REPORT

Hoylake Beach Geomorphology and Ecology Study

Client: Wirral Borough Council

Reference: PC2553-ZZ-XX-RP-Z-0001

Status: Final/01

Date: 18 February 2022

HASKONINGDHV UK LTD.

Honeycomb
Edmund Street
Liverpool
L3 9NG
United Kingdom
Industry & Buildings
VAT registration number: 792428892

+44 151 2362944 **T**
+44 151 2272561 **F**
info.liv@gb.rhdhv.com **E**
royalhaskoningdhv.com **W**

Document title:	Hoylake Beach Geomorphology and Ecology Study
Document short title:	
Reference:	PC2553-ZZ-XX-RP-Z-0001
Status:	01/Final
Date:	18 February 2022
Project name:	Hoylake Beach Geomorphology and Ecology Study
Project number:	PC2553
Author(s):	David Brew, Alexandra Scullion, Stuart Morris, Jamie Gardiner and Oliver Bull
Drafted by:	David Brew, Alexandra Scullion, Stuart Morris, Jamie Gardiner and Oliver Bull
Checked by:	David Brew and Jamie Gardiner
Date:	18/02/2022
Approved by:	Jamie Gardiner
Date:	18/02/2022

Classification
Project related

Table of Contents

Table of Tables

Table of Figures

Appendices

Acronyms

AEP	Annual Exceedance Probability
AStGWF	Areas Susceptible to Ground Water Flooding
BMP	Beach Management Plan
CFDB	Coastal Flood Boundary Dataset
DAS	Discretionary Advice Service
EA	Environment Agency
FZ3	Flood Zone 3
HAT	Highest Astronomical Tide
HRA	Habitats Regulations Assessment
HTL	Hold The Line
MHW	Mean High Water
MHWN	Mean High Water Neap
MHWS	Mean High Water Spring
MLWN	Mean Low Water Neap
MLWS	Mean Low Water Spring
NE	Natural England
NVC	National Vegetation Classification
OD	Ordnance Datum
pSPA	proposed Special Protection Area
SAC	Special Area of Conservation
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
SWL	Sill Water Level

1 Introduction

1.1 Background to the study

In 1999, Wirral Metropolitan Borough Council (Wirral Council)), commissioned a study to examine the issue of rising beach levels at West Kirby and Hoylake at the northwest corner of the Wirral Peninsula. The objectives were to provide advice on long-term coastal change, identify management options and preferred management policies, as a basis for public consultation (Jemmett and Smith, 2000). Wirral Council invited comment on the suggested options and 20 actions were identified for ongoing management of the beaches at West Kirby and Hoylake. None of the actions identified were formally adopted by Wirral Council.

In 2010, Wirral Council applied for and received assent from Natural England to undertake beach management at Hoylake Beach for a period of five years. The management comprised:

- spraying both *Spartina anglica* and *Puccinellia maritima* using approved glyphosate herbicide Roundup Bio-active Gold;
- spraying isolated clumps of *S. anglica* using approved glysophate herbicide Roundup Bio-active Gold using a hand-held lance spray;
- mechanically raking the amenity beach using either a comb rake or a Barber Surf rake;
- removal of accumulated wind-blown sand, to be recycled within local protected sites including the;
    - Dee Estuary Site of Special Scientific Interest (SSSI), Special Area of Conservation (SAC), Special Protection Area (SPA) and Ramsar site;
    - North Wirral Foreshore SSSI; and
    - Mersey Narrows and North Wirral Foreshore proposed SPA (pSPA) and pRamsar site[1].

In 2016, Wirral Council applied for consent to continue these activities at Hoylake as part of a wider beach management proposal that also included the management of beaches at West Kirby, Wallasey and New Brighton. They commissioned a Habitats Regulations Assessment (HRA) to support the application (AECOM, 2016).

In March 2016, Natural England granted assent for a period of five years, beginning 1st April 2016, for the specific beach management actions shown in **Table 1.1**. The beach at Hoylake was selectively sprayed with glysophate herbicide, within defined limits (**Figure 1-1**) to control the growth and spread of *S. anglica* and *P. maritima*. In August 2019, the spraying of the beach at Hoylake received adverse publicity on social media and in the press, and Wirral Council passed a motion ‘Glyphosate Free Wirral’ detailing how it intended to minimise glyphosate use except for invasive species management. In November 2019, Wirral Council requested Natural England to provide advice under their Discretionary Advice Service (DAS) as to how they should define management actions to “ensure that the natural environment is conserved, enhanced and managed for the benefit of future generations, whilst contributing to sustainable development”.

[1] *Now Mersey Narrows and North Wirral Foreshore SPA and Ramsar site*

Table 1.1. Assented beach management actions at Hoylake between 1st April 2016 and August 2019

Hoylake Beach
Spraying with Roundup glyphosate-based weed killer once per year in August; raking three times a week during April to September (inclusive); and removal of wind-blown sand from the seawall as and when it accumulates. The area to be raked extends from the lifeboat station to Red Rocks in a band 100m wide, 0-100m from the wall. Raking will be undertaken using a tractor and comb rake to remove vegetation followed by a tractor and Barber Surf rake. The area to be sprayed extends from the lifeboat station to Red Rocks, in a band 100m wide, 0-100m from the wall using a tractor with a boom and in addition if necessary between 100-120m from the wall with a knapsack sprayer (additional 20m band). Spraying with Roundup was deemed the best option for managing *S. anglica* at Hoylake Beach, as physical removal (excavation of material) may lead to further spread of the species and, as test digging has shown, leaves the rhizome behind. Rotoburying is not possible at this location due to the soft sediment. Smothering techniques and grazing are unsuitable at this location due to its use as an amenity beach and burning is not effective.

Figure 1-1. Beach management areas for raking and spraying at Hoylake approved in 2016 (AECOM, 2016)

In 2020, Wirral Council halted both mechanical raking and the use of glyphosate chemicals to control the growth of saltmarsh vegetation. Other management actions continued including the removal of wind-blown sand from against the seawall. The spread of this sand is partially controlled by fences attached to the promenade railings, but it still causes drains to be blocked and is a nuisance on the road and to properties on North Parade. The current consent for these operations expired on 31st March 2021 and Wirral Council is separately applying for Natural England assent to continue them for a further 24 months.

Natural England provided advice to Wirral Council regarding beach management in March 2020 (**Appendix B**). Natural England recommended and supported the development of a more holistic Beach Management Plan (BMP). This plan would be developed through an inclusive engagement process with a wide range of stakeholders that represent a variety of opportunities and constraints such as conservation, economic, legal and sustainability. Natural England indicated that there needed to be a better understanding of coastal change and habitat development at Hoylake and the value that these would bring.

A wide range of views are present regarding the future management of Hoylake beach including continued removal of grasses, using mechanical operations or alternative methods. Other views however advocate for allowing natural succession and the management of natural features and habitats.

Wirral Council wishes to address all the conflicting views and reach a consensus on a way forward for managing the beach at Hoylake by producing a new BMP for the frontage. In order to support development of the BMP the Council commissioned this Geomorphology and Ecology study to provide data and information to enable informed decisions to be made.

1.2 This Study

The overall purpose of this study is to provide an evidence base for preparation of a BMP that defines the requirements for future management of the beach at Hoylake for coastal defence, amenity and nature conservation. The key elements of this evidence base provided in this report are:

- an overview of historical evolution of the Hoylake frontage and changes in beach morphology;
- an overview of beach ecology including a National Vegetation Classification (NVC) survey;
- predictions of future morphological and ecological change using a range of future climate change (sea-level rise) scenarios for selected shoreline management scenarios;
- a Natural Capital Value assessment on the selected shoreline management scenarios;
- a review of present and future flood risk under the selected shoreline management scenarios; and
- potential opportunities and constraints of the selected shoreline management scenarios.

To understand the overall implications of future beach management that encapsulates all the potential options which the BMP would consider, the following two shoreline management scenarios were developed:

- Do Nothing: allow the shoreline to develop without intervention; and
- Do Everything: manage the shoreline by continually removing all vegetation.

Future morphological and ecological changes within the study area (see **Section 1.3**) have been predicted over the next 10 (2032), 20 (2042) and 50 years (2072), which is considered a suitable timeframe to inform the BMP. Given the inherent uncertainty with predictions further into the future, it was not considered appropriate to extend the study any further into the future.

Climate change projections were extracted from the UK Climate Projections (UKCP18) database. A range of projections are available based on three emissions scenarios (low, medium and high) and their confidence levels (5%, 50% and 95%). Predicted sea-level rise due to medium emissions (at the 50% confidence level) has been applied to each of the future years (2032, 2042 and 2072) in order to predict future changes. Whist the actual rise in sea level could be better or worse, depending on how the climate changes, the medium emissions (at the 50% confidence level) scenario was considered most appropriate to predict future morphological and ecological changes.

