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Dynamic Coast - National Coastal Change Assessment: Cells 8 and 9 - The Western Isles

Main report here

Published by CREW – Scotland's Centre of Expertise for Waters. CREW connects research and policy, delivering objective and robust research and expert opinion to support the development and implementation of water policy in Scotland. CREW is a partnership between the James Hutton Institute and all Scottish Higher Education Institutes supported by MASTS. The Centre is funded by the Scottish Government.

Please reference this report as follows: Hansom, J.D., Fitton, J.M., and Rennie, A.F., (2017) Dynamic Coast - National Coastal Change Assessment: Cells 8 and 9 - The Western Isles, CRW2014_02.

Available online with Main report at: https://www.crew.ac.uk/publication/scotlands-coastal-change-assessment

Dissemination status: Unrestricted

National Coastal Change Assessment
Steering Committee

Coastal Change & Vulnerability Assessment

Dynamic Coast – Scotland's National Coastal Change Assessment

Executive Summary

- Cell 8 extends along the Minch or east coast of the Western Isles between Barra Head in the south to Tiumpan Head in the north. Cell 9 extends along the Atlantic coast of the Western Isles from Barra Head in the south to Tiumpan Head in the north.
- In Cells 8 and 9 Mean High Water Springs extends to 4,415 km which makes up around 22% of the Scottish coastline. Of this length, 91% (4,015 km) has been categorised as hard and mixed, 9% (376 km) as soft and 1% (23%) as artificial.
- Within the historical period of 1890-1970s (74 years) a little less than half of the soft shoreline has not changed significantly (44%), accretion has occurred along 23% of soft coasts with erosion occurring along 33%.
- The period from the 1970s to modern spans 37 years, so the historical period data has been normalised to 37 years to allow comparison with the modern period. When this adjustment has been applied the extent of erosion has reduced from 16% historical period to 13% post 1970s, the extent of stability has reduced from 73% to 76% and the extent of accretion has increased from 11% to 12%.
- The average rate of retreat has quickened from the historical to the recent period (0.6 m/yr to 1.3 m/yr) whilst accretion has fallen slightly from 0.9 m/yr to 0.8 m/yr.
- There has been a slight reduction in the extent of erosion and leading to an increase in accretion and stability. Nevertheless the rate of erosion is increasing. Such a pattern is comparable with other rocky dominated coastal cells seeing more modest changes, perhaps due to an increased level of protection offered by the surrounding rock-dominated shore.

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.

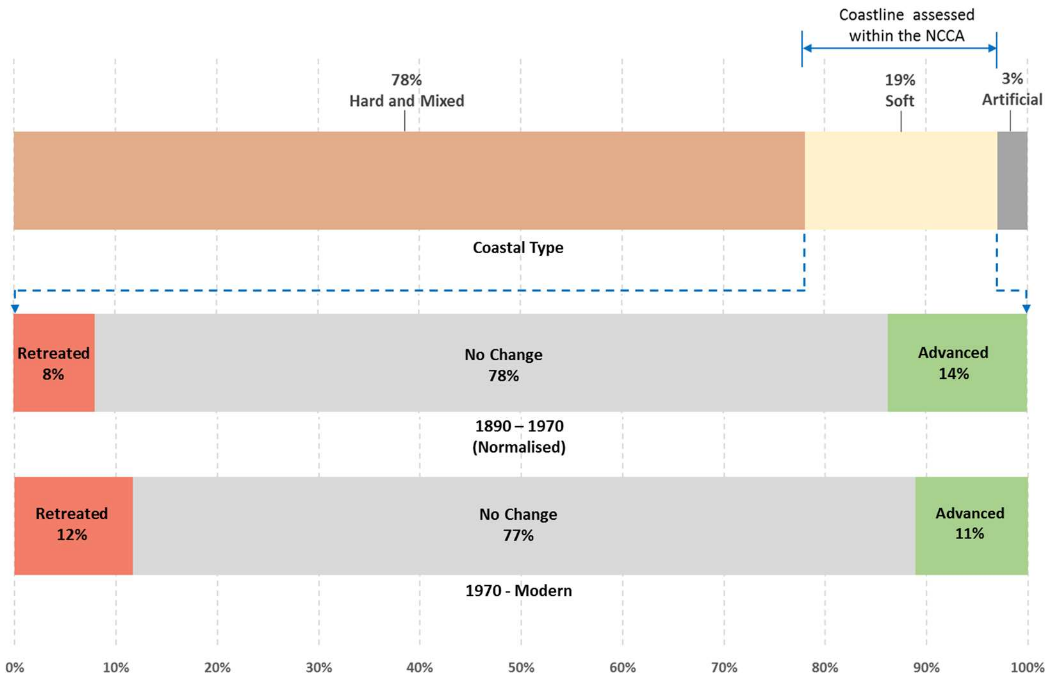

Figure 1: National coastal change results showing the proportion of soft coast retreating, stable and advancing within each change category in the historical (ca. 1890-1970 normalised for time period) and recent (ca. 1970-Present) time periods.

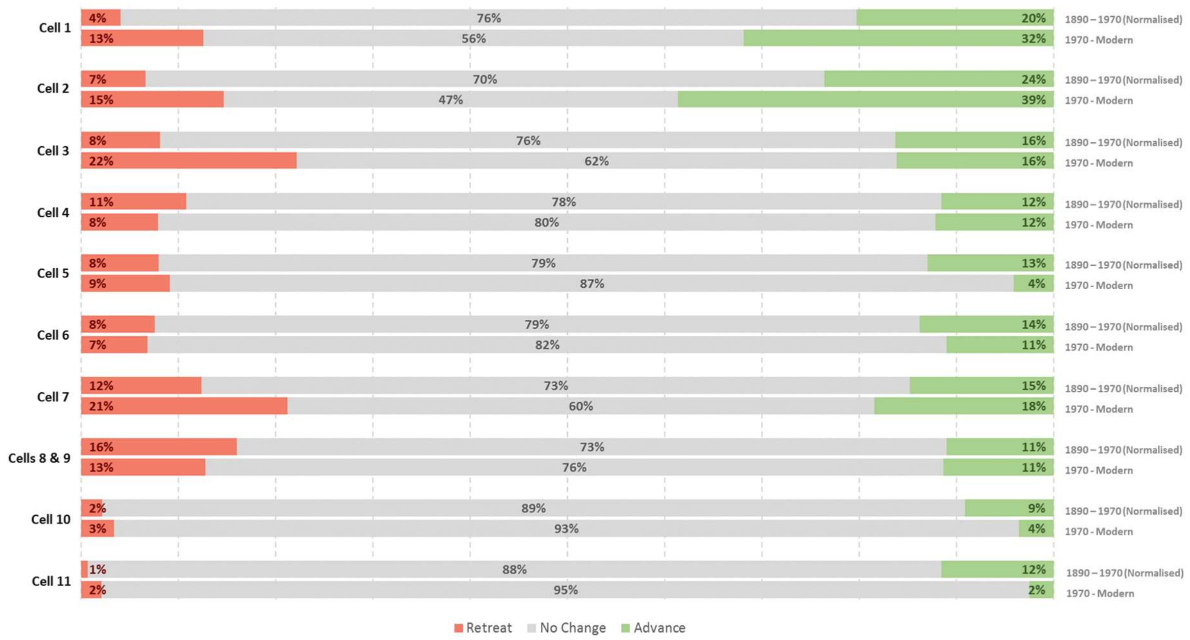

Figure 2: National coastal change results showing historical (ca. 1890-1970, normalised for time period) and recent (ca. 1970 Present.) % of coastal cell showing retreat (red), stability (grey) and advance (green) for soft coast within each cell.

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.

Cells 8 and 9 - The Western Isles

Cell 8 extends along the rock-dominated but relatively sheltered Minch or east coast of the Western Isles from Barra Head in the south to Tiumpan Head in the north. Cell 9 extends along the more exposed and often sandy Atlantic coast of the Western Isles from Tiumpan Head in the north to Barra Head in the south. The sub-cell boundaries are shown in Figure 8.9.1 below. Further contextual information about the processes operating in Cells 8 and 9 can be found in Ramsay & Brampton (2000).

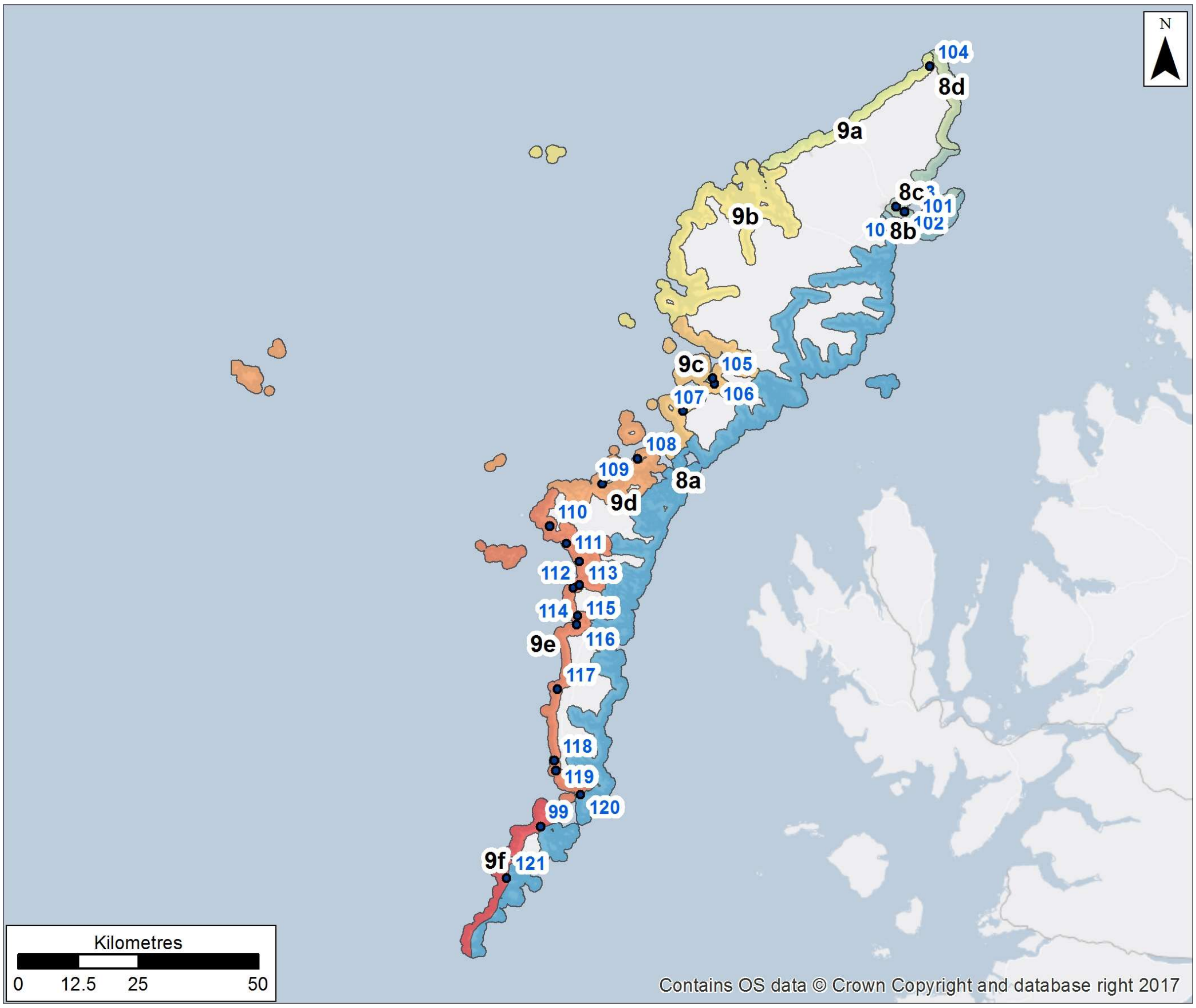

Figure 8.9.1: The sub-cell boundaries of Cells 8 and 9 and locations of sites discussed in this report (blue numbers).

Physical Overview

In Cells 8 and 9 Mean High Water Springs (MHWS) extends to 4,415 km which makes up around 22% of the Scottish coastline. Of this length, 91% (4,015 km) has been categorised as hard and mixed, 9% (376 km) as soft and 1% (23%) as artificial (Table 8.9.1). Within the historical period a little less than half of the soft shoreline has not changed significantly (44%), accretion has occurred along 23% of soft coasts with erosion occurring along 33% (Figure 8.9.2). The period from the 1970s to modern spans 37 years, so the historical data has been normalised to 37 years to all comparisons with modern period.

When this adjustment has been applied the extent of erosion has reduced from 16% historical period to 13% post 1970s, the extent of stability has reduced from 73% to 76% and the extent of accretion has increased from 11% to 12%. The average rate of retreat has quickened from the historical to the recent period (0.6 m/yr to 1.3 m/yr) whilst accretion has fallen slightly from 0.9 m/yr to 0.8 m/yr. Such a pattern is comparable with other rocky dominated coastal cells seeing more modest changes, perhaps due to an increased level of protection offered by the surrounding rock-dominated shore. Further statistics for Cells 8 and 9 can be found in Table 9.1 and Table 9.2 at the end of this report.

Table 8.9.1: Proportion of each coastal type within Cells 8 and 9.

Modern Coastal Type	Length	
	km	%
Soft	375.8	9%
Artificial	23.4	1%
Hard and Mixed	4014.7	91%
Total Length (excluding tidally influenced inlets)	4413.8	100%

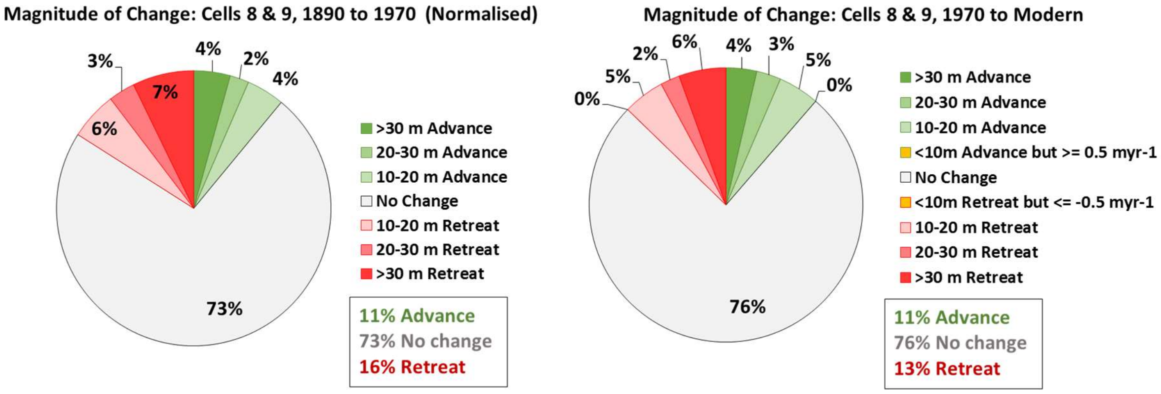

Figure 8.9.2: Coastal change results for Cells 8 and 9 showing the proportional amount of change in the historical (ca. 1890-1970 normalised) and recent (ca. 1970-Present) periods. Rounding errors may produce small % differences between Figure 2 and Figure 8.9.2.

