970 and modern data**.
Within the soft sections of Cell 1, **49%** has **not changed** significantly between **1890 and 1970**; compared with **56%** between **1970 and the modern data**.

Table 1.2: A summary of the average rates, average change distances, and lengths of advance, retreat, and no change within sub-cells of Cell 1.

Coastal Cell	Overall change (1)			Advance (2)			Retreat (3)			Insignificant change (4)		
	Average 1890 to 1970 Change on Soft Coast (m)	Average 1890 to 1970 Change Rate on Soft Coast (m/year)	Length of Soft Coast (km)	Average 1890 to 1970 Soft Coast Advance (m)	Average 1890 to 1970 Advance Rate on Soft Coast (m/year)	Length of Soft Coast Advance (km)	Average 1890 to 1970 Soft Coast Retreat (m)	Average 1890 to 1970 Retreat Rate on Soft Coast (m/year)	Length of Soft Coast Retreat (km)	Average 1890 to 1970 Soft Coast Insignificant Change (m)	Average 1890 to 1970 Retreat Rate on Soft Coast (m/year)	Length of Soft Insignificant Change (km)
Sub-cell 1a	51.2	0.62	49.4	121.4	1.46	21.5	-18.3	-0.21	4.4	0.4	0.01	23.6
Sub-cell 1b	11.3	0.12	26.1	30.2	0.31	10.7	-22.8	-0.24	2.4	2.0	0.02	13.0
Sub-cell 1c	20.4	0.22	32.9	51.7	0.56	13.8	-18.0	-0.24	2.5	0.2	0.00	16.6
Sub-cell 1d	7.5	0.10	3.2	17.9	0.23	1.1	-10.7	-0.12	0.1	2.2	0.03	2.0
Cell 1	31.6	0.37	111.7	77.8	0.91	47.1	-19.4	-0.22	9.4	0.8	0.01	55.2
	-	-	-	-	-	42.2%	-	-	8.4%	-	-	49.4%

Coastal Cell	Overall change			Advance			Retreat			Insignificant change (4)		
	Average 1970 to Modern Change on Soft Coast (m)	Average 1970 to Modern Change Rate on Soft Coast (m/year)	Length of Soft Coast (km)	Average 1970 to Modern Soft Coast Advance (m)	Average 1970 to Modern Advance Rate on Soft Coast (m/year)	Length of Soft Coast Advance (km)	Average 1970 to Modern Soft Coast Retreat (m)	Average 1970 to Modern Retreat Rate on Soft Coast (m/year)	Length of Soft Coast Retreat (km)	Average 1890 to 1970 Soft Coast Insignificant Change (m)	Average 1890 to 1970 Retreat Rate on Soft Coast (m/year)	Length of Soft Insignificant Change (km)
Sub-cell 1a	12.8	0.63	43.0	54.6	2.37	14.5	-44.8	-1.37	5.9	1.0	0.04	22.6
Sub-cell 1b	28.6	1.32	27.3	64.4	2.98	12.3	-20.0	-0.91	1.9	1.8	0.08	13.1
Sub-cell 1c	-1.5	-0.06	31.4	21.9	0.72	6.2	-40.3	-1.40	5.2	1.3	0.04	20.0
Sub-cell 1d	2.7	0.07	3.6	16.6	0.53	0.6	-13.5	-0.58	0.3	1.9	0.06	2.7
Cell 1	12.3	0.59	105.2	51.6	2.26	33.5	-38.8	-1.29	13.2	1.3	0.05	58.5
	-	-	-	-	-	31.9%	-	-	12.6%	-	-	55.6%

1 Overall change shows the mean value for the whole cell / sub-cell, averaging gains and losses.
2 Advance shows the mean value for the shoreline gains, where there has been greater than 10 m of change, or change which is faster than 0.5 m/yr.
3 Retreat shows the mean value for the shoreline losses, where there has been greater than 10 m of change, or change which is faster than 0.5 m/yr.
4 Insignificant change shows the lengths of coastline which have changed less than 10 m.

NB: Avoid comparing distances of change (i.e. km) but rather use proportions (i.e. %) to avoid cartographic differences between the years.

Table 1.3: A summary of the length of change within each change distance category in the historical (ca. 1890-1970) and recent (ca. 1970-Present) time periods in Cell 1.

1890-1970	Cell 1		Sub-cell 1a		Sub-cell 1b		Sub-cell 1c		Sub-cell 1d	
	Length (km)	Length (%)	(km)	(%)	(km)	(%)	(km)	(%)	(km)	(%)
>30 m Advance	25.5	23%	12.6	11%	3.7	3%	9.1	8%	0.1	0%
20-30 m Advance	7.2	6%	2.1	2%	2.6	2%	2.2	2%	0.3	0%
10-20 m Advance	14.5	13%	6.7	4%	4.4	4%	2.5	2%	0.8	1%
No Change	55.2	49%	23.6	21%	13.0	12%	16.6	15%	2.0	2%
10-20 m Retreat	7.4	7%	3.5	3%	1.8	2%	2.0	2%	0.1	0%
20-30 m Retreat	0.9	1%	0.4	0%	0.2	0%	0.4	0%	0.0	0%
>30 m Retreat	1.1	1%	0.4	0%	0.5	0%	0.2	0%	0.0	0%
Total length	**111.7**	**100%**	**49.5**	**44%**	**26.1**	**23%**	**32.9**	**29%**	**3.2**	**3%**