1.3 Study Area

Hoylake Beach extends from the Red Rocks in the southwest to the RNLI Lifeboat Station in the northeast. The beach is approximately 2km long and 2km wide from the seawall to the low water mark of spring tides (see **Figure 1.2**). A selection of photographs can be seen in **Figure 1.3**.

1.4 Structure of this report

This report is structured as follows:

- **Section 1** (this first section) provides the background to the project, study area and the purpose of the report.
- **Section 2** provides a coastal geomorphology and ecology review of Hoylake Beach.
- **Section 3** describes historic morphological change of Hoylake Beach.
- **Section 4** provides projections of future sea-level rise.
- **Section 5** outlines predictions of future coastal change and potential limits of vegetation.
- **Section 6** provides a flood risk assessment of Hoylake Beach.
- **Section 7** outlines the opportunities and constraints of the potential future beach management scenarios.
- **Section 8** concludes the report and provides recommendations.
- **Section 9** lists the references used to inform this study and report.

Legend:

Study Area

Source: © Haskoning DHV UK Ltd, 2021;
Contains OS data © Crown copyright and database right, 2021.

Client:	Project:
Wirral Borough Council	Hoylake Beach Geomorphology and Ecology Study

Title:

Study Area

Figure:	1-2	Drawing No:	PC2553-RHD-ZZ-XX-DR-Z-0014		
Revision:	Date:	Drawn:	Checked:	Size:	Scale:
P01	24/01/2022	JT	DB	A3	1:100,000

Co-ordinate system: British National Grid

ROYAL HASKONINGDHV
INDUSTRY & BUILDINGS
2 ABBEY GARDENS
GREAT COLLEGE STREET
LONDON
SW1P 3NL
+44 (0)20 7222 2115
www.royalhaskoningdhv.com

Photo 1: East of Kings Gap slipway

Photo 2: Isolated patches of vegetation present on upper-middle beach

Photo 3: Vegetation on upper beach adjacent to North Parade

Photo 4: Looking towards the old lifeboat station slipway

Photo 5: Looking towards Kings Gap slipway

Photograph 6: View from Kings Gap slipway towards Red Rocks

Photograph 7: Sideview of Kings Gap slipway

Photograph 8: View from Red Rocks towards the RNLI station

Figure 1-3. Photos taken in 2021 showing vegetation on the upper beach at Hoylake (photos taken by Royal HaskoningDHV).

2 Coastal Geomorphology and Ecology

2.1 Geomorphological Setting

Hoylake Beach is located at the northwest corner of the Wirral Peninsula bounded by the Dee Estuary to the southwest, the Mersey Estuary to the northeast and Liverpool Bay and the Irish Sea to the northwest (see **Figure 1.2**). Along the inner Dee Estuary, the Wirral Peninsula is characterised by saltmarsh backed by a narrow sand beach and low dunes in places (Halcrow, 2018). To the northwest, along the outer reaches of the Dee Estuary the coast is dominated by sand, gravel and cobbles which are backed by cliffs (Halcrow, 2010). The cliffs are up to 18m high and formed of glacial sediment. Moving towards the estuary mouth, the coast between West Kirby and Hilbre Point is comprised of a wide intertidal sandflat backed by dunes. The rocks exposed at Hilbre Point and Red Rocks are sandstone (Halcrow, 2018).

As the coast changes orientation to the northeast along north Wirral (encompassing Hoylake), it is characterised by sand beaches and large intertidal sand banks. One of the largest features at Hoylake is East Hoyle Bank, a sand bank which extends from the mouth of the Dee Estuary to Leasowe Lighthouse (Halcrow, 2010).

The Shoreline Management Plan policy for Hoylake Beach is Hold the Line (HTL) for the next three epochs (100 years) with the intention to "*manage flood and erosion risk by maintaining existing defences and beach management. As part of a wider strategy, undertake a more detailed study into risks and the viability of maintaining defences*" (Halcrow, 2010)

2.2 Wind

The prevailing wind direction across the eastern Irish Sea and northwest England coast is from the west to southwest sector (Pye and Blott, 2009; Brown *et al.*, 2013) (**Figure 2-1**). During summer, the wind direction is more evenly distributed around the sectors, whereas in winter the dominant wind direction is from the southwest, from the Atlantic (Halcrow, 2010).

2.3 Offshore Waves

Measured significant wave heights and directions collected between November 2002 and August 2017 at the Liverpool WaveNet buoy located approximately 17km offshore from Hoylake Beach in 22m of water are presented in **Figure 2-2**. The wave rose shows that waves up to 4m high approach from the west to west-northwest, with smaller waves up to 2.5m high approaching with less frequency from the northwest. Brown *et al.* (2010) calculated that the 1 in 100-year extreme wave height at the Liverpool WaveNet buoy, is 7.3m.

2.4 Nearshore Waves

The dominant wave direction at Hoylake is from the northwest. However, the largest waves originate from the west as these waves are not limited by fetch or water depth. The annual mean significant wave height at the shoreline is only about 0.8m, due to the significant attenuation of waves across the wide intertidal area, including East Hoyle Bank.

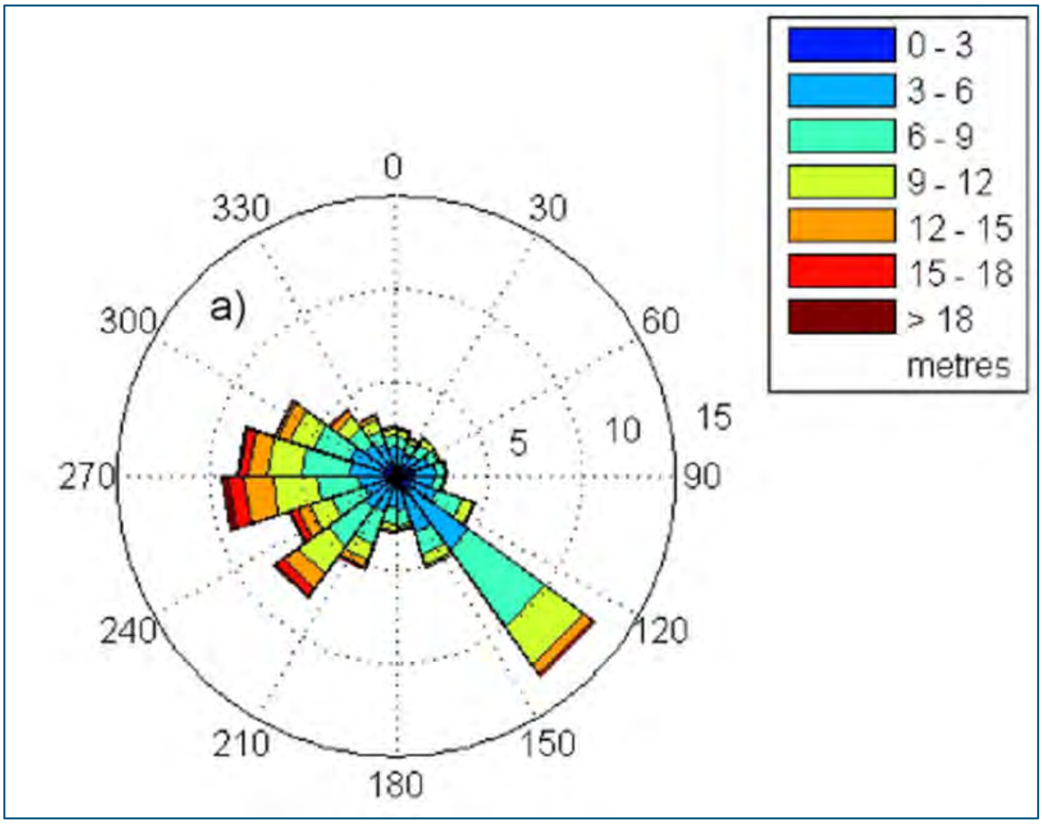


Figure 2-1. Wind rose from Hilbre Island (west of Hoylake) meteorological station for 2005-2012 (Brown et al., 2013)