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 Cells 8 and 9 a total land area of 90 ha, which supports various assets, is anticipated to be lost by 2050. No residential and non-residential properties within the areas expected to be eroded. When areas that erosion may influence are included then a further eight residential and non-residential properties are anticipated. For a full summary of vulnerable assets see Table 9.3 at the end of this report.

Sub-Cell Summaries

Cell 8 - Barra Head to the Butt of Lewis (Minch Coastline)

Sub-cell 8a - Barra Head to Stornoway Harbour

8a.1 Traigh Mhor Eoligarry, Barra (Site 99)

Historic Change: Despite its sheltered situation, MHWS at Traigh Mhor has been subject to movement between 1901 and 1972. In the south of the bay up to 90 m has been lost whereas some 20 m of gain is noted in the north (Figure 8.1:). In the most recent time period from 1972 to 2016, the southern part of the bay has accreted by up to 25 m over its 1972 position, whilst the northern part has eroded by up to 30 m from its 1972 position. To the north at the clachan of Eoligarry itself, some 30 m has been eroded over 200 m of mainly sand dune crofting land between 1967 and 2016. The dunes and much of the foreshore is part of Barra Special Area of Conservation (SAC) and Eoligarry Site of Special Scientific Interest (SSSI).

Figure 8.1: MHWS position in 1890, 1970s, and Modern datasets at Traigh Mhor Eoligarry. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: Traigh Mhor is the main landing beach for Barra airfield and so its future trends are of upmost importance, as noted by Hansom and Comber (1996). The main access road to the northern part of Barra runs close to the shore and the airport facilities also lie with a few metres of MHWS in the centre of the bay. Although erosion is noted in both the north and south bay, this is not expected to continue in the future due to the resilience of the hinterland as estimated by the Underlying Physical Susceptibility Model (Fitton et al., (2016)).

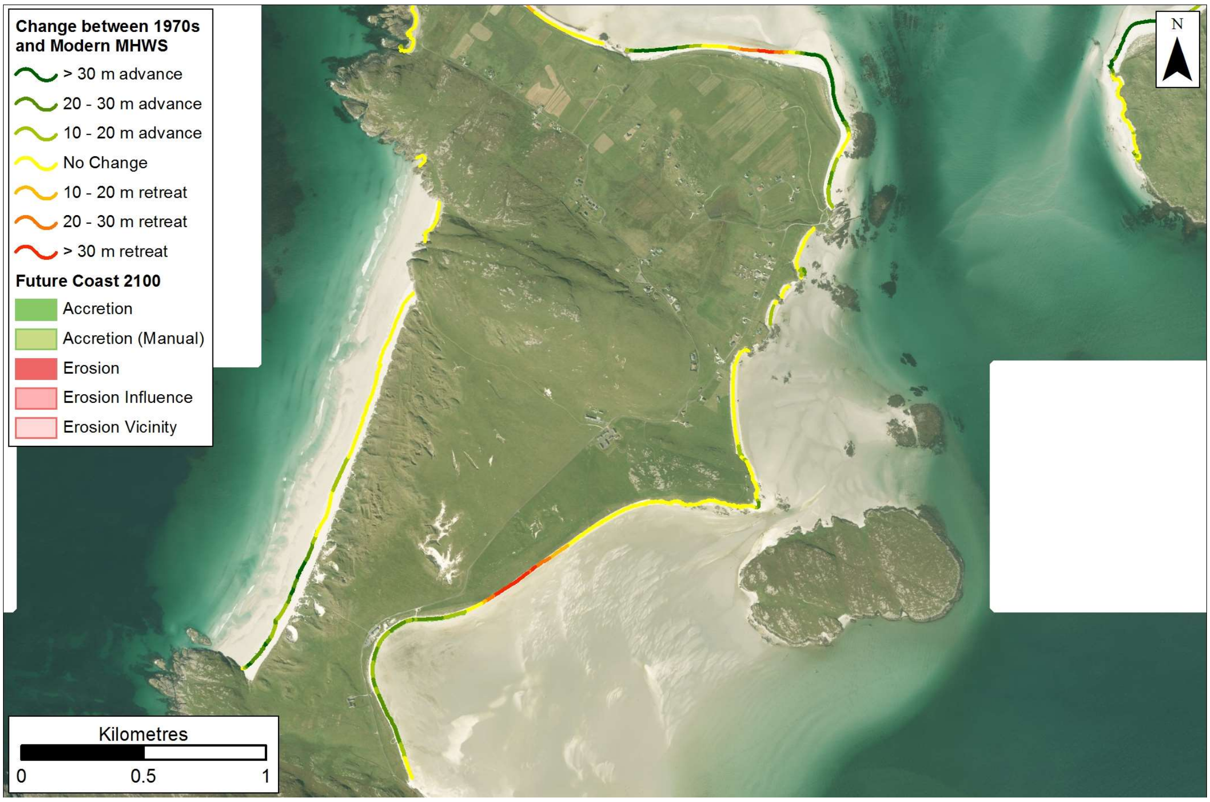

Figure 8.2: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Traigh Mhor Eoligarry. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Sub-cell 8b - Stornoway Harbour to Tiumpan Head

8b.1 Holm (SW of Braigh) (Site 100)

Historic Change: The small tombolo at Holm has undergone erosion on both sides between 1895 and 1964, with the maximum occurring on the south side of up to 30 m and then a further 10 m between 1964 and 2013 (Figure 8.3). The north coast lost up to 6m on average up to 1964 but has since been protected by boulder defences and a seaward movement of MHWS.

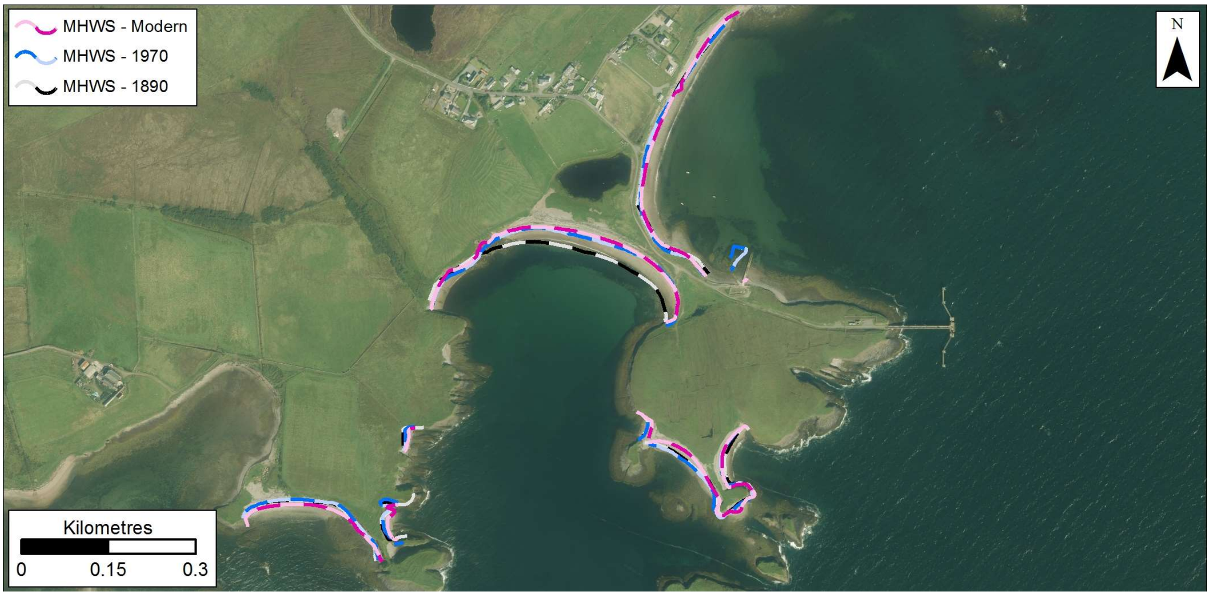

Figure 8.3: MHWS position in 1890, 1970s, and Modern datasets at Holm. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Figure 8.4: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Holm. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: Although recent erosion is limited on the south side of the tombolo, and is not flagged as an issue at present, the tombolo itself houses an oil pipeline and access road from a landing stage situated at the end of the islet to the east. As a result, it is an area that may be of concern in the future if these rates change (Figure 8.4). The northern side is already protected and it may be that the south side requires similar protection in the future.

8b.2 The Braigh (Site 101)

Historic Change: The Braigh tombolo connects mainland Lewis with the Point peninsula. Along the main tombolo the 1985 MHWS is closely matched by the 1964 and 2013 lines, except in the northwest where the modern line lies 40 m seaward of the 1895 line showing accretion along this section (Figure 8.5). The Braigh is defended by structures along both its south and north sides but in spite of this, there has been landward movement of the MHWS between 1964 and 2013. In the centre of the north side and in the southeast corner where there has been up to 20 m of erosion. This section of beach has groynes fitted and the losses relate to changes in beach position either side of the groynes and so may not be significant in the long term.

Of more concern is the area to the west of the south side of the Braigh. Here 30 m of beach was lost between 1895 and 1964 and a further 30 m to 2013 with modern aerial photography showing the vegetation edge of low lying marshy ground occurring some 20 m behind MHWS. Behind this runs the main road to Stornoway and the access road to Stornoway airport.

To the east of the Braigh (north coast), St Columba's Church Scheduled Monument lies within the dunes.

Figure 8.5: MHWS position in 1890, 1970s, and Modern datasets at the Braigh. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: The Braigh is an important lifeline link between the settlement at Point and Stornoway town and, although protected on both flanks, it is subject to significant storm activity and is overwashed in places. As such, there are areas where the beach that partly protects the sea wall is vulnerable. This includes a 260 m stretch in the southeast corner, which impinges on a similar length of roadway, and a 120 m stretch in the centre north of the car park A further 60 m of roadway may similarly be affected in the future at the southwest corner.

Of more concern is the 650 m of projected erosion along the marshy frontage that sits to the south of the main roadway and the airport north/south runway (Figure 8.6). A boulder bund has been constructed along the lagoon frontage but does not extend either side of it and so there is the possibility of flanking erosion leading to extended flooding that may extend beyond the road as far as the airport runway.

Figure 8.6: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at the Braigh. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Sub-cell 8c - Tiumpan Head to Tolsta Head

8c.1 Stornoway Airport (Site 102)

Historic Change: Historical changes from 1895 along the beaches at the south end of Broad Bay and the north end of Stornoway Airport appear to show erosion of 30 m (0.3 m/yr) in the south up to 1990, stability in centre and 80 m of accretion in the north and around the point. However, the 1970s map has the same geometry and given the very rectilinear nature of the beach to the east of the runways it may have originally been engineered. Nevertheless, there has developed an erosional bight at the south end of the runway boulder protection that has removed 11.5 m between 1990 and 2013 (0.50 m/yr). The gain at the northern end of the beach between 1895 and 1990 of 130 m (1.4 m/yr) is largely due to the creation of the runway extension. The 1895 shoreline used to arc westwards into the inlet.

The dunes and foreshore to the north of the airport and surrounding Traigh Mhealaboist and Sands o' Tong are part of the Tong Saltings Site of Special Scientific Interest.

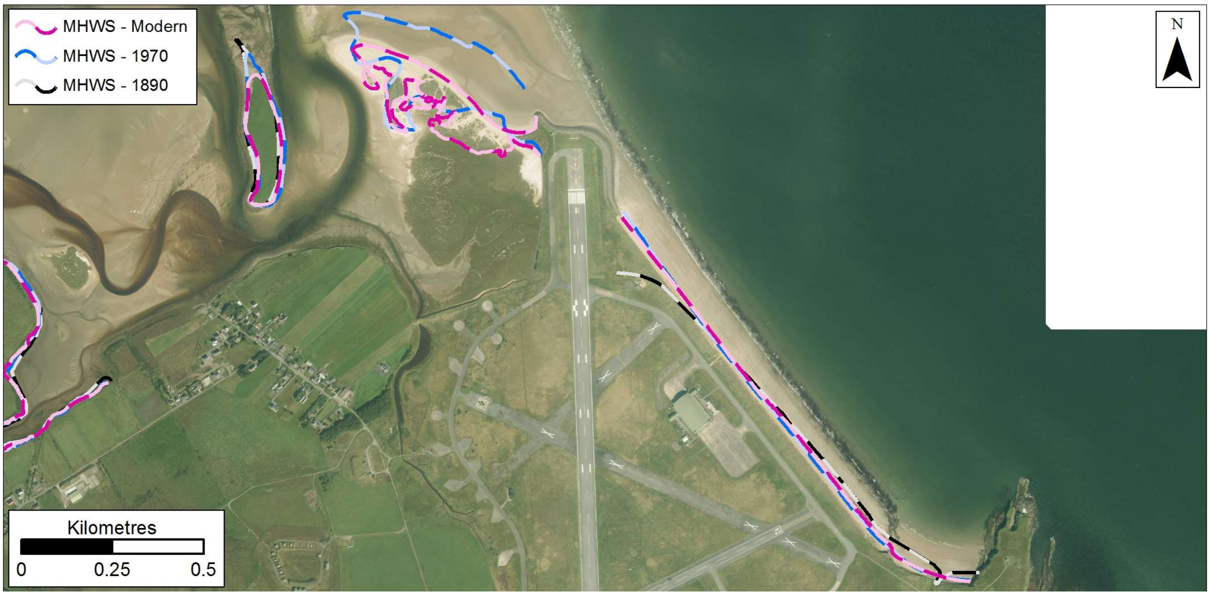

Figure 8.7: MHWS position in 1890, 1970s, and Modern datasets at Stornoway Airport. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: Stornoway Airport is an important strategic and lifeline asset for Lewis and Harris and so in spite of there being no serious erosion projected by 2050, there remains a potential flooding issue given the low-lying nature of the ground. The 9 m erosional bight at the end of the runway boulder protection shows a further 10 m loss to the edge of the vegetation (Figure 8.8). Although this falls short of the distance to flag concern, it remains close to this limit and so is an area of concern for the future if those rates increase even if only slightly.