	Cell 1		Sub-cell 1a	Sub-cell 1b	Sub-cell 1c	Sub-cell 1d
Max advance (m)	628	John Muir Country Park	628	257	246	44
Average change (m)	31.6		51.2	11.3	20.4	7.5
Max retreat (m)	95	John Muir Country Park	95	85	79	13

1970-Modern	Cell 1		Sub-cell 1a		Sub-cell 1b		Sub-cell 1c		Sub-cell 1d	
	Length (km)	Length (%)	(km)	(%)	(km)	(%)	(km)	(%)	(km)	(%)
>30 m Advance	10.0	10%	4.6	4%	4.5	4%	0.9	1%	0.0	0%
20-30 m Advance	6.9	7%	2.8	3%	2.2	2%	1.7	2%	0.2	0%
10-20 m Advance	15.9	15%	6.7	6%	5.4	5%	3.5	3%	0.3	0%
<10m Advance but >= 0.5 myr^{-1}	0.7	1%	0.3	0%	0.2	0%	0.1	0%	0.1	0%
No Change	58.5	56%	22.6	21%	13.1	12%	20.0	19%	2.7	3%
<10m Retreat but <= -0.5 myr^{-1}	0.2	0%	0.1	0%	0.1	0%	0.1	0%	0.0	0%
10-20 m Retreat	4.4	4%	1.8	2%	0.9	1%	1.4	1%	0.3	0%
20-30 m Retreat	2.4	2%	1.0	1%	0.6	1%	0.8	1%	0.0	0%
>30 m Retreat	6.2	6%	3.0	3%	0.3	0%	2.9	3%	0.0	0%
Total length	**105.2**	**100%**	**43.0**	**41%**	**27.3**	**26%**	**31.4**	**30%**	**3.6**	**3%**

	Cell 1		Sub-cell 1a	Sub-cell 1b	Sub-cell 1c	Sub-cell 1d
Max advance (m)	516	John Muir Country Park	516	347	103	29
Average change (m)	12.3		12.8	28.6	-1.5	2.7
Max retreat (m)	-157	John Muir Country Park	-157	-38	-111	-23

Asset Vulnerability Statistics for Cell 1

Table 1.4: A summary of the number, length, or area of assets within the erosion, erosion influence, and erosion vicinity buffers of the future coastline projections for Cell 1.

Cell 1	Units	Modern to 2050				2050+			
		Erosion	Erosion Influence	Erosion Vicinity	Total	Erosion	Erosion Influence	Erosion Vicinity	Total
Community Services	Number	-	-	-	-	-	-	-	-
Non Residential Property	Number	10	2	23	35	13	2	36	51
Residential Property	Number	10	6	187	203	34	12	274	320
Septic Water Tanks	Number	-	-	1	1	-	-	1	1
Utilities	Number	-	-	2	2	-	-	4	4
Rail	Length (km)	-	0.0	0.1	0.2	0.0	0.0	0.1	0.2
Roads (SEPA)	Length (km)	-	-	0.5	0.5	0.1	0.0	0.9	1.0
Roads (OS)	Length (km)	0.0	0.0	1.0	1.1	0.1	0.1	1.1	1.3
Clean Water Network	Length (km)	0.0	0.1	1.1	1.2	0.1	0.1	1.6	1.9
Total Anticipated Erosion	Area (hectares)	17.9	7.9	53.4	79.2	30.6	9.2	59.1	98.9
Runways	Area (hectares)	-	-	-	-	-	-	-	-
Cultural Heritage	Area (hectares)	1.9	1.0	6.9	9.8	2.1	1.1	7.5	10.7
Environment	Area (hectares)	1.9	0.8	4.8	7.5	2.7	0.8	5.2	8.8
Flooding (200 year envelope)	Area (hectares)	5.1	1.2	7.1	13.4	6.5	1.3	7.7	15.5
Flooding (1000 year envelope)	Area (hectares)	6.0	1.6	8.3	15.9	7.7	1.6	8.8	18.1
Erosion within PVAs	Area (hectares)	11.7	5.1	34.8	51.6	18.2	5.9	38.0	62.1
Erosion outwith of PVAs	Area (hectares)	6.2	2.8	18.6	27.6	12.4	3.3	21.1	36.8
Battlefields	Area (hectares)	-	-	0.04	0.04	-	-	0.4	0.4
Gardens and Designed Landscapes	Area (hectares)	2.3	1.1	7.0	10.4	2.5	1.2	7.3	10.9
Properties in Care	Area (hectares)	-	0.002	0.351	0.353	-	0.0	0.4	0.4
Scheduled Monuments	Area (hectares)	-	0.0	0.4	0.4	-	0.0	0.4	0.4
Nature Conservation Marine Protected Areas	Area (hectares)	-	-	-	-	-	-	-	-
National Nature Reserves (NNR)	Area (hectares)	-	-	-	-	-	-	-	-
Special Areas of Conservation (SAC)	Area (hectares)	-	-	-	-	-	-	-	-
Special Protection Areas (SPAs)	Area (hectares)	0.1	0.0	0.7	0.8	0.1	0.0	0.7	0.8
Sites of Special Scientific Interest (SSSI)	Area (hectares)	2.1	0.9	5.2	8.2	2.9	0.9	6.0	9.9

References

Ramsay, D.L. and Brampton, A.H. (2000) Coastal Cells in Scotland: Cell 1 - St Abb's Head to Fife Ness. Scottish Natural Heritage Research, Survey and Monitoring, Report No 143.

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