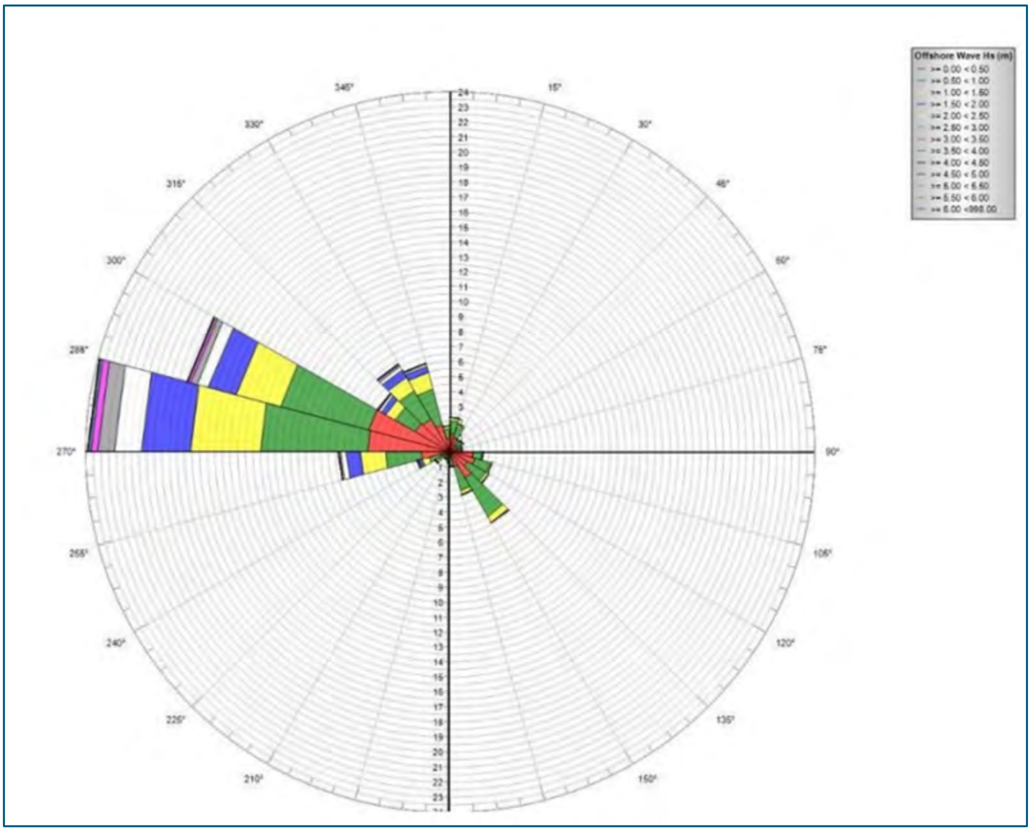


Figure 2-2. Wave rose for the Liverpool Bay WaveNet buoy (2002-2017) (Halcrow, 2018)

2.5 Water Levels

The tides in Liverpool Bay are semi-diurnal and macro-tidal. Water levels at Liverpool (Gladstone Dock approximately 12km northeast of Hoylake Beach) are presented in **Table 2.1**. The predicted spring and neap tide ranges are 8.27m and 4.29m, respectively (National Tidal and Sea Level Facility, 2021).

Table 2.1. Tidal datums at Liverpool between 1991 and 2020 (National Tidal and Sea Level Facility, 2021)

Location	Predicted Elevation (m OD)				
	MLWS	MLWN	MHWN	MHWS	HAT
Liverpool (Gladstone Dock)	-3.87	-1.77	2.54	4.46	5.44
MLWS=Mean Low Water Spring; MLWN=Mean Low Water Neap; MHWN=Mean High Water Neap; MHWS=Mean High Water Spring; HAT=Highest Astronomical Tide					

2.6 Tidal Currents

Tidal currents flow parallel to the North Wirral frontage. The average flood tidal current velocities are higher than the average ebb velocities (Pye, 1996).

2.7 Sediment Sources

The main source of sediment into inner Liverpool Bay is erosion of geological units deposited during the Pleistocene glacial period exposed on the Irish seabed. The sediment is then transported onshore, where East Hoyle Bank acts as a major local sediment sink/temporary store immediately offshore from Hoylake Beach. Sediment sources from the Mersey and Dee Rivers are very small in comparison to the marine sources (Halcrow, 2018).

2.8 Coastal Sediment Distribution

Coastal Engineering (2015) analysed and presented the results of particle size analyses conducted on over 2,200 sediment samples collected during 2014-2015 from intertidal locations within Shoreline Management Plan area 22 (Cell 11), which includes North Wirral and the Hoylake frontage (**Figure 2-3**). The results were compared to an earlier survey undertaken in 2009-2010. The results show that North Wirral, including Hoylake Beach, is dominated by sand across the beach profile, with muddy sand in places on the upper parts of northeast Hoylake Beach in both 2010 and 2014-2015.

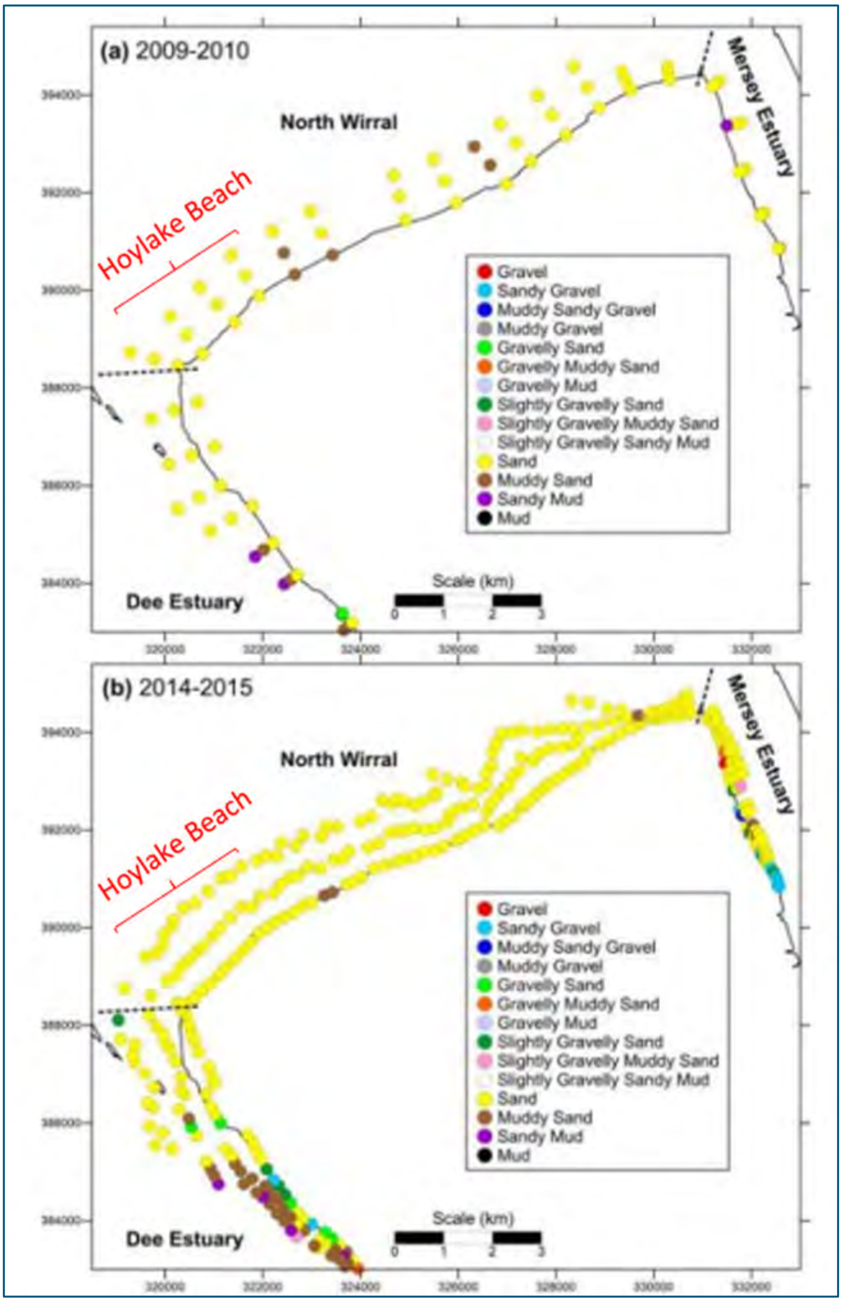


Figure 2-3. Spatial plot of sediment textures along North Wirral frontage in 2009-2010 (top) and 2014-2015 (bottom) (Coastal Engineering, 2015)

2.9 Sediment Transport

Three main sediment transport mechanisms occur at Hoylake Beach: waves, currents and wind. These mechanisms are described below.

2.9.1 Waves and Tidal Currents

Some of the sediment is transported along the coast by waves from southwest to northeast (Halcrow, 2010) (**Figure 2-4**). Although the net direction of sediment transport is wave-driven from southwest to northeast, some sand transport can occur in the opposite direction when wind and wave activity is from the northeast

(Jemmett and Smith, 2000). Some of the sediment is also transported to Hoylake Beach by strong tidal currents at Hilbre Point (Jemmett and Smith, 2000).