Figure 8.8: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Stornoway Airport. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

8c.2 Sands of Tong (Site 103)

Historic Change: Teanga Tunga is the southern trending spit partially enclosing the Sands of Tong. The peninsula had breached before 1890s, however the subsequent widening of the breach may have been accelerated as a result of wave changes due to the construction of RAF Stornoway in the 1940s and the building of the north/south runway. The western face has advanced 17 m between 1895 and

1984 (0.2 m/yr), however more recently it has retreated westwards up to 10 m between 1984 and 2013 (0.3 m/yr) (Figure 8.9). More substantial changes have occurred at the central breach, which has widened from 135 m in 1895, to 235 m in 1984 and 286 m in 2013. This behaviour is entirely expected and reflected on other submerging shores in the Western Isles and Northern Isles of Scotland.

Within the inlet itself, substantial changes have occurred in the saltmarsh area where up to 400 m has been gained between 1971 and 2013. This may result from the widening of the spit allowing enhanced access of sediment from Broad Bay into the Sands of Tong inner bay. The saltmarsh at the west / head of the inlet has retreated 250 m in the recent period (1971 to 2013). The spit and salt marsh are part of Tong Saltings SSSI.

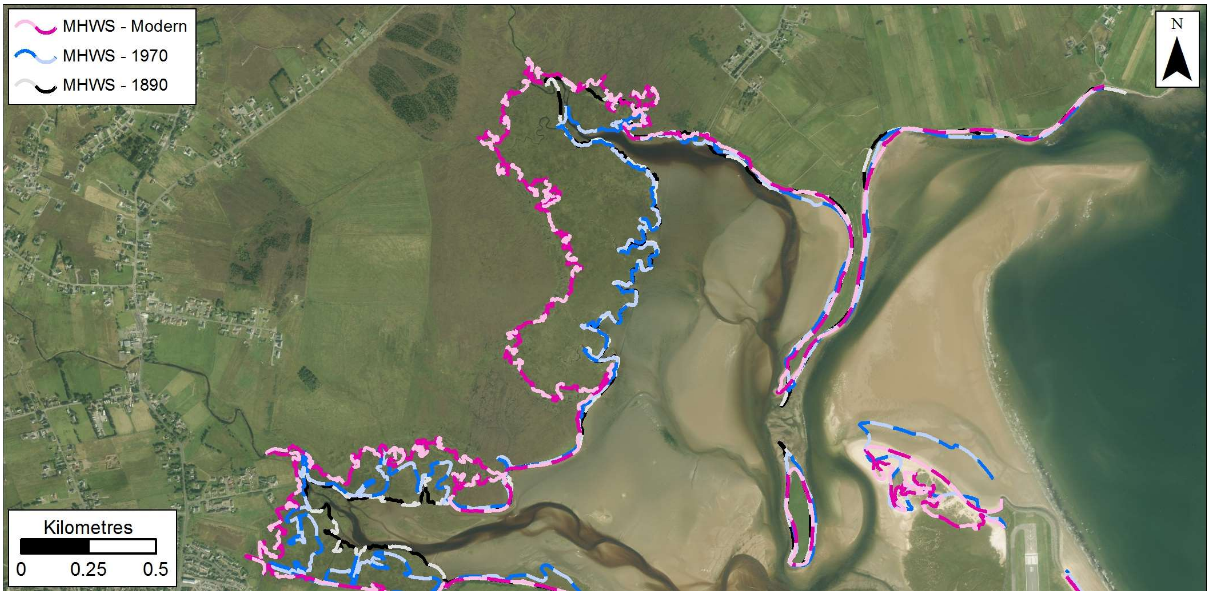

Figure 8.9: MHWS position in 1890, 1970s, and Modern datasets at the Sands of Tong. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: Teanga Tunga, the southern trending spit partially enclosing the Sands of Tong, has a long history of movement with breaching. The modern retreat rate places the spit structure within an area anticipated to erode by 2050. If this occurs then it might be expected that the rate of retreat in the saltmarsh to the west accelerates, since the erosion rate there has been high in the recent period. Much will depend on whether the sediment released by the anticipated erosion of Teanga Tunga and the spit at the end of the airport runway, is recycled within the bay. If this occurs, then it may be anticipated that the saltmarsh edge is buried by a sandy, but protective, beach ridge. This may result in the loss of saltmarsh area, but at the benefit of a more resilient coastal edge. Either way, the Sands of Tong area is vulnerable to change, most likely borne by the outer coast and the salt marsh edge. The risk is low for the houses that lie to the west.

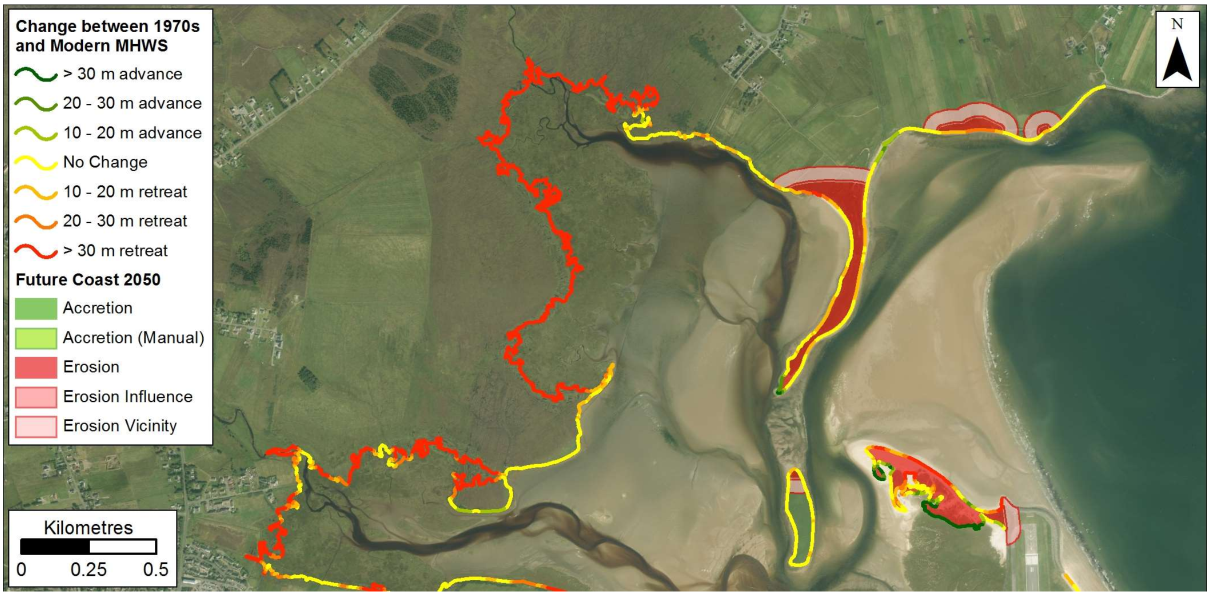

Figure 8.10: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at the Sands of Tong. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Sub-cell 8d - Tolsta Head to Butt of Lewis

Other than a long and stable sand beach at Tolsta, the rest of this sub-cell is dominated by rock cliffs. There are no changes of note within this sub-cell.

Cell 9 – Butt of Lewis to Barra Head (Atlantic Coast)

Sub-cell 9a - Butt of Lewis to Tiumpan

9a.1 Eoropie (Site 104)

Historic Change: The beach, backing dunes and machair at Eoropie extends over 500m in length and shows 40 m of accretion between 1895 and 1990 in the south and some stability in the north (Figure 9.1). Between 1990 and 2013, the MHWS in the south has moved landward by up to 25 m but has not reached the 1895 position, with equal amounts of accretion and erosion in the north. The vegetation edge lies some distance landward and the dune area has been subject to quarrying in the past for sand. It is unknown whether this continues, but shell sand is a valuable asset to add to the calcium-poor peat lands of the adjacent crofts.

Future Vulnerability: The recent erosion in the south of Eoropie gives rise for some concern since up to 45 m of losses over the southern 250 m of the beach are predicted by 2050 (Figure 9.2), however no assets are thought to be impacted other than the loss of dune and machair. This beach is extensively used for recreational purposes and is common grazing and so it is likely that should erosion commence, remedial action (dune fencing and stock exclusion) will be undertaken to mitigate the rate and impact of erosion

Figure 9.1: MHWS position in 1890, 1970s, and Modern datasets at Eoropie. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

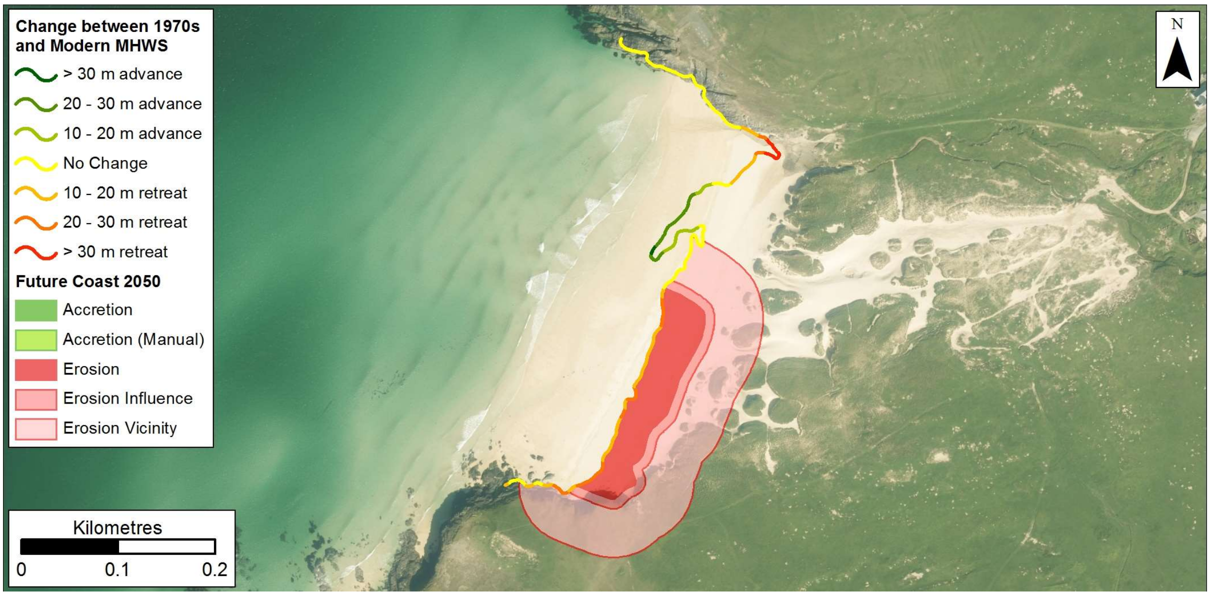

Figure 9.2: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Eoropie. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Sub-cell 9b - Tiumpan to Hushinish Point

There are no changes of note within this sub-cell

Sub-cell 9c - Hushinish Point to Sound of Harris

9c.1 Luskentyre and Taransay (Site 105)

Historic Change: There has been substantial landward migration of 60 m to 1974 along Traigh Rosamol on the west shore of Luskentyre and a lesser amount on the south shore. The 2014 Ordnance Survey (OS) line lies on top of the 1974 line and so it is likely that it has not been surveyed since and is unreliable. However, it is clear from the aerial photography that some cutting back of the high dune cliff has occurred along both shores. The true position of the modern MHWS may lie 50 m landward in some places.

On the east side of Taransay facing Luskentyre, a small 530m long spit is shown to be further north and more extensive in 1895. By 1974 its length had reduced to 100 m, moved south and become stubbier with losses on the north and gains on the south. Approximately 100 m of recession occurred on the north between 1895 and 1974 and this is thought to continue (though calculated using the unreliable OS 2014 line).

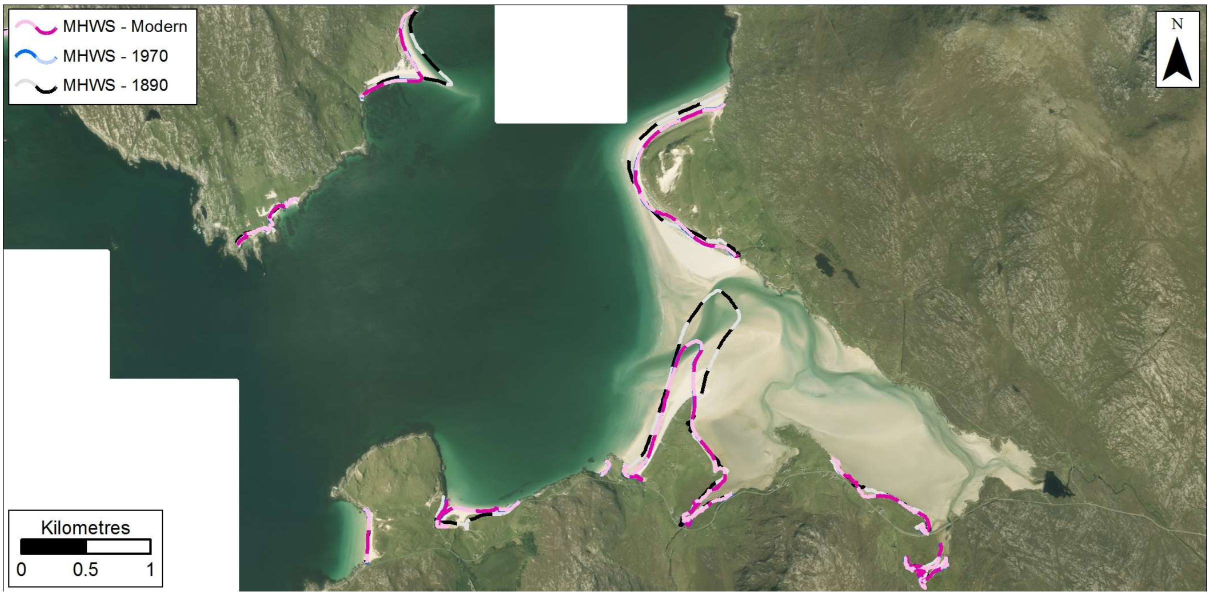

Figure 9.3: MHWS position in 1890, 1970s, and Modern datasets at Luskentyre and Taransay. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: As the the latest MHWS line is the same as the 1974 MHWS position, no change is seen to have occurred at this location (Figure 9.4). Possible future change is therefore not estimated here. At bay mouth locations such as Luskentyre (and Seilebost on the south side) there is constant change occuring that is related to both atlantic wave approach, but also the changing routes of the tidal channels of the inlet. At Luskentyre, there are no built assets close to the shore that may be at risk if the past rates change and so there are no anticipated vulnerability issues.

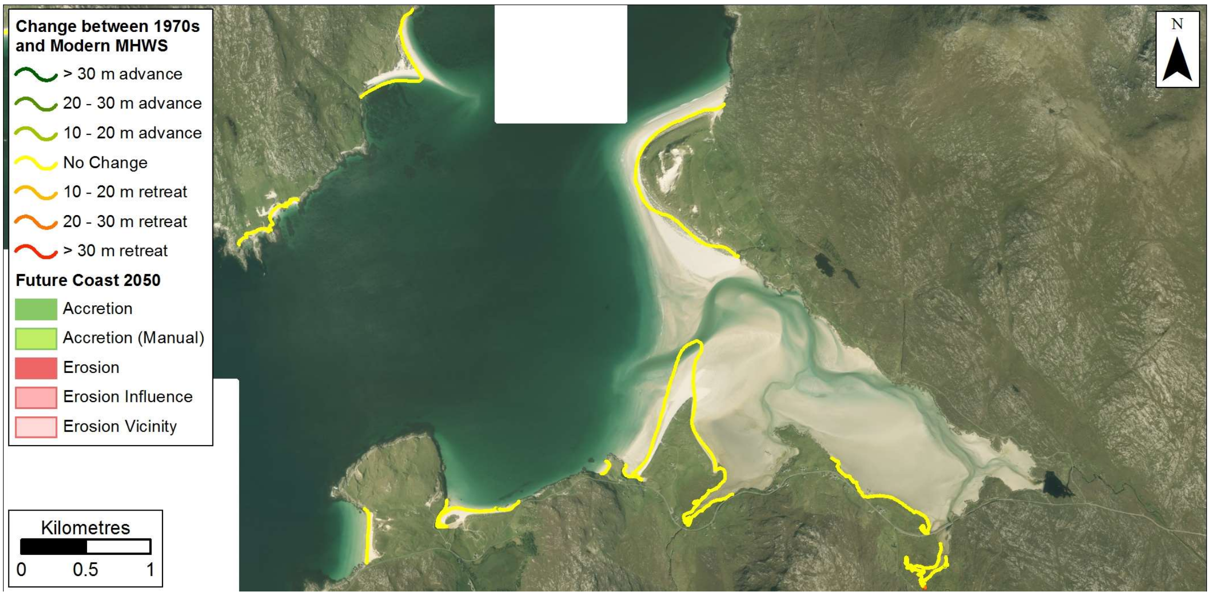

Figure 9.4: Change between the 1970 and Modern MHWS data at Luskentyre and Taransay. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

9c.2 Seilebost (Site 106)

Historic Change: At the spit of Seilebost there has been a substantial reduction in the spit area and backing machair with 130 m loss (2 m/yr) between 1901 and 1971 at the tip and a narrowing of 55 m loss from the southern end of the western side (Figure 9.5). Recent change shows nothing significant, but this is based on the OS mapping which is out of date and unreliable. The aerial imagery suggests that the real position of the modern MHWS has moved 20-30 m landward at the south end and up to 100 m landward at the tip and so the spit continues to shorten. The foreshore and links form part of the Luskentyre Banks and Saltings Site of Special Scientific Interest.

Figure 9.5: MHWS position in 1890, 1970s, and Modern datasets at Seilebost. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: As the the latest MHWS line is the same as the 1974 MHWS position, 'no change' is seen to have occurred at this location (Figure 9.6). Possible future change is therefore not estimated here. Based on the aerial photography alone, if the recent erosion were to continue then the tip of the penunsula may continue to shorten (releasing sediments into the intertidal area) and the western flank of the dunes may continue to retreat towards the east. The land to the rear is in agricultural use and, although there is a farm located in mid-spit, vulnerability is anticpiated to be low.

Figure 9.6: Change between the 1970 and Modern MHWS data at Seilebost. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

9c.3 Northton Bay SSSI (Traigh Scarista) (Site 107)

Historic Change: At Northton Bay and Traigh Scarista there have been large changes in the configuration of the MHWS with substantial amounts of accretion within the sheltered bay. Along the north part of Scarista where the 1901 line lies close to the 1971 line, there have been minor changes and although the 2014 OS line is known to be inaccurate, aerial photography confirms limited change in the modern period. At the west side of the beach and into Northton Bay, between 1901 and 1973, some 430 m of accretion has occurred at 6 m/yr, with the MHWS line migrating well to the west (Figure 9.7). Given the partially and unvegetated nature of these dunes comparisons with aerial photography for the location of the modern MHWS remains problematic, although the bay is likley to continue to act as a sediment trap having undergone accretion and no erosion. Northton Bay is a Site of Special Scientific Interest.

Figure 9.7: MHWS position in 1890, 1970s, and Modern datasets at Northton Bay. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Figure 9.8: Change between the 1970 and Modern MHWS data at Northton Bay. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: As the the latest MHWS line is the same as the 1974 MHWS position, 'no change' is seen to have occurred at this location (Figure 9.8). Possible future change is therefore not estimated here. Given the partially and unvegetated nature of these dunes, comparisons with aerial photography for the location of the modern MHWS remains problematic. Other than several crofts behind Scarista beach (which is stable), there are no other built assets at Northton and so the anticipated level of vulnerability remains low.

Sub-cell 9d - Sound of Harris to Griminish Point

9d.1 Berneray (Site 108)

Historic Change: Almost all the 5.5 km west face of Berneray has undergone erosion between 1901 and 1967 with up to 50 m being lost and a further 50 m (Figure 9.9) to date up to the vegetation line, as shown on aerial photography (the 2014 OS line is unreliable). The eastern half of Berneray is Special Protection Area and a Site of Special Scientific Interest.

Figure 9.9: MHWS position in 1890, 1970s, and Modern datasets at Berneray. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Figure 9.10: Change between the 1970 and Modern MHWS data at Berneray. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: As the the latest MHWS line is the same as the 1974 MHWS position, 'no change' is seen to have occurred at this location (Figure 9.10). Nevertheless, the aerial photography shows that, despite ongoing erosion, the level of vulnerability is low given the lack of built assets along this shore.

9d.2 Udal and Solas Peninsula (Site 109)

Historic Change: There have substantial changes on both sides of the Udal peninsula as well as along the beach to the south at Solas. On the east side of Udal some 310 m (4.5 m/yr) has been lost between 1907 and 1970 (Figure 9.11), with a further 670 m lost to 2014 (OS line is unreliable). More recent surveys indicate the losses are continuing and encroaching into the flat machair behind the fronting dune cordon, which has been lost in places. This has also resulted in the southward trending spit at Udal progressively moving westward at a rate of about 2.5 m/yr. On the southern part of the Udal peninsula some 80m has been lost along the machair frontage and this is continuing at present. One additional aspect of the erosion at Udal relates to the twin rocky headlands on the north coast on the opposite side of the east-facing eroding beach. At both headlands, the 1907 MHWS lies seawards and connected them as vegetated tombolos. By 1970 the northern one had narrowed to an overwashed beach ridge and by 2015 MHWS had moved so that the north headland is now an islet and the south headland has narrowed to a few metres of dune. It will be breached in the future. Recession of the MHWS on the connecting beaches has accompanied this breakup and the true 2016 position of MHWs on the northern beach is some 30-40m landward of that depicted by the OS 2014 line.

Along the beach at Solas, some 90 m has been lost between 1907 and 1970 and although the OS 2014 line is unreliable, aerial photography and recent ground survey confirms that this shore continues to recede to the landward and south.

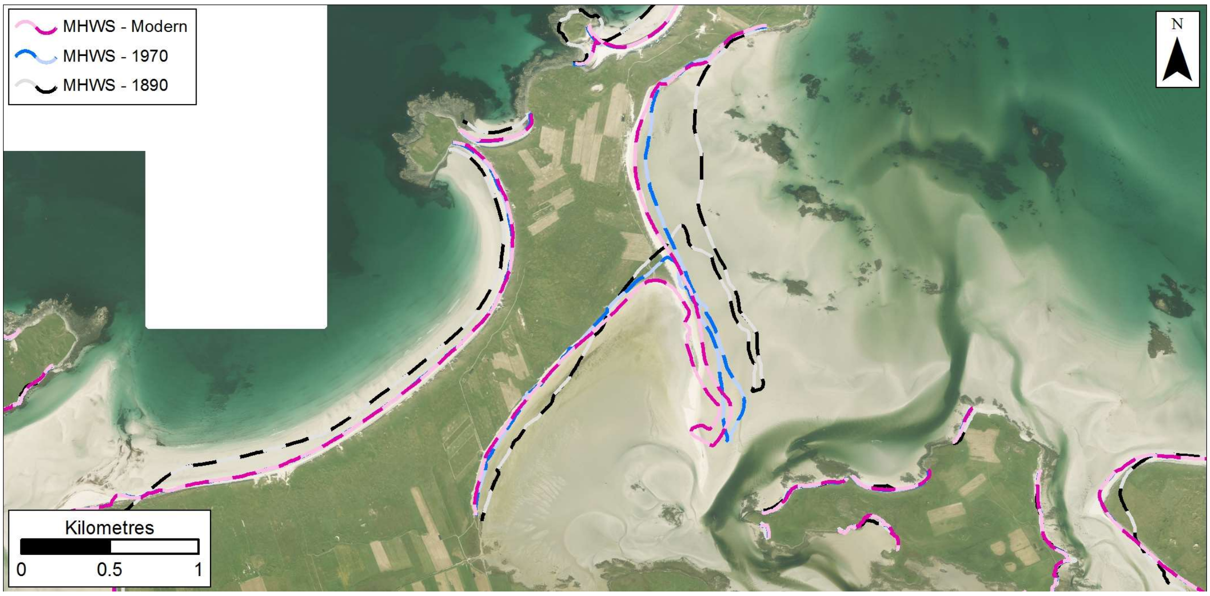

Figure 9.11: MHWS position in 1890, 1970s, and Modern datasets at Udal and Solas Peninsula. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future vulnerability: Over a distance of 2 km, the valuable agricultural machair land on the east side of Udal is vulnerable to future erosion that may extend inland by 50 m by 2050 (Figure 9.12). Loss of productive machair land continues and in places the protective low dune cordon has been eroded and overwash has occurred. Sand infilling of the eroded gap and dune repairs occurred in 2014 along with realignment of the coastal access track. . In the north, at the two headlands, there exists considerable archaeological interest that is vulnerable to further landward erosion of the dune line south of the recently breached tombolo at the north headland. Vulnerability is gauged to be low at Udal and Solas given the lack of built assets, although losses of machair land that is locally valuable for agriculture and has a high conservation status is of concern.

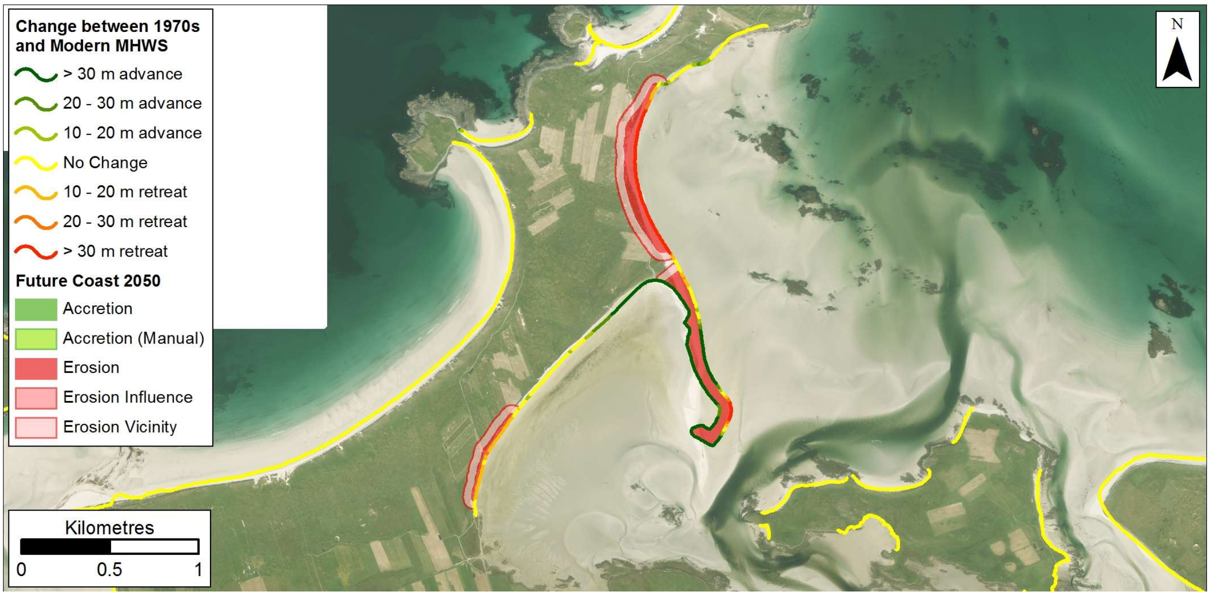

Figure 9.12: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Udal and Solas Peninsula. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Sub-cell 9e - Griminish Point to Sound of Barra

9e.1 Paible (Site 110)

Historic Change: Changes at the entrance to Loch Paible between 1901 and 1967 and then from 1967 to 2014 have resulted in the entrance being widened by recession of the northern shore by 80 m, most likely due to a shift in the main channel that has also produced accretion on the south shore (Figure 9.13). Erosion of the inner saltmarsh edge and at the entrance has recently exposed important archaeological finds but no fixed assets are nearby and vulnerable. The dunes to the north of Paibeil are part of the North Uist Machair Special Area of Conservation and the Balranald Bog and Loch nam Feithean Site of Special Scientific Interest.

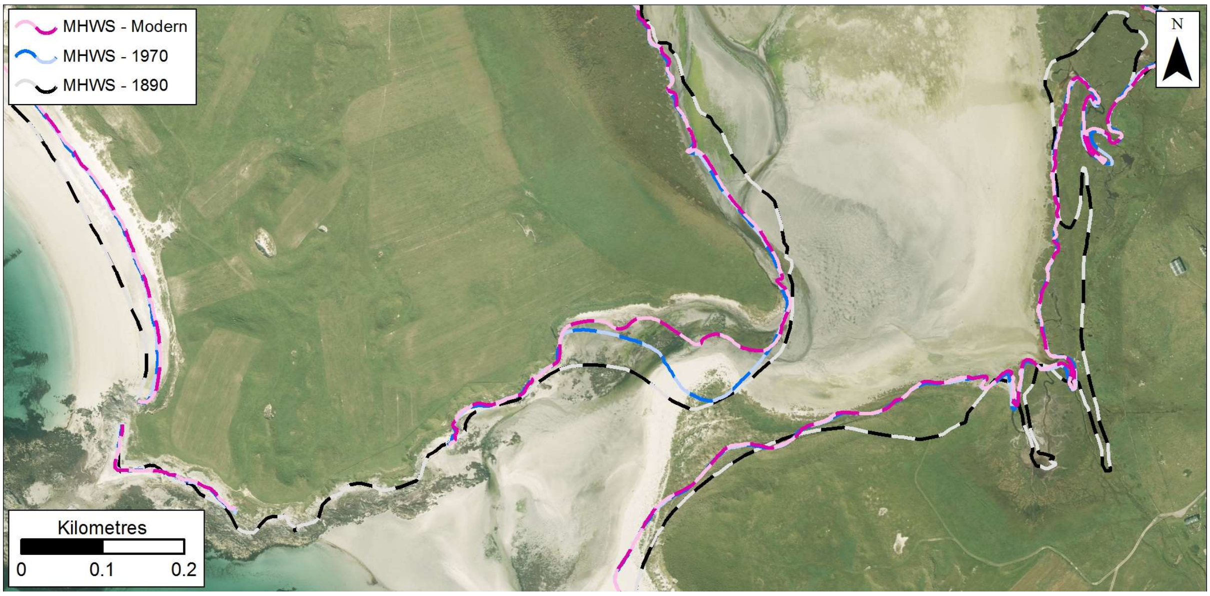

Figure 9.13: MHWS position in 1890, 1970s, and Modern datasets at Paible. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: Should the changes associated with the northern movement of the tidal channel continue then up to 35 m of the machair may be lost, resulting in the release of sediment into Loch Paible. There are no built assets within this area and so vulnerability is judged to be low.