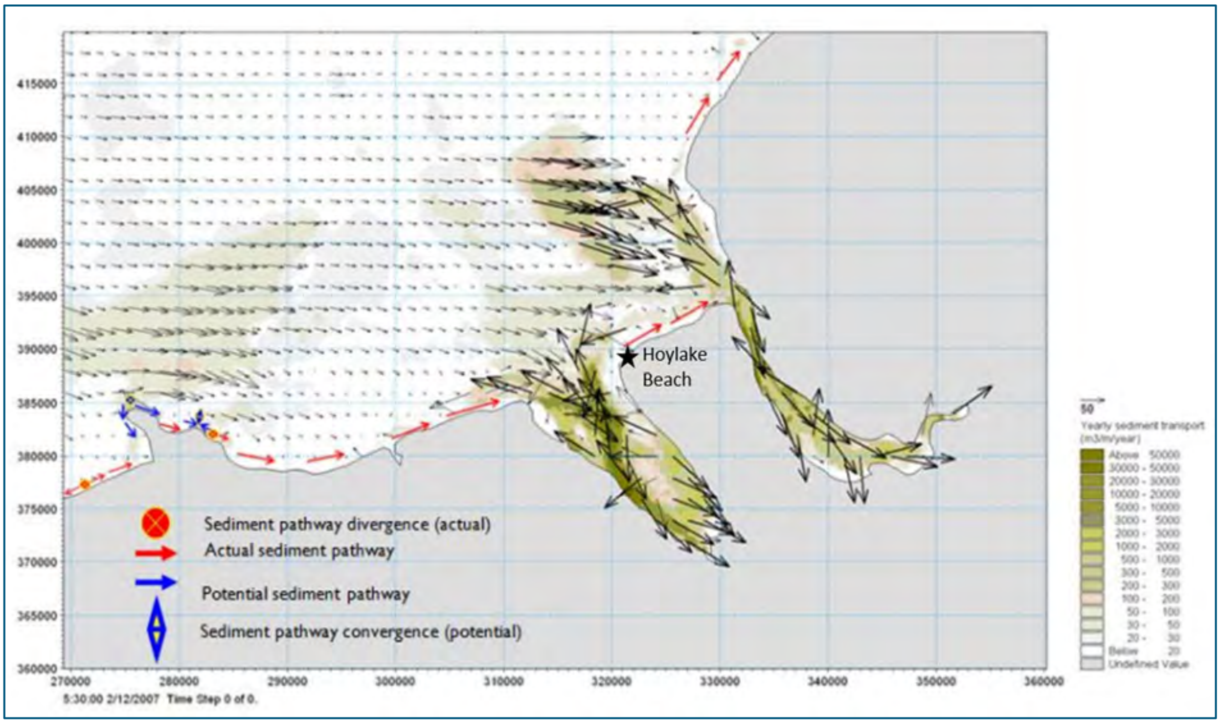


Figure 2-4. Regional sediment transport in the vicinity of Hoylake Beach (Halcrow, 2010)

2.9.2 Wind

Hoylake Beach has a shallow slope (1:400), which provides a large surface area for wind to dry intertidal sand and transport it landward (Jemmett and Smith, 2000). Wind-blown sand accretion occurs on the upper beach at Hoylake (Halcrow, 2018). This accretion against the seawall may be due to the increased sheltering of the upper beach from wave action provided by the growth of East Hoyle Bank, and/or increased wind-blown sand supply from the bank at low tide (Halcrow, 2018). Anecdotal evidence suggests that the seawall was 6-10 feet (2-3m) above the beach surface in the 1940s but was 0.6m above the beach in some locations in 2016 (Jemmett and Smith, 2000, Halcrow, 2018). The increase in beach levels and concomitant seaward movement of the low water mark and extension of East Hoyle Bank is likely to have reduced the importance of waves and tidal current transport relative to wind-blown transport (more of the East Hoyle Bank will be drier more often).

2.10 Coastal Structures

Almost the entire North Wirral frontage is artificially defended by structures including a seawall, revetment, offshore breakwaters and rock groynes which have fixed the existing coastal position (AECOM, 2016). Hard coastal defences in the area began with the Wallasey Embankment in the 1840s. Tracing the top of the entire seawall, the mean elevation is 6.22m OD. The mean elevations along four sections (so as not to include beach entrances/slipways) are (**Figure 2-5**):

- Section 1 (south) - 6.80m OD;
- Section 2 - 5.89m OD;
- Section 3 - 6.81m OD; and
- Section 4 (north) - 6.29m OD.

Figure 2-5. Sections of seawall measured for elevation using the LiDAR

2.11 Ecology of Hoylake Beach

The study area is subject to the following, overlapping, designations:

- North Wirral Foreshore SSSI, designated for features such as non-breeding birds, intertidal sediments, and saltmarshes.
- Mersey Narrows and North Wirral Foreshore SPA/Ramsar site, designated for non-breeding birds.
- Dee Estuary SSSI and SAC, designated for features including intertidal sediments, reefs, saltmarsh and sand dunes.

2.11.1 NVC Survey

A NVC survey was undertaken to classify and map habitats present within the survey area and to provide a conservation assessment of the vegetation communities recorded. Habitats were recorded and classified following the standard NVC protocol (Rodwell, 2006; Stace, 2019). A Garmin 62st GPS was used to record locations. Maps were produced using QGIS 3.4 Madeira (2018). Nomenclature of higher plant species followed Stace (2019). The findings of the NVC survey are summarised below, with the report provided in **Appendix B**.

In accordance with the NVC methodology, five or more quadrats were recorded for most vegetation communities. However, for vegetation communities which covered smaller areas, fewer quadrats were recorded. In this case, each quadrat was analysed separately, and the community was assigned on the basis of the components of each quadrat. For very small, fragmentary stands of vegetation, a full species list was made, and abundance was noted using the DAFOR scale (D=Dominant; A=Abundant, LF=Locally Frequent, F=Frequent, O=Occasional, R=Rare). The whole stand was then compared to the NVC descriptions and assigned to a community on this basis.

A total of 103 vascular plant species and one bryophyte species were recorded in the survey area across 27 quadrats. The location of quadrats is shown on **Figure 2-6**. Two vegetation communities were identified:

- approximately 10ha of SM13 *P. maritima* saltmarsh community: a generally species-poor grassland dominated by the grass *P. maritima* (Common Saltmarsh-grass), with associates such as *Tripolium pannonicum* (Sea Aster), annual *Salicornia* agg (annual Glasswort agg) and *Suaeda maritima* (Annual Sea-blite); and
- approximately 0.6ha of SM6 *S. anglica* saltmarsh community at the west end of the site dominated by Common Cordgrass *S. anglica*.

Figure 2-6. Location of quadrats and vegetation community distribution (source: Ruffino, 2021)

The NVC survey recorded whether the vegetation was dense or sparse as shown in **Figure 2-7**. This shows a tendency for denser vegetation landward, with sparser vegetation towards the sea. By comparing the vegetation boundaries with 2021 elevation data from LiDAR, the mean elevation of the seaward boundaries of the dense and sparse vegetation are approximately 4.5m OD and 4.3m OD, respectively.

Figure 2-7. Distribution of dense (black hashed lines) and sparse (red lines) vegetation (source; Ruffino, 2021)

In addition to the saltmarsh species which comprise SM13 *P. maritima* saltmarsh community, and SM6 *S. anglica* saltmarsh community, a number of species present are also associated with strandline and embryo dune habitats (Joint Nature Conservation Committee, 2004), including:

- Strandline: Sea rocket *Cakile maritima*, Prickly saltwort *Kali turgidum, and* Saltbush *Atriplex* spp; and
- Embryo dune: Sand couch grass *Elymus farctus*, Sand ryegrass *Leymus arenarius* and Marram grass *Ammophila arenaria*.

From a conservation perspective, the vegetation communities on site are of high conservation value: SM13 *P. maritima* saltmarsh community is of importance for conservation at international level, as it is one of the vegetation communities included within Annex I Habitat 1330 'Atlantic salt meadows (Glauco-Puccinellitalia maritimae)'. This habitat is also the primary reason for selection of the Dee Estuary as an SAC. At national level, Section 41 of the Natural Environment and Rural Communities Act 2006 lists coastal saltmarsh as a habitat of principal importance in England. The NVC survey identified the rare and/or notable plant species shown in **Table 2.2**.

Table 2.2. Rare and/or notable plant species

Species	Status
Catabrosa aquatica	Classified as vulnerable in England
Triglochin palustris	classified as Near Threatened in England
Crithmum maritimum	Locally Rare in VC58 Cheshire
Polygonum oxyspermum	Locally Rare in VC58 Cheshire

3 Historic Beach Morphological Change

According to Halcrow (2018), the North Wirral frontage has generally been stable or accreting over the last 20 years with small, isolated, areas of erosion. Historic morphological change along Hoylake Beach has been investigated by comparing LiDAR data captured between 2002 and 2021 in a GIS.