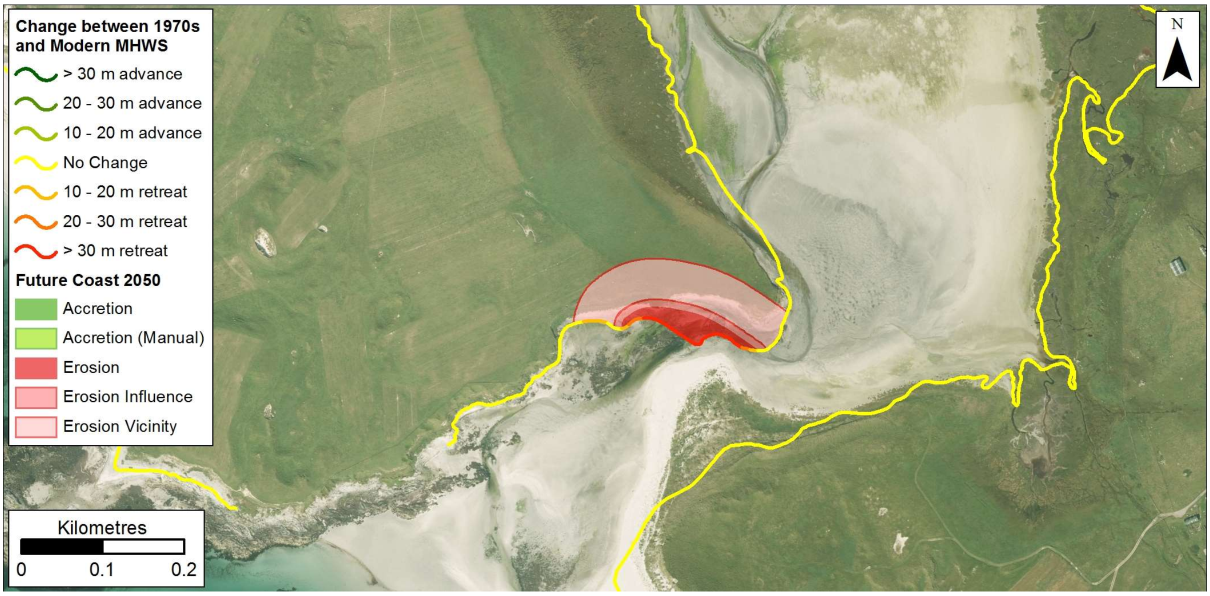

Figure 9.14: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Paible. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

9e.2 Kirkibost (Site 111)

Historic Change: At Kirkibost Island there have been losses around most of the island between 1901 and 1967 of up to 70 m on both the exposed west coast and the sheltered east. Between 1967 and 2006 (LiDAR) the west coast appears to have moved seaward by up to 20 m. The east coast however, has continued to recede by up to 50 in places with the northern tip receding by this amount to reoccupy its 1901 position (Figure 9.15). Kirkibost is part of the North Uist Machair Special Area of Conservation and the Baleshare and Kirkibost Site of Special Scientific Interest.

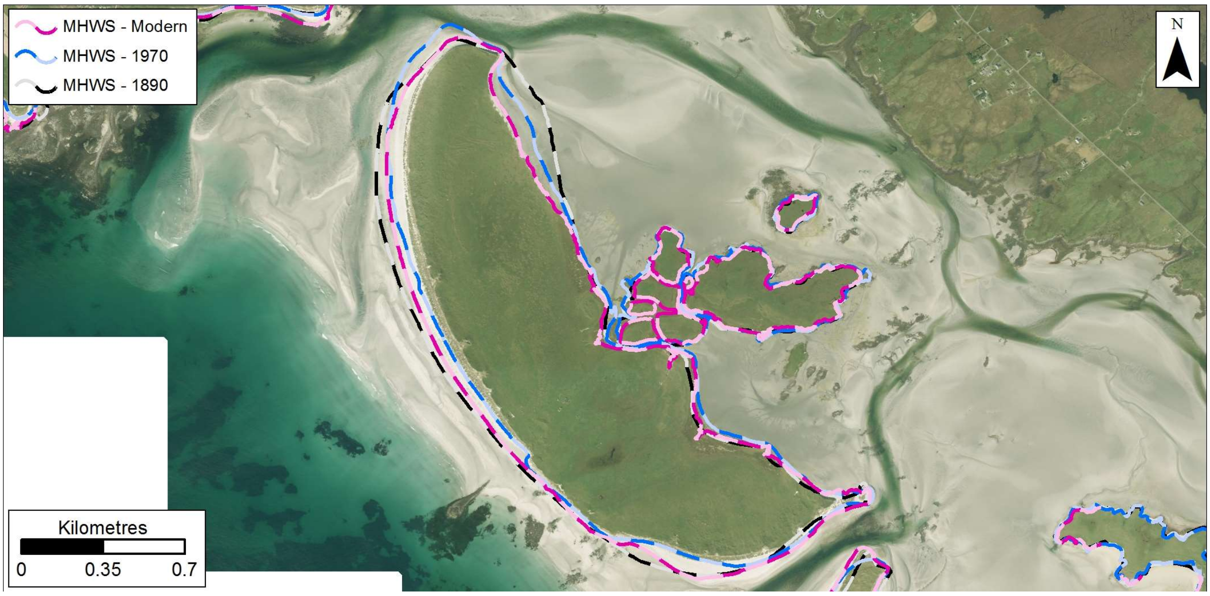

Figure 9.15: MHWS position in 1890, 1970s, and Modern datasets at Kirkibost. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: A continuation of losses in the east at the current rate will result in reduced areas of saltmarsh and sand dune. Similarly, losses on the west coast have resumed judging from the position of the vegetation line on the recent photography (Figure 9.16). No fixed assets exist on the island but it remains an important, but shrinking, SSSI for birds and machair habitat. Kirkibost, along with Baleshare to the south, together provide an important sheltering function for the croft land and communities that lie on the main island to the east.

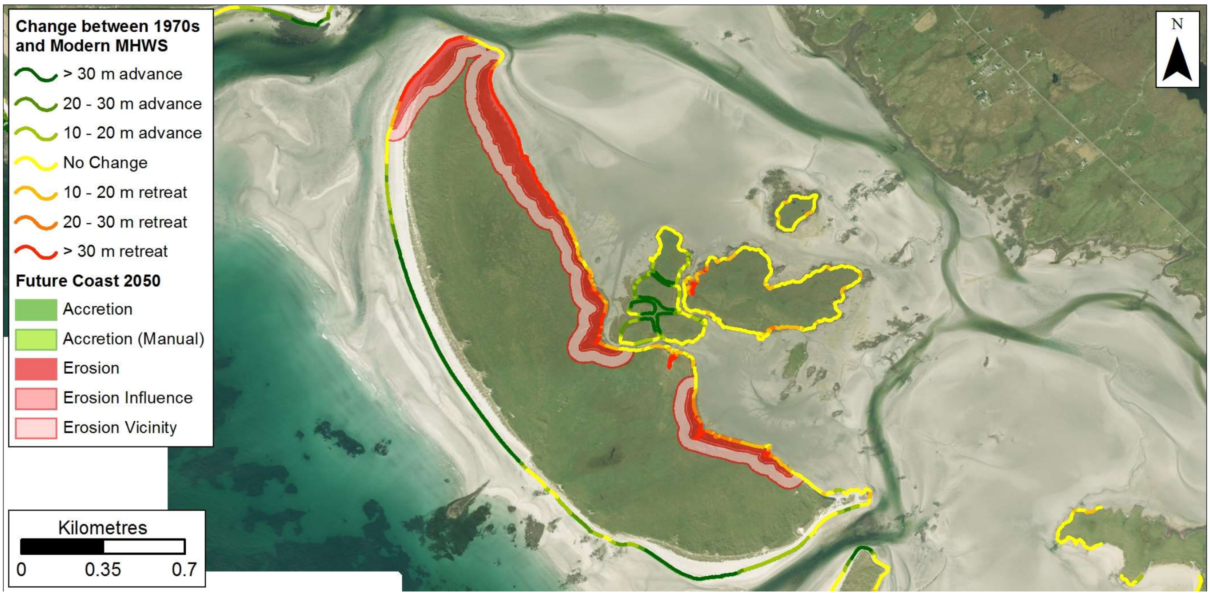

Figure 9.16: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Kirkibost. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

9e.3 Baleshare (Site 112)

Historic Change: The position of the 1901 MHWS and the 1967 and 2006 lines all show remarkable coincidence along both the northern and southern parts of Baleshare. This is apart from the northern and southern tips which both show various gains and losses as the access channels to the tidal lagoon to the east have shifted (Figure 9.17). On the other hand, some 1.8 km of the central section backed by agricultural machair land is shown to be erosional with up to 35m being lost between 1967 and 2006. Larger losses have occurred on the inner east coast where 200m up to 1967, then 50 m up to 2006 has been lost over a 1.5 km length of coast. Baleshare is part of the North Uist Machair Special Area of Conservation and the Baleshare and Kirkibost Site of Special Scientific Interest.

Figure 9.17: MHWS position in 1890, 1970s, and Modern datasets at Baleshare. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

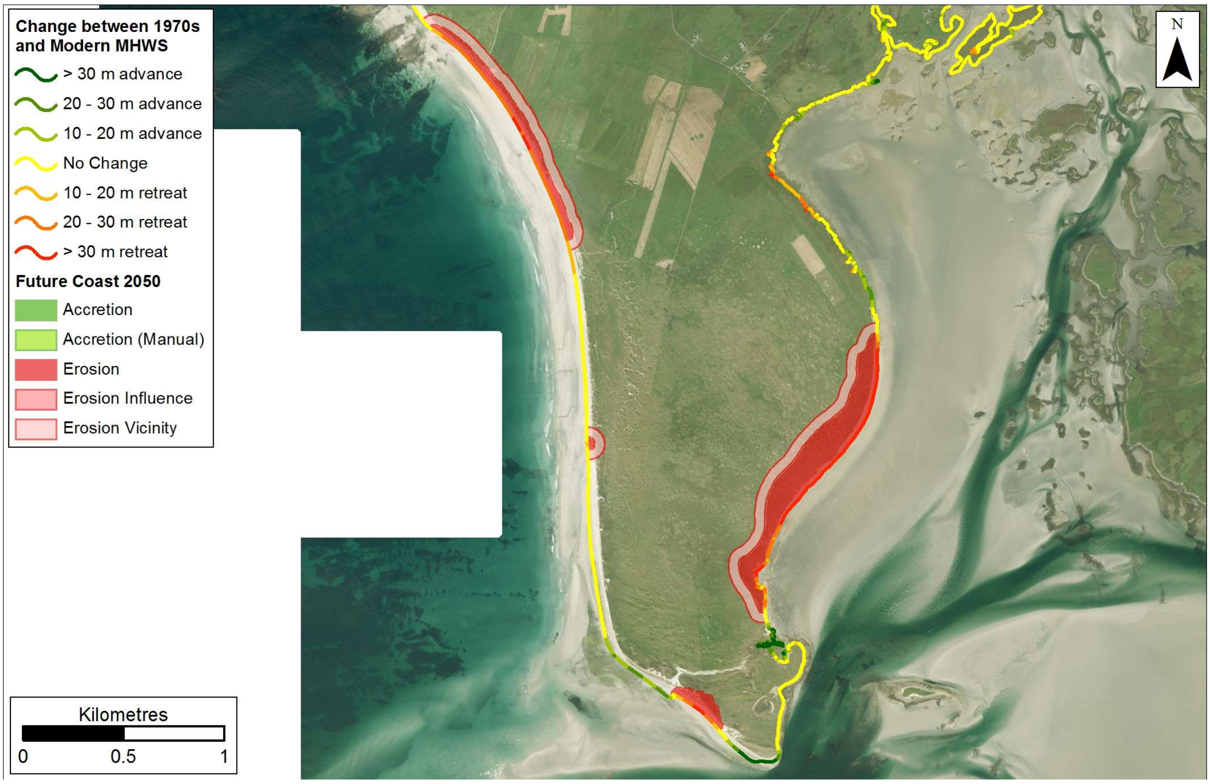

Figure 9.18: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Baleshare. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future vulnerability: Approximately 1.8 km of Baleshare may erode a further 40 m inland by 2050 with the likelihood that the length of coast affected will also increase (Figure 9.18). However, the land affected behind the beach is agricultural machair with no fixed assets other than an access road and car park for recreational access to the present coast. Much of the beach at this point is composed of medium gravels and it is possible that the rate of erosion will be slowed and ultimately self-healed by gravel accumulation over time. So, despite extensive areas of anticipated erosion by 2050, the level of vulnerability of assets is judged to be limited.

9e.4 Benbecula Airport and Balivanich (Site 113)

Historic Change: Substantial changes have taken place on the sandy peninsula that now houses Benbecula airport. The 1901 position of MHWS in the south at Balivanich eroded landward by 70 m up to 1967 whilst the northern part had apparently advanced seaward by 250 m over the same period (Figure 9.19). However, the construction of the RAF airfield early in WW2 on the site (Figure 9.20 and Figure 9.21) of an earlier grass airstrip led to levelling of the dunes and deposition of the sand spoil to seaward and so at least some, and possibly all, of the accretion noted before 1967 may be artificial. There exists anecdotal evidence that, within the last 150 years, machair extended to seaward of the islet of Sgeir a Cheothian now located 500 m offshore of Balivanich. This is consistent with ongoing long-term loss of land at Balivanich. Nevertheless, between 1967 and 2006 ongoing accretion seems to have occurred in the north and stability in the south, the latter as a function of coast defences to protect the south west corner of the runway. Since 2006, the air photography shows there has been erosion of up to 60m north of the end of the extended runway defences and up to 80m of erosion at the northern end of the north/south runway. The defences at Balivanich have been progressively extended in response to erosional bights that have developed at the north end of the defences. This is a common failing where defences end and the erosion continues. There is now a developing bight at the end of the 1.1km of defences that protect the western taxiway where it runs near the coastal edge

Figure 9.19: MHWS position in 1890, 1970s, and Modern datasets at Benbecula Airport and Balivanich. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Figure 9.20: Oblique aerial view of RAF Benbecula, from west-south-west, while the runways were under construction in 1941-1942. The method used was known as 'sand carpet', which consisted of bitumen laid directly over compacted sand, resulting in a flexible surface. (© IWM (HU 92989))

Figure 9.21: Undated, but believed to be 1940s photo of RAF Benbecula from the north (coastalcommand206.com).