3.1 Changes between 2002 and 2008

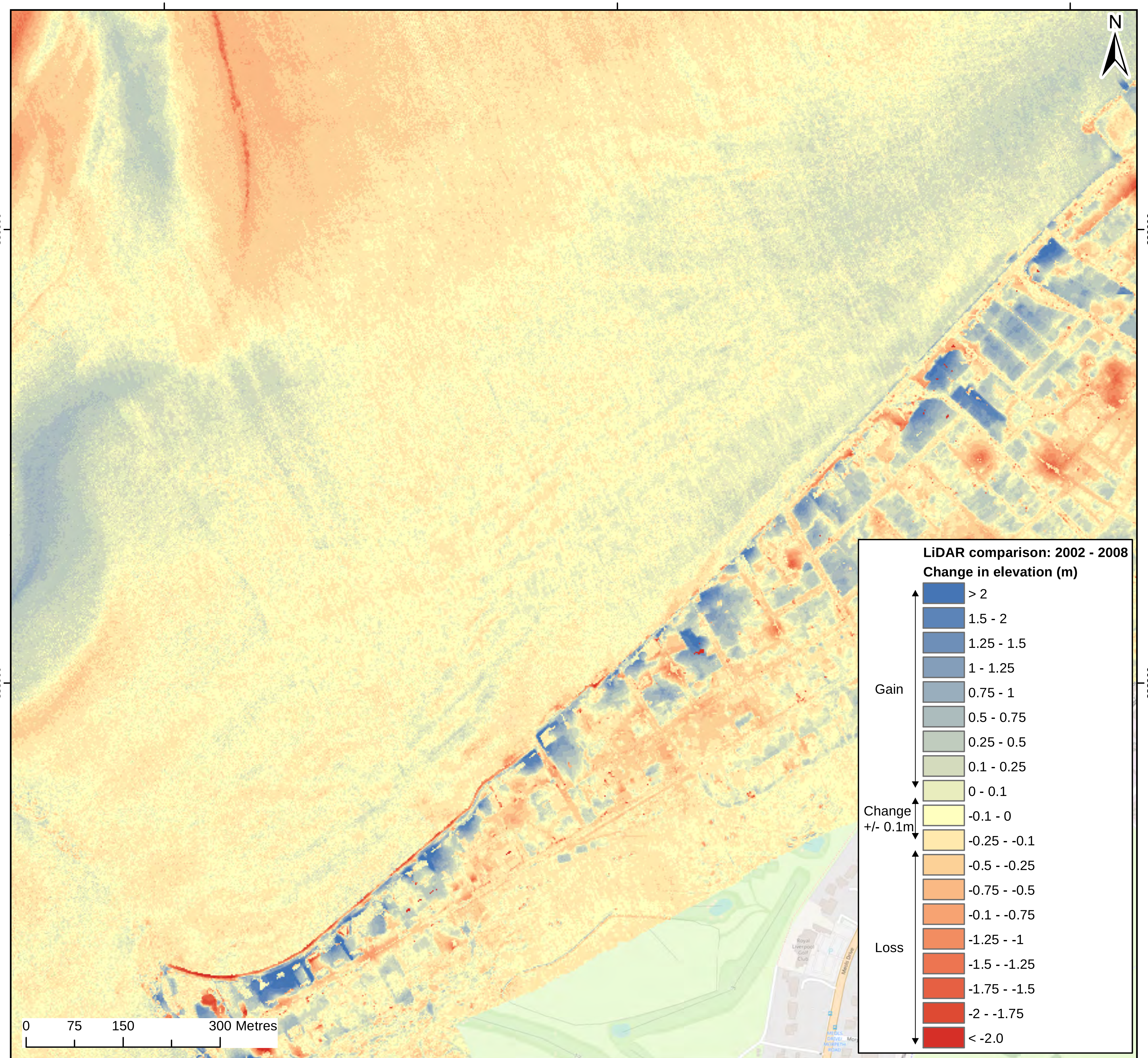
Figure 3-1 shows the elevation difference between the beach in 2002 and 2008. The dominant processes across much of the intertidal area were erosion or stability, apart from the upper beach in the northeast (and small areas in the southwest), where accretion took place. There is evidence for migration of sand bars across the middle-upper beach of the southwest frontage, which manifest as linear bands of erosion and accretion oriented parallel to the coast. Accretion occurred along the upper beach of the northeast frontage, gradually transitioning to accretion across the entire beach profile at the northernmost extent. A GIS calculation of beach change within the dense vegetation area mapped by the 2021 NVC survey describes average accretion of about 0.08m over this six-year period (13mm/year).

Wirral Council (2003) observed low beach levels in 2002, evidenced by the toe exposure on the northern side of Beach Road. They described a movement of the wrack lines further offshore along the beach northeast past Courtenay Road towards Kings Gap, which indicated higher beach levels compared to the southwest. In 2008, Wirral Council (2009) described an increase in beach levels along the beach north of the Beach Road slipway, which had risen slightly to cover the '*vertical face supporting the apron to the sea wall*'. The presence of vegetation on the beach to the east of Beach Road slipway was also noted. At King's Gap, the report noted that there is '*evidence of windblown sand accumulation against the minor promontory of the King's Gap slipway*'. The observations of Wirral Council (2003, 2009) support the LiDAR comparison, showing that beach levels were lower in the southwest and raised in the northeast between 2002 and 2008, particularly north of Kings Gap slipway.

3.2 Changes between 2008 and 2013

Figure 3-2 shows the elevation difference between the beach in 2008 and 2013. In contrast to the 2002 to 2008 evolution, beach changes between 2008 and 2013 were dominated by little change or accretion across the entire area. Accretion was greater in the northeast than the southwest. Sand bar migration, in the form of linear accreting areas, is visible on the middle beach. A GIS calculation of beach change within the dense vegetation area mapped by the NVC survey describes average accretion of about 0.21m over this five-year period (42mm/year).

Wirral Council (2014) noted the alternating form of the beach since 2010, which has been both smooth and dry in nature (2011) and at other times holding water due to its rippled (sand bars) nature (2010 and 2012). In 2013, a few areas were observed to be holding water '*where vegetation growth was taking hold*' or '*in scour ponds in front of the defences*'. Vegetation growth was observed about 50-75m seaward of the shoreline from Beach Road to Kings Gap.



Legend:

Source: © Haskoning DHV UK Ltd, 2021;
Contains OS data © Crown copyright and database right, 2021.

Client:	Project:
Wirral Borough Council	Hoylake Beach Geomorphology and Ecology Study

Title: LiDAR comparison 2002 and 2008

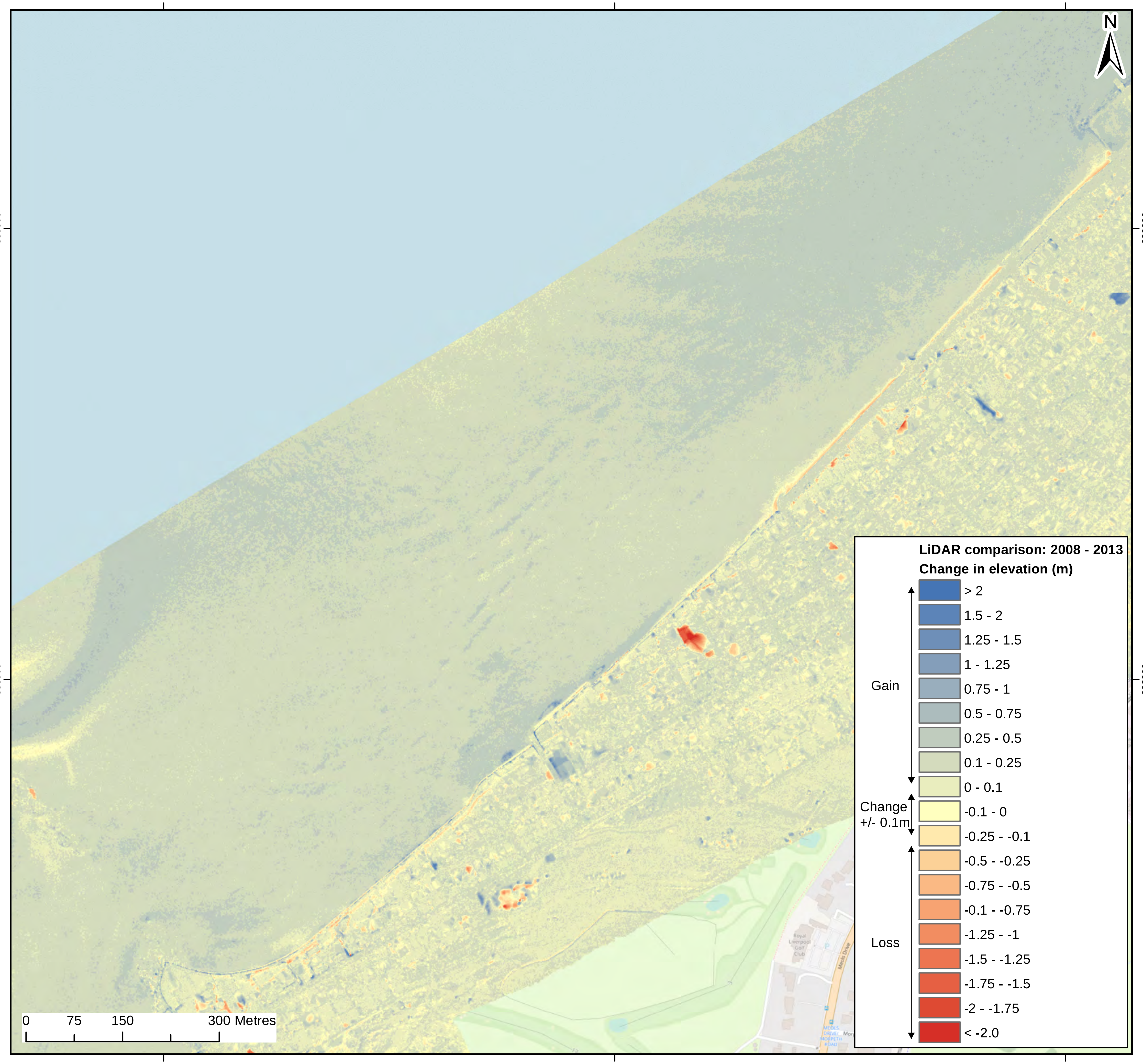
Figure: 3-1 | Drawing No: PC2553-RHD-ZZ-XX-DR-Z-0001