Future Vulnerability: Defences have been extended progressively north for 1.1km from the town of Balivanich in response to frontal erosion and the end-of-defence erosional bights that have affected the western end of the east/west runway (Figure 9.22). It is also clear from the position of the vegetation and coastal edge (from photography) that in spite of a coincidence of the positions of MHWS in 1967 and 2006 (LiDAR), that erosion is ongoing and that the entire western face of the airport may be vulnerable by 2050. Such erosion is already evident and will continue, particularly at the end of any defences that might be emplaced or extended. Vulnerability here is high.

Figure 9.22: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Benbecula Airport and Balivanich. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

9e.1 Balivanich Primary school and the B892 through Balivanich (Site 114)

Historic Change: The 1901 position of MHWS is depicted as 26 m landward of its position in 2006 and landward of the line of the B892 at Balivanich. Similarly, Balivanich Primary School (abandoned in 2005) lies within 2 m of the 1901 position. In spite of minor seaward movement of the MHWS line by 1967 and 2006, the actual coastal edge lies to the landward. Both the road and school however, have been subject to overwash of beach gravels during storms, the most recent of which led to the abandonment of the school in the aftermath of the 2005 storm event.

Figure 9.23: MHWS position in 1890, 1970s, and Modern datasets at Balivanich Primary School. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: Although the change is not deemed significant (greater than ±10 m of change), this section of Balivanich and the B892 remains of concern for the future and will soon require robust management decisions. Whilst the former school building is currently for sale (September 2016) the viability of this building (and parts of the site) is uncertain.

9e.2 Borve to Liniclate (Site 115)

Historic Change: The 1901 position of MHWS along the shore at Borve is depicted as lying landward of the 1967 line and now coincides with the 2006 line (Figure 9.24). The coast has been protected by boulders because of the 20 m of erosion since 1967. The area of recent erosion extends south beyond the defences and so there is an area of concern that extends to beyond the farm buildings at Borve. Of more concern is the continuation of erosion to the north of Borve Point and into the bay of Lub Bhan. Here recession of 90 m occurred 1901-1967 and 90 m 1967-2006, with a further 20-30 m since then south of the site of Liniclate School and the Dark Island Hotel. Some of this recession is associated with channel shifts into the South Ford but the low-lying nature of the hinterland gives cause for concern about future erosion rates.

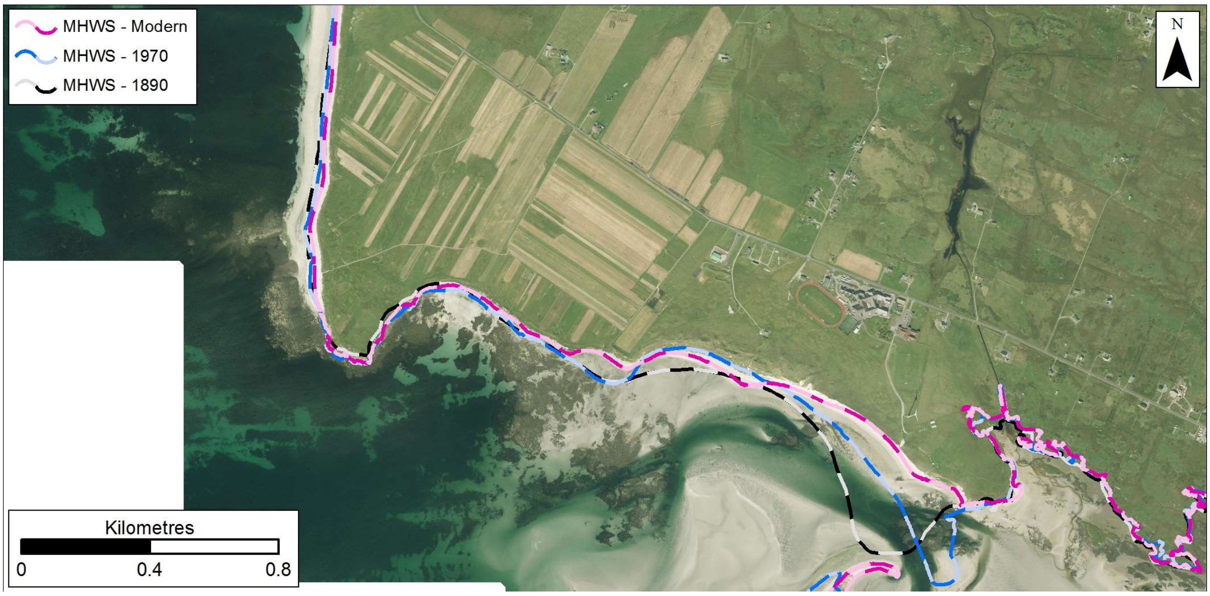

Figure 9.24: MHWS position in 1890, 1970s, and Modern datasets at Borve to Liniclate. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: By 2050 some 600 m of shore may erode up to 50 m inland at Liniclate if current rates persist (Figure 9.25), possibly exacerbated by enhanced flooding due to the proximity of a flood drain channel to the east of the eroding area. No built assets are directly vulnerable along this shore yet the position of the only secondary school in the Uists, sited on low-lying land behind an eroding shore, suggests that there may be cause for concern if erosion rates change in the future.

Figure 9.25: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Borve to Liniclate. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

9e.3 Gualan Island (Site 116)

Historic Change: Gualan Island lies at an important point in the entrance to the South Ford and has shown a significant amount of both movement and resilience over the years. The 1901 position shows it to lie up to 100 m west so that MHWS on both sides, west and east, lie seaward of their current position (Figure 9.26). Approximately, 70 m was lost between 1901 and 1967, then 30 m to 2016, with the central area being completely overwashed during several storm events since, and including, the 2005 storm.

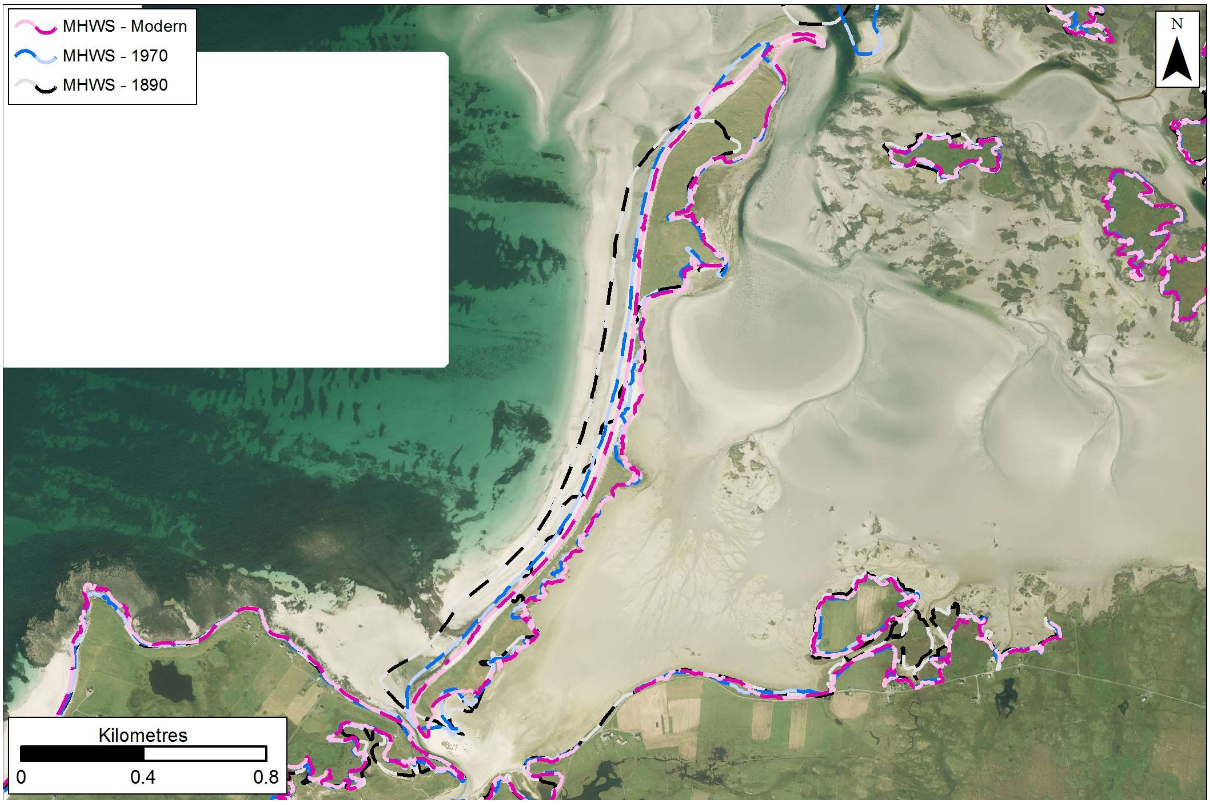

Figure 9.26: MHWS position in 1890, 1970s, and Modern datasets at Gualan Island. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: Gualan remains of concern since a continuation of the past erosion rates may result in a further 20-30 m being lost along the outer facing coast (Figure 9.27). However, despite this dynamism, there is clear evidence of the ability of Gualan to self-repair after storm events and there is no reason to suspect that this will change if the availability of repair sediment is not curtailed (e.g. perhaps by proliferation of coast defences elsewhere). There is evidence to suggest that the infilling of the western part of the south ford is due to the construction of the causeway from South Uist to Benbecula. If the causeway was to be re-engineered to allow more water and sediment to pass to the east (as is proposed) then sediment patterns would change that may affect (and accelerate) the eastward movement and adjustment of Gualan. One short to medium term option under consideration at present is to undertake a beach feeding programme to help stabilise Gualan, perhaps using the substantial amount of sediment accumulated at the inner and south end of the island at Eochar.

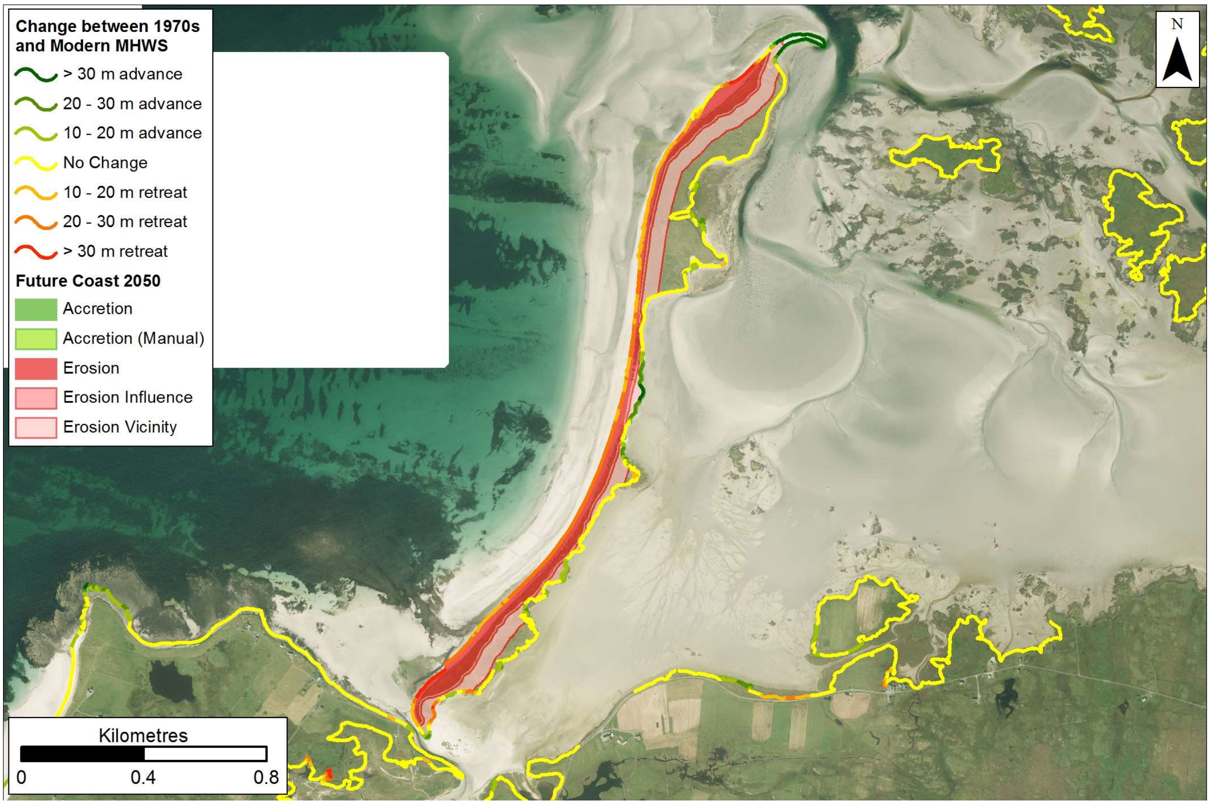

Figure 9.27: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Gualan Island. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

9e.4 Stoneybridge (Site 117)

Historic Change: At Stoneybridge, the 1901 MHWS line lies some 15 m west of the 1967 line and a further 10 m west of the 2005 line although this reduces to the south end where rock is encountered and the lines coalesce (Figure 9.28). In response to storm overwash of gravels at this point, a 330 m boulder revetment has been erected to protect the tarmac side road that runs between Stoneybridge and Peninarine.

Figure 9.28: MHWS position in 1890, 1970s, and Modern datasets at Stoneybridge. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: In spite of the 330 m long boulder revetment at Stoneybridge, some 450 m of shore is likely to be vulnerable by 2050 at either side of the revetment if erosion rates persist (Figure 9.29). As a result, the viability of the revetment itself will be in question as will the viability of the side road that it protects and rerouting of the carriageway may be needed. An allied issue is that the inland slope (a negative gradient) landward of the cordon of low dunes along this stretch of coast renders the hinterland vulnerable to erosion-related flooding and thus the integrity of the coastal fringe (whether natural or artificial) takes on a more strategic and greater significance. The vulnerability of the roadway at this point remains high.