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
P02	14/10/2021	JT	DB	A3	1:6,000
P01	20/09/2021	JT	DB	A3	1:6,000

Co-ordinate system: British National Grid

Royal HaskoningDHV
Enhancing Society Together

ROYAL HASKONINGDHV
INDUSTRY & BUILDINGS
2 ABBEY GARDENS
GREAT COLLEGE STREET
LONDON
SW1P 3NL
+44 (0)20 7222 2115
www.royalhaskoningdhv.com



Legend:

Client:	Project:
Wirral Borough Council	Hoylake Beach Geomorphology and Ecology Study

Title: LiDAR comparison 2008 and 2013

Figure: 3-2 | Drawing No: PC2553-RHD-ZZ-XX-DR-Z-0002

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
P02	14/10/2021	JT	DB	A3	1:6,000
P01	20/09/2021	JT	DB	A3	1:6,000

Co-ordinate system: British National Grid

Royal HaskoningDHV
Enhancing Society Together

ROYAL HASKONINGDHV
INDUSTRY & BUILDINGS
2 ABBEY GARDENS
GREAT COLLEGE STREET
LONDON
SW1P 3NL
+44 (0)20 7222 2115
www.royalhaskoningdhv.com

3.3 Changes between 2013 and 2018

Figure 3-3 shows the elevation difference between the beach in 2013 and 2018. Similar to the 2008 to 2013 period, the beach is dominated by stability or accretion. However, in contrast to 2008 to 2013, accretion was dominant along the southwest frontage. Sand bar migration is visible across the middle beach in the southwest. Further northeast, the beach was dominated by little change or lower magnitude accretion. A GIS calculation of beach change within the dense vegetation area mapped by the NVC survey describes average accretion of about 0.05m over this five-year period (10mm/year).

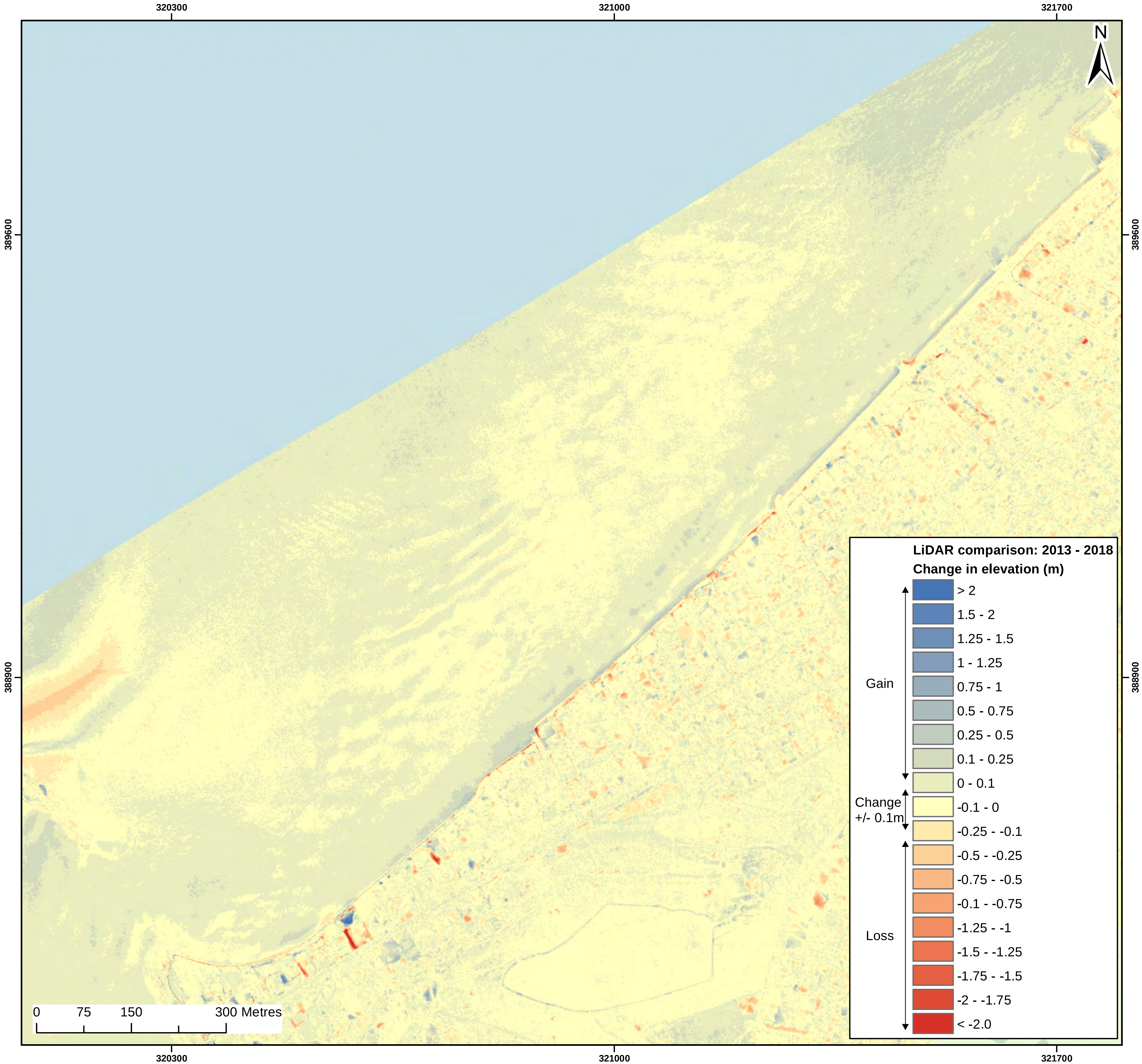
In 2018, Wirral Council (2019) noted that '*beach levels were higher with scour ponds along the toe of the defences between Red Rocks and Beach Road largely filled in*' and '*an increase in the greening of the beach across this section*' (Red Rocks – Beach Road). Between Beach Road and Kings Gap there was '*noticeably more growth*' compared to 2017, particularly closer to the shoreline. Beach levels were reported as still high ('*there is little freeboard between the beach and the top of the publicly maintained sea wall*') between Kings Gap and Hoylake RNLI Lifeboat Station, with some additional vegetation closer to the shoreline (Wirral Council, 2019).

3.4 Changes between 2018 and 2021

Figure 3-4 shows the elevation difference between the beach in 2018 and 2021. The entire beach is dominated by little change or accretion. The migration of sand bars is again visible on the middle to upper beach in the southwest. A GIS calculation of beach change within the dense vegetation area mapped by the NVC survey describes average accretion of about 0.07m over this three-year period (23mm/year). During a shoreline inspection in 2021, vegetation was observed on the upper beach along much of the frontage, which had expanded on the upper beach since 2018 (Wirral Council, 2022).

3.5 Changes between 2002 and 2021

The overall change in beach topography between 2002 and 2021 is shown in **Figure 3-5**. Over the entire 19-year period, the intertidal area was dominated by accretion. Erosion is concentrated along a short 200m section north from Red Rocks and small, isolated patches at the toe of the seawall along the southwest part of the beach. Movement of sand bars has occurred along the upper-middle beach in the southwest. A GIS calculation of beach change within the dense vegetation area mapped by the NVC survey describes average accretion of about 0.34m over this 19-year period (18mm/year). Changes between 2008 and 2021 (**Figure 3-6**) shows a comparison of beach topography between 2008 and 2021 (pre- and post-glyphosate application). The overall pattern of change is similar to 2002-2021, where the beach is dominated by accretion. Erosion occurs in small sections at the toe of the seawall, primarily in the southwest. A GIS calculation of beach change within the dense vegetation area mapped by the NVC survey describes average accretion of about 0.33m over this 13-year period (25mm/year).