Figure 9.29: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Stoneybridge. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

9e.5 Kilpheder (Site 118)

Historic Change: At Kilpheder, the 1901 MHWS line lies some 60 m seaward the 1967 line along the coast to the north and south. The 2005 LiDAR line lies on the 1967 position at the seaward-most point but lies seaward of it both to the north and south (Figure 9.30). At the point itself, recession and storm overwash was such that the Local Authority gave permission to insert a 300 m long gravel bund to protect the productive machair land that lies behind. The inland slope here (negative gradient) would mean that if the dune cordon or its replacement defence bund were to be eroded, then the inundation potential during storms would be enhanced. The bund has been progressively eroded and undermined by wave activity and erosional bights have developed at either extremity, but it has slowed erosion rates at the point itself and temporarily arrested any immediate threat of overwash and breaching.

Figure 9.30: MHWS position in 1890, 1970s, and Modern datasets at Kilpheder. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: In spite of the 300 m long boulder revetment at Kilpheder, flanking erosion of up to 20 m has occurred between 2005 and 2016 along the shores north and south of the point protection. This is not shown in the NCCA results as the data used here is from 2005 (Figure 9.31). Indeed, the gravel protection itself is undermined and the capping of dune sand and marram has long since been removed by storm activity and unrestricted grazing due to fence destruction during storms.

Figure 9.31: Change between the 1970 and Modern MHWS data at Kilpheder. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

If recent erosion rates persist, much of this shore is likely to be vulnerable by 2050 at either side of, and including, the revetment. As a result, the allied issue is that the negative landward gradient beyond the low dune cordon renders the hinterland vulnerable to erosion-related flooding. Thus, the integrity of the coastal fringe (whether natural or artificial) takes on a more strategic and greater significance. There are extensive low-lying areas within the interior of the South Uist which form a network of winter lochs, where the winter elevated water table causes freshwater flooding. Historical research identifies that these were once more extensive and used for inland navigation, prior to their draining in the nineteenth century (Angus, 2017). The negative gradient and absolute altitude in these areas raises significant questions about their inherent vulnerability given the past and anticipated relative sea level rise (Figure 9.32). The issue of 'negative gradients' are considered further in the recommendation section of the national overview.

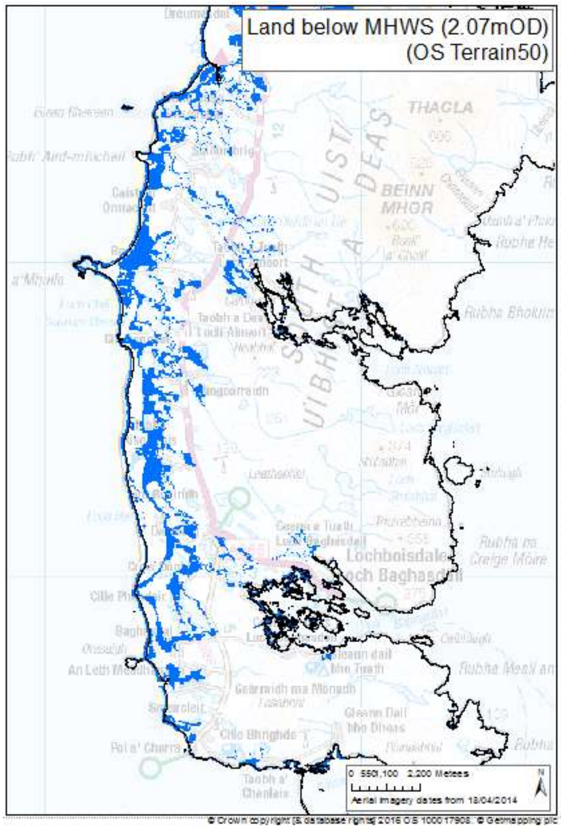

Figure 9.32: Blue areas represent land that has a lower elevation than the current MHWS elevation of 2.07 m OD, and is therefore at risk from flooding if coastal erosion removes natural defences.

9e.6 North Boisdale (Site 119)

Historic Change: Rapid erosion has occurred at Isle Orosay and at the exit of the stream to the south at Garrynamonie. Some 50 m was lost between 1895 and 1967 and a further 25 m to 2005 and the coast continues to recede here, in spite of old fishing nets being laid to slow the rate. At the stream exit to the south, some 35 m was lost between 1975 and 2006 with a further 20 m to 2016 (Figure 9.33). The losses here are likely due to the southward deflection of the stream channel over time, but since the dune ridge is high at this point and the eroded land is valuable machair, there remain local concerns about the progress of the erosion.

Figure 9.33: MHWS position in 1890, 1970s, and Modern datasets at North Boisdale. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: The projected rates of erosion to 2050 at North Boisdale amount to 20 m recession over approximately 60 m of coast north and south of the point (Figure 9.34). The erosion area impinges on access tracks and the erosion vicinity may affect the factory site to the rear. Vulnerability is gauged at high.

Figure 9.34: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at North Boisdale. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

9e.7 Eriskay (Site 120)

Historic Change: At the landfall of the South Uist to Eriskay causeway the small beach to the west has shown some variability that may give cause for concern. Between 1967 and 2014 (OS Master Map) there has been up to 15 m of recession, with the roadway being a further 15 m to the east (Figure 9.35). It appears that the rocky outcrops to the north have been reinforced with boulders but the small beach has not. The foreshore (seawards) is part of the Sound of Barra Special Area of Conservation.

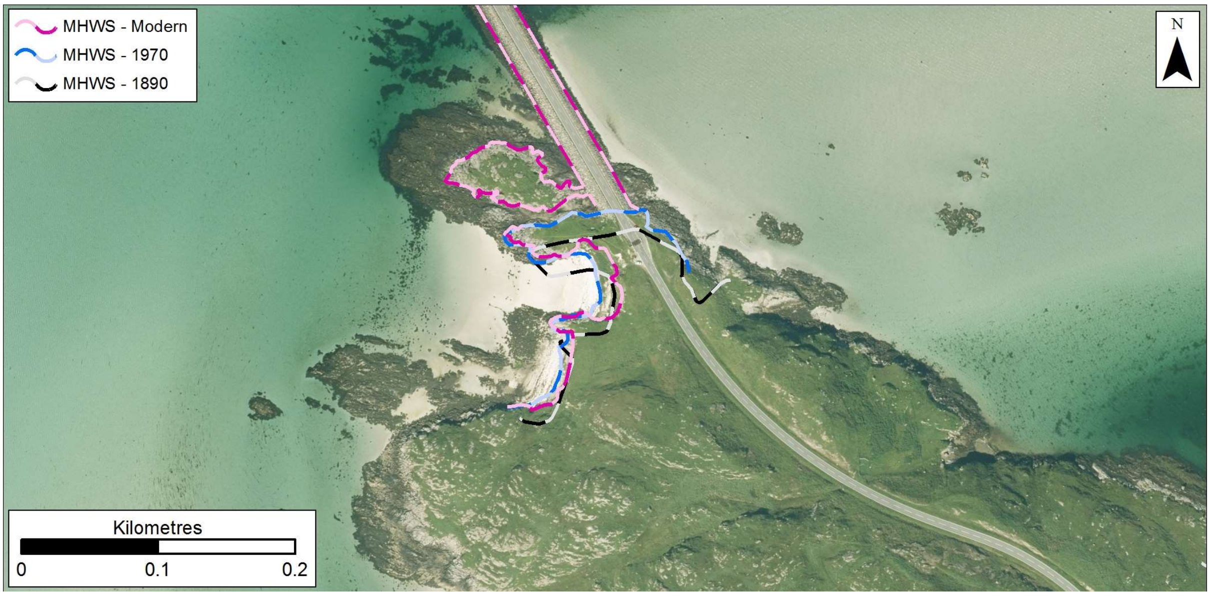

Figure 9.35: MHWS position in 1890, 1970s, and Modern datasets at Eriskay. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: Given the proximity of the lifeline roadway that links Eriskay to South Uist, the rate of erosion detected by the forward look is of concern. This is not only because of the roadway directly affected but also since the erosion affected and vicinity spans the entire peninsula that supports the access to the causeway (Figure 9.36). This is a recent issue that has developed since the causeway was emplaced in 2001. Before this the ferry service to Eriskay landed at a different and more sheltered spot.

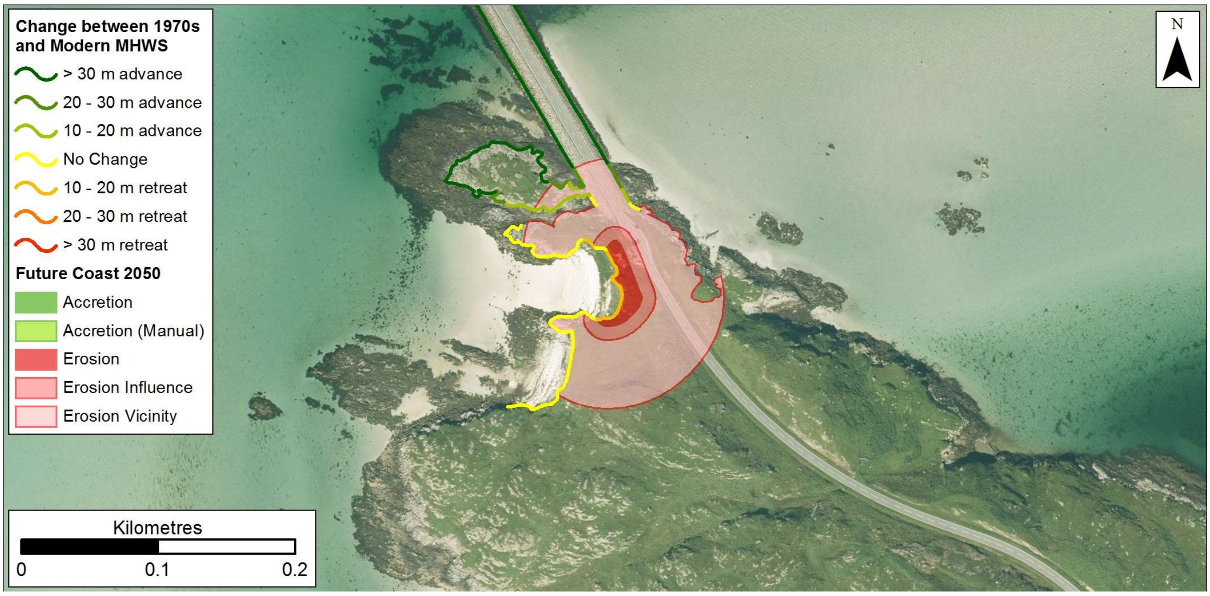

Figure 9.36: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Eriskay. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Sub-cell 9f - Sound of Barra to Barra Head

9f.1 Vatersay Tombolo (Site 121)

Historic Change: The 900 m long dune and machair tombolo connecting Barra and Vatersay is a long-lived and substantial feature that is 350 m wide at its narrowest. On the west, there is a good degree of stability suggested between 1901 and 1967, followed by approximately 18 m of erosion to 2016 (Figure 9.37). On the eastern side, the northern part shows 30 m of accretion between 1901 and 1967, where it remains stable to 2016. In the south, the lines are approximately coincident. The dune toe and vegetation edge lies up to 20 m landward of the OS line in the north and up to 10 m in the south. This is consistent with recent ground observations that show the dunes to be erosional along this east face and subject to substantial wind-driven blowout development. Blowout development has affected the higher dunes and dune toe on the west facing side but there has been successful dune rehabilitation works conducted here that have arrested further degradation.

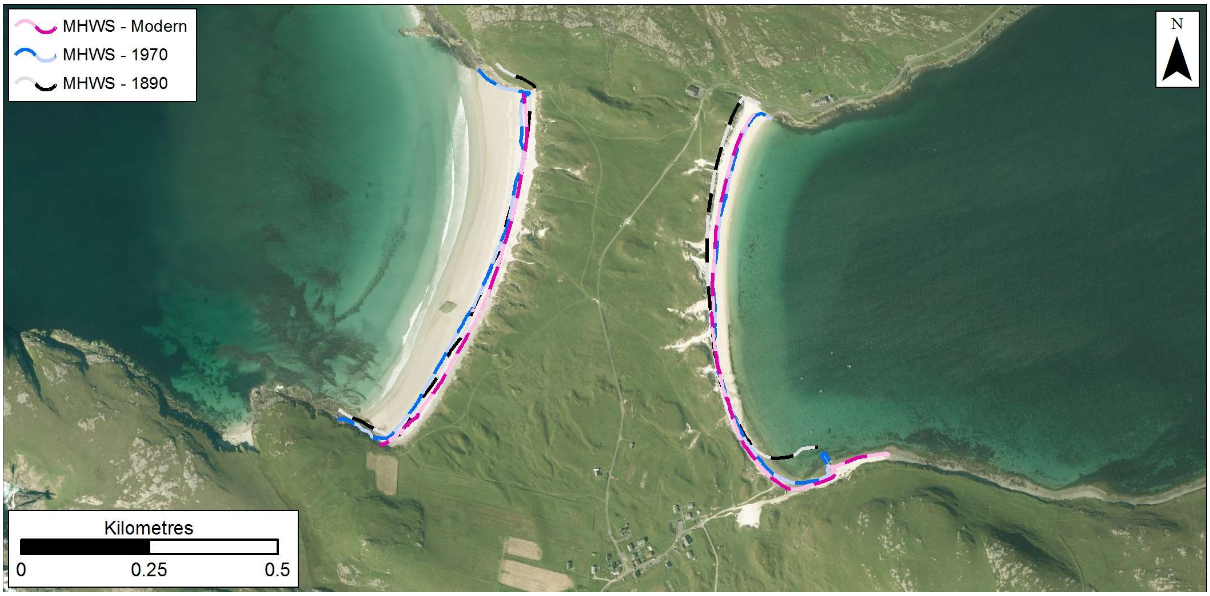

Figure 9.37: MHWS position in 1890, 1970s, and Modern datasets at Vatersay tombolo. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: No assets are close to the areas that might be affected by erosion in the future although wind-blown sand frequently veneers the roadway (Figure 9.38). It is also likely that any erosion of the east face can be addressed with soft coastal management techniques such as dune rehabilitation. Although, erosion is noted on the western bay, this is not expected to continue in the future due to the resilience of the hinterland as estimated by the Underlying Physical Susceptibility Model (Fitton et al., (2016)).