Legend:

Client:	Project:
Wirral Borough Council	Hoylake Beach Geomorphology and Ecology Study

Title:

LiDAR comparison 2013 and 2018

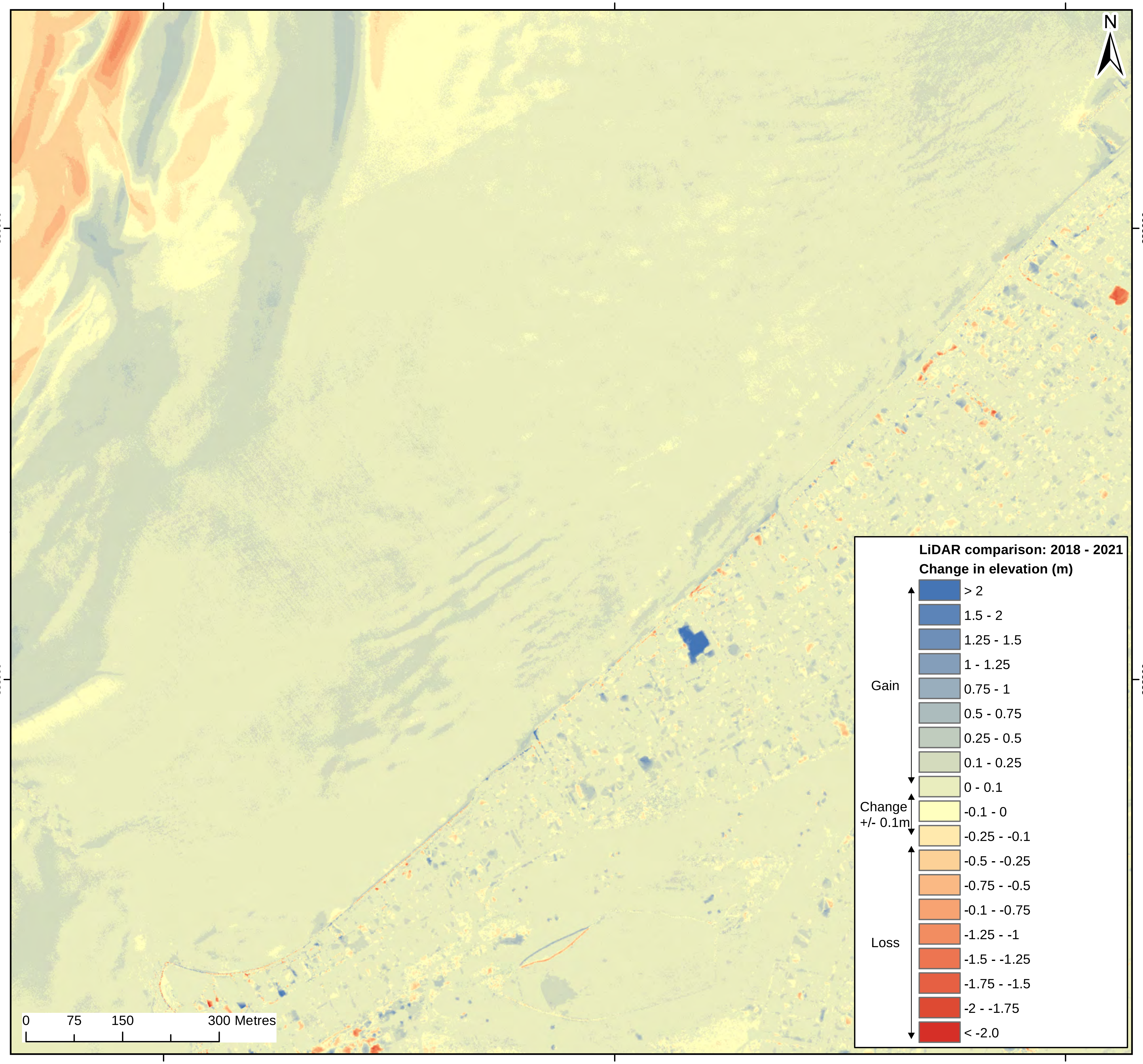
Figure:	3-3	Drawing No:	PC2553-RHD-ZZ-XX-DR-Z-0003

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
P02	14/10/2021	JT	DB	A3	1:6,000
P01	20/09/2021	JT	DB	A3	1:6,000

Co-ordinate system: British National Grid

Royal HaskoningDHV
Enhancing Society Together

ROYAL HASKONINGDHV
INDUSTRY & BUILDINGS
2 ABBEY GARDENS
GREAT COLLEGE STREET
LONDON
SW1P 3NL
+44 (0)20 7222 2115
www.royalhaskoningdhv.com



Legend:

Client:	Project:
Wirral Borough Council	Hoylake Beach Geomorphology and Ecology Study

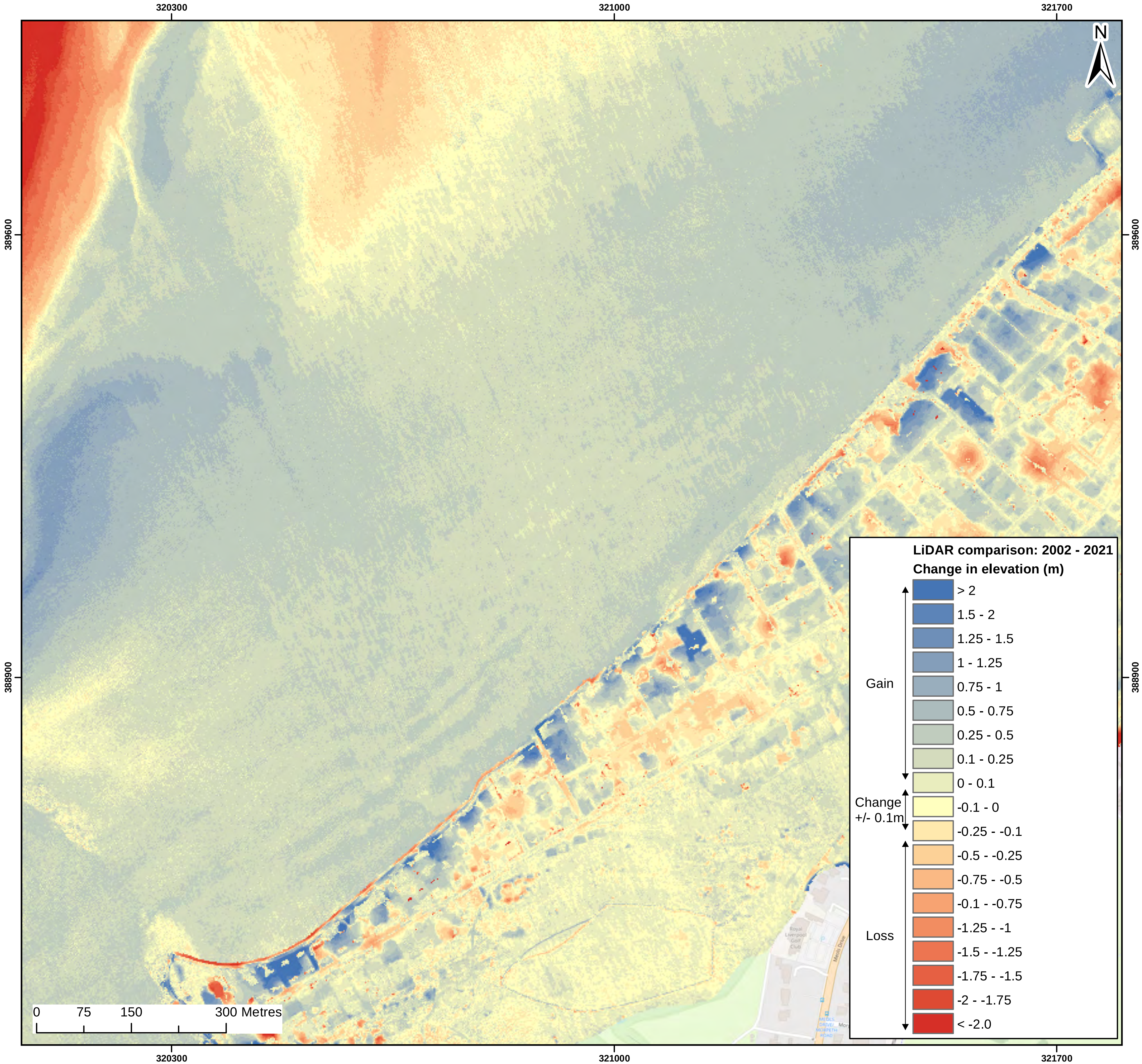
Title: LiDAR comparison 2018 and 2021

Figure:	3-4	Drawing No:	PC2553-RHD-ZZ-XX-DR-Z-0004		
Revision:	Date:	Drawn:	Checked:	Size:	Scale:
P02	15/10/2021	JT	DB	A3	1:6,000
P01	20/09/2021	JT	DB	A3	1:6,000

Co-ordinate system: British National Grid

Royal HaskoningDHV
Enhancing Society Together

ROYAL HASKONINGDHV
INDUSTRY & BUILDINGS
2 ABBEY GARDENS
GREAT COLLEGE STREET
LONDON
SW1P 3NL
+44 (0)20 7222 2115
www.royalhaskoningdhv.com



Legend:

Source: © Haskoning DHV UK Ltd, 2021;
Contains OS data © Crown copyright and database right, 2021.