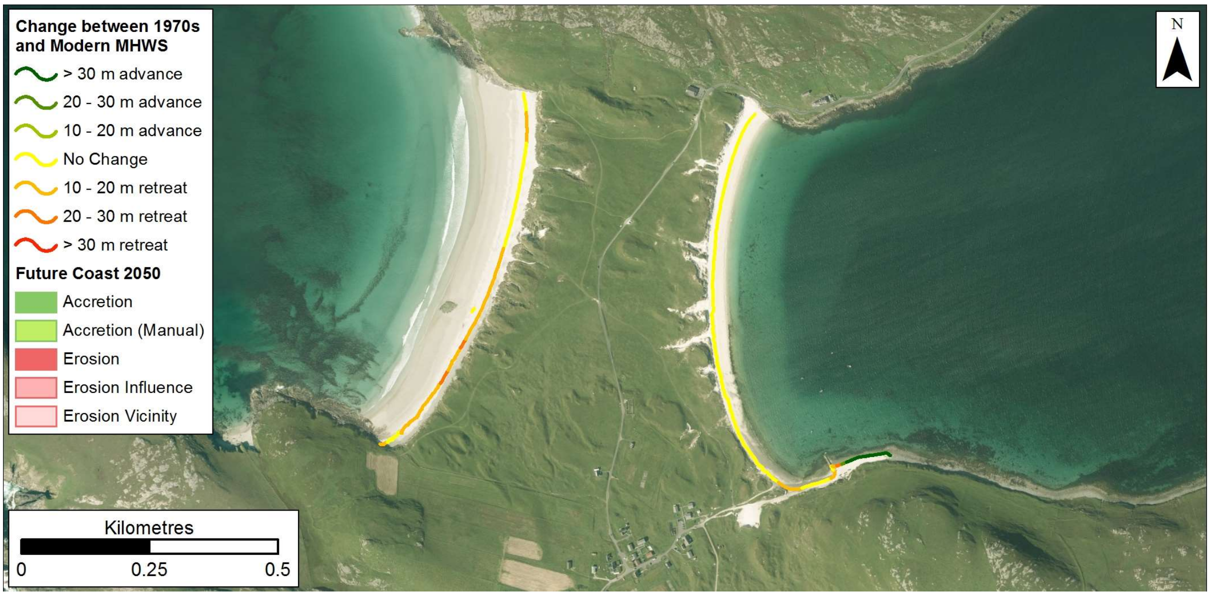

Figure 9.38: Change between the 1970 and Modern MHWS data at Vetersay tombolo. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Coastal Change Statistics for Cells 8 & 9

Within the soft sections of Cells 8 & 9, **23%** has been **advancing** between **1890 and 1970**; compared with **11%** between **1970 and modern data**.
Within the soft sections of Cells 8 & 9, **33%** has been **retreating** between **1890 and 1970**; compared with **13%** between **1970 and modern data**.
Within the soft sections of Cells 8 & 9, the **average rate of advance** is **0.9 m/yr** between **1890 and 1970**, and **0.8 m/yr** between **1970 and modern data**.
Within the soft sections of Cells 8 & 9, the **average rate of retreat** is **-0.6 m/yr** between **1890 and 1970**, and **-1.3 m/yr** between **1970 and modern data**.
Within the soft sections of Cells 8 & 9, **44%** has **not changed** significantly between **1890 and 1970**; compared with **76%** between **1970 and the modern data**.

Table 9.1: A summary of the average rates, average change distances, and lengths of advance, retreat, and no change within sub-cells of Cells 8 and 9.

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 8a	-2.5	-2.82	4.0	40.8	0.60	0.7	-24.0	-0.34	1.5	-2.4	-0.03	1.8
Sub-cell 8b	-3.8	-0.04	6.6	22.5	0.22	0.5	-20.3	-0.21	1.5	-1.0	-0.01	4.6
Sub-cell 8c	14.6	0.14	26.7	147.4	1.57	5.4	-54.5	-0.61	7.2	-0.8	-0.01	14.2
Sub-cell 8d	14.3	0.19	3.4	24.4	0.31	2.0	-16.4	-0.19	0.1	1.8	0.02	1.3
Sub-cell 9a	-21.5	-0.28	13.2	20.8	0.25	3.6	-111.6	-1.44	3.3	0.4	0.01	6.3
Sub-cell 9b	1.0	0.02	16.0	25.6	0.36	3.6	-22.1	-0.30	3.7	0.7	0.01	8.7
Sub-cell 9c	32.2	0.46	29.1	124.8	17.80	10.3	-38.4	-0.55	9.1	0.0	0.00	9.8
Sub-cell 9d	-3.7	-0.05	67.3	64.0	0.93	14.8	-50.4	-0.73	23.7	0.0	0.00	28.8
Sub-cell 9e	-3.6	-0.05	167.8	52.1	0.72	35.5	-39.1	-0.54	61.7	-0.5	-0.01	70.6
Sub-cell 9f	-8.2	-0.12	26.0	22.7	0.33	6.3	-43.7	-0.63	8.3	0.4	0.01	11.4
Cell 8 & 9	4.2	-0.39	360.0	63.7	0.86	82.6	-43.5	-0.60	120.0	-0.3	0.00	157.5
	-	-	-	-	-	22.9%	-	-	33.3%	-	-	43.7%

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 1970 to Modern Soft Coast Insignificant Change (m)	Average 1970 to Modern Retreat Rate on Soft Coast (m/year)	Length of Soft Insignificant Change (km)
Sub-cell 8a	1.8	0.04	14.5	21.8	0.50	1.18	-12.7	-0.29	0.21	0.2	0.00	13.1
Sub-cell 8b	-6.6	-0.28	4.9	17.4	0.68	0.13	-25.6	-1.17	1.09	-1.9	-0.07	3.7
Sub-cell 8c	-41.4	-1.09	29.2	29.1	1.20	1.67	-92.3	-2.47	13.46	-1.2	-0.04	14.1
Sub-cell 8d	-1.2	-0.08	3.9	14.5	0.37	0.79	-25.6	-0.89	0.7	0.8	0.01	2.4
Sub-cell 9a	0.4	0.00	13.5	23.3	0.76	0.57	-18.7	-0.76	0.86	0.7	0.02	12.0
Sub-cell 9b	1.3	0.03	16.4	12.8	0.30	0.01	-	-	-	1.3	0.03	16.4
Sub-cell 9c	-0.2	0.00	29.8	10.4	0.25	0.03	-19.2	-0.43	0.09	-0.1	0.00	29.7
Sub-cell 9d	2.1	0.05	69.2	55.2	1.20	4.37	-33.1	-0.75	2.34	-0.3	-0.01	62.4
Sub-cell 9e	-0.5	-0.02	175.2	26.3	0.77	28.9	-29.9	-0.89	26.8	-0.4	-0.01	119.5
Sub-cell 9f	4.2	0.09	19.3	28.8	0.64	5.1	-30.4	-0.70	2.4	0.5	0.01	11.8
Cell 8 & 9	-2.8	-0.08	375.8	29.3	0.80	42.7	-47.1	-1.32	48.0	-0.2	-0.01	285.0
	-	-	-	-	-	11.4%	-	-	12.8%	-	-	75.8%

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 9.2: 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 Cells 8 and 9.

1890-1970	Cell 8 & 9		Sub-cell 8a		Sub-cell 8b		Sub-cell 8c		Sub-cell 8d		Sub-cell 9a		Sub-cell 9b		Sub-cell 9c		Sub-cell 9d		Sub-cell 9e		Sub-cell 9f	
	Length (km)	Length (%)	(km)	(%)	(km)	(%)	(km)	(%)	(km)	(%)	(km)	(%)	(km)	(%)	(km)	(%)	(km)	(%)	(km)	(%)	(km)	(%)
>30 m Advance	32.2	9%	0.3	0%	0.1	0%	2.7	1%	0.4	0%	0.7	0%	0.9	0%	4.9	1%	7.5	2%	13.3	4%	1.4	0%
20-30 m Advance	16.8	5%	0.1	0%	0.0	0%	0.9	0%	1.0	0%	0.7	0%	0.6	0%	2.4	1%	2.6	1%	7.0	2%	1.6	0%
10-20 m Advance	33.6	9%	0.3	0%	0.4	0%	1.8	0%	0.6	0%	2.2	1%	2.1	1%	3.0	1%	4.6	1%	15.2	4%	3.4	1%
No Change	157.5	44%	1.8	1%	4.6	1%	14.2	4%	1.3	0%	6.3	2%	8.7	2%	9.8	3%	28.8	8%	70.6	20%	11.4	3%
10-20 m Retreat	42.3	12%	0.7	0%	0.7	0%	2.1	1%	0.1	0%	0.9	0%	2.0	1%	2.9	1%	6.4	2%	23.4	7%	2.9	1%
20-30 m Retreat	23.5	7%	0.3	0%	0.7	0%	1.2	0%	0.0	0%	0.3	0%	0.8	0%	1.5	0%	3.3	1%	13.9	4%	1.5	0%
>30 m Retreat	54.2	15%	0.5	0%	0.2	0%	3.8	1%	0.0	0%	2.0	1%	0.9	0%	4.7	1%	14.0	4%	24.4	7%	3.9	1%
Total length	**360.0**	**100%**	**4.0**	**1%**	**6.6**	**2%**	**26.7**	**7%**	**3.4**	**1%**	**13.2**	**4%**	**16.0**	**4%**	**29.1**	**8%**	**67.3**	**19%**	**167.8**	**47%**	**26.0**	**7%**

Max advance (m)	660	Northton	91	77	644	42	55	81	660	329	353	110
Average change (m)	4.2		-2.5	-3.8	14.6	14.3	-21.5	1.0	32.2	-3.7	-3.6	-8.2
Max retreat (m)	-334	Loch Ordais	-55	-33	-240	-28	-334	-57	-146	-314	-292	294

1970-Modern	Cell 8 & 9		Sub-cell 8a		Sub-cell 8b		Sub-cell 8c		Sub-cell 8d		Sub-cell 9a		Sub-cell 9b		Sub-cell 9c		Sub-cell 9d		Sub-cell 9e		Sub-cell 9f	
	Length (km)	Length (%)	(km)	(%)	(km)	(%)	(km)	(%)	(km)	(%)	(km)	(%)	(km)	(%)	(km)	(%)	(km)	(%)	(km)	(%)	(km)	(%)
>30 m Advance	13.6	4%	0.1	0%	0.0	0%	0.5	0%	0.0	0%	0.1	0%	0.0	0%	0.0	0%	3.0	1%	8.4	2%	1.5	0%
20-30 m Advance	10.9	3%	0.4	0%	0.0	0%	0.3	0%	0.0	0%	0.2	0%	0.0	0%	0.0	0%	0.6	0%	7.4	2%	2.0	1%
10-20 m Advance	18.2	5%	0.7	0%	0.1	0%	0.9	0%	0.8	0%	0.3	0%	0.0	0%	0.0	0%	0.8	0%	13.0	3%	1.6	0%
<10m Advance but >= 0.5 myr^{-1}	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.1	0%	0.0	0%
No Change	285.0	76%	13.1	3%	3.7	1%	14.1	4%	2.4	1%	12.0	3%	16.4	4%	29.7	8%	62.4	17%	119.5	32%	11.8	3%
<10m Retreat but <= -0.5 myr^{-1}	0.0	0%	-0.4	0%	0.4	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.1	0%	0.0	0%
10-20 m Retreat	18.4	5%	0.2	0%	0.4	0%	3.2	1%	0.3	0%	0.6	0%	0.0	0%	0.0	1%	1.1	0%	11.5	3%	1.0	0%
20-30 m Retreat	8.6	2%	0.0	0%	0.2	0%	1.4	0%	0.2	0%	0.2	0%	0.0	0%	0.0	0%	0.2	0%	5.9	2%	0.4	0%
>30 m Retreat	20.9	6%	0.4	0%	0.0	0%	8.9	2%	0.2	0%	0.1	0%	0.0	0%	0.0	0%	1.0	0%	9.3	2%	1.0	0%
Total length	**375.7**	**100%**	**14.5**	**4%**	**4.9**	**1%**	**29.2**	**8%**	**3.9**	**1%**	**13.5**	**4%**	**16.4**	**4%**	**29.8**	**8%**	**69.1**	**18%**	**175.2**	**47%**	**19.3**	**5%**

Max advance (m)	189	Sanday	119	38	110	22	69	13	11	189	129	86
Average change (m)	-2.8		1.8	-6.6	-41.4	-1.2	0.4	1.3	-0.2	2.1	-0.5	4.2
Max retreat (m)	-293	Stornoway	-47	-23	-293	-68	-42	-19	-32	-70	-152	-90

Asset Vulnerability Statistics for Cells 8 and 9

Table 9.3: 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 Cells 8 and 9.

Cell 8 & 9	Units	Modern to 2050				2050+			
		Erosion	Erosion Influence	Erosion Vicinity	Total	Erosion	Erosion Influence	Erosion Vicinity	Total
Community Services	Number	-	-	1	1	-	-	1	1
Non Residential Property		-	-	3	3	1	-	5	6
Residential Property		-	-	2	2	4	1	6	11
Septic Water Tanks		-	-	2	2	-	1	1	2
Utilities		-	-	1	1	-	-	1	1
Rail	Length (km)	-	-	-	-	-	-	-	-
Roads (SEPA)		0.0	0.0	1.1	1.2	0.6	0.2	1.1	1.9
Roads (OS)		-	-	0.0	0.0	-	-	0.0	0.0
Clean Water Network		0.0	0.1	0.7	0.8	0.8	0.1	0.8	1.8
Total Anticipated Erosion	Area (hectares)	89.9	24.6	129.2	243.7	136.8	25.5	142.5	304.8
Runways		0.0	0.1	0.7	0.8	1.0	0.3	1.2	2.4
Cultural Heritage		-	-	-	-	-	-	-	-
Environment		45.1	13.1	65.0	123.2	86.5	12.9	73.7	173.0
Flooding (200 year envelope)		50.6	8.4	40.0	99.0	69.9	7.8	38.9	116.6
Flooding (1000 year envelope)		52.5	8.8	42.8	104.1	74.5	8.3	41.6	124.4
Erosion within PVAs		26.3	9.6	47.7	83.6	55.1	9.3	55.7	120.1
Erosion outwith of PVAs		63.6	15.0	81.5	160.1	81.7	16.2	86.8	184.7
Battlefields		-	-	-	-	-	-	-	-
Gardens and Designed Landscapes		-	-	-	-	-	-	-	-
Properties in Care		-	-	-	-	-	-	-	-
Scheduled Monuments		-	-	-	-	-	-	-	-
Nature Conservation Marine Protected Areas		-	-	-	-	-	-	-	-
National Nature Reserves (NNR)		5.5	3.3	21.2	30.0	11.0	3.5	21.1	35.5
Special Areas of Conservation (SAC)		27.9	11.7	56.3	95.8	59.2	11.5	65.3	136.0
Special Protection Areas (SPAs)		28.7	12.5	62.3	103.5	61.4	12.5	72.6	146.6
Sites of Special Scientific Interest (SSSI)		36.9	11.8	57.5	106.3	68.5	11.7	66.5	146.7

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CREW is a Scottish Government funded partnership between the James Hutton Institute and Scottish Universities.