Client:	Project:
Wirral Borough Council	Hoylake Beach Geomorphology and Ecology Study

Title:

LiDAR comparison 2002 and 2021

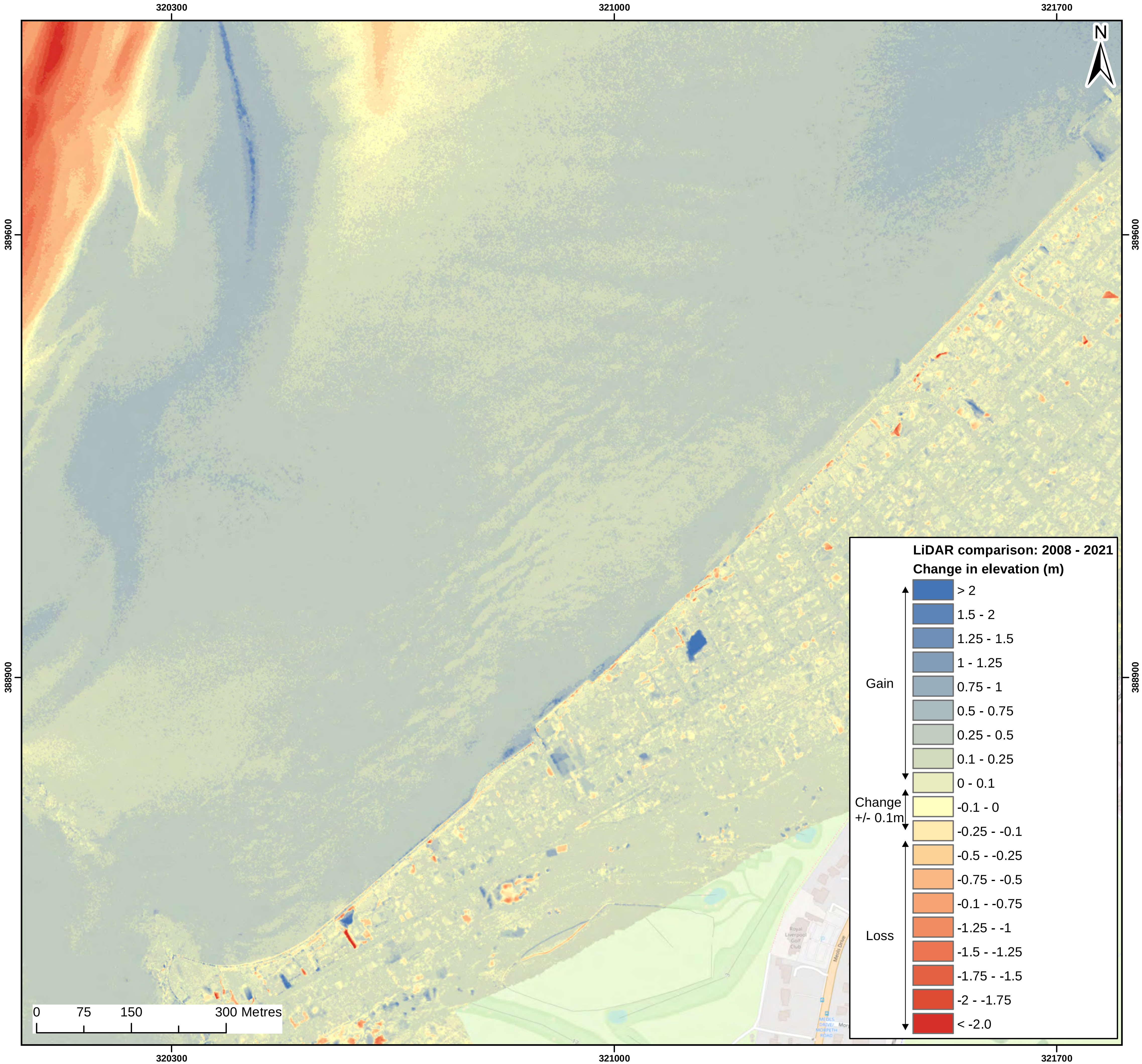
Figure: 3-5 Drawing No: PC2553-RHD-ZZ-XX-DR-Z-0005

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
P02	15/10/2021	JT	DB	A3	1:6,000
P01	20/09/2021	JT	DB	A3	1:6,000

Co-ordinate system: British National Grid

Royal HaskoningDHV
Enhancing Society Together

ROYAL HASKONINGDHV
INDUSTRY & BUILDINGS
2 ABBEY GARDENS
GREAT COLLEGE STREET
LONDON
SW1P 3NL
+44 (0)20 7222 2115
www.royalhaskoningdhv.com



Legend:

Source: © Haskoning DHV UK Ltd, 2021;
Contains OS data © Crown copyright and database right, 2021.

Client:	Project:
Wirral Borough Council	Hoylake Beach Geomorphology and Ecology Study

Title:

LiDAR comparison 2008 and 2021

Figure: 3-6	Drawing No: PC2553-RHD-ZZ-XX-DR-Z-0006

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
P02	15/10/2021	JT	DB	A3	1:6,000
P01	20/09/2021	JT	DB	A3	1:6,000

Co-ordinate system: British National Grid

Royal HaskoningDHV
Enhancing Society Together

ROYAL HASKONINGDHV
INDUSTRY & BUILDINGS
2 ABBEY GARDENS
GREAT COLLEGE STREET
LONDON
SW1P 3NL
+44 (0)20 7222 2115
www.royalhaskoningdhv.com

3.6 Summary

Table 3.1 summarises the average accretion rates within the vegetation zones mapped by the NVC survey and the area outside those zones (non-vegetated). The comparison of LiDAR data shows that average accretion rates along the upper beach where the current dense vegetation is located have varied depending on the time series assessed. Shorter-term average accretion rates have ranged from 13mm/year (0.08m) between 2002 and 2008, to 42mm/year (0.21m) between 2008 and 2013. Longer-term average rates have ranged from 18mm/year (0.34m) between 2002 and 2021 (the longest period assessed) to 25mm/year (0.33m) between 2008 and 2021.

Table 3.1. Accretion rates (m) between 2002 and 2021 within the vegetation zones mapped by the NVC survey

Years	Average change (m) within the dense vegetation polygon	Average change (m) within the outer limit polygon excluding dense vegetation	Average change (m) outside the vegetation polygons
2002-2008	0.08	0.05	0.08
2008-2013	0.21	0.22	0.24
2013-2018	0.05	0.05	0.04
2018-2021	0.07	0.06	0.06
2002-2021	0.34	0.26	0.31
2008-2021	0.33	0.32	0.32

4 Sea-level Rise

4.1 Relative Sea-level Rise

Historic data shows that the global temperature has risen since the beginning of the 20th century and predictions are for an accelerated rise, the magnitude of which is dependent on the magnitude of future emissions of greenhouse gases and aerosols. To compare relative sea-level rise with the historic beach morphological change data derived from LiDAR between 2002 and 2021, and to determine a future climate change sea-level allowance for Hoylake in 10, 20 and 50-years' time, this study uses the data of the UK Climate Projections (UKCP18) user interface[2] for the model grid cell that covers the coast (**Figure 4-1**). UKCP18 relative sea-level rise estimates use 1990 as their starting year and are based on the IPCC 5th Assessment Report. They are available for low (RCP2.6), medium (RCP4.5) and high (RCP8.5) emissions scenarios and presented by UKCP18 as central estimates of change (50% confidence level, 50th percentile) in each scenario with an upper 95% confidence level (95th percentile) and a lower 5% confidence level (5th percentile).

Figure 4-1. UKCP18 model grid used to derive sea-level rise projections for Hoylake

[2] (https://ukclimateprojections-ui.metoffice.gov.uk/ui/home)

Relative sea-level rise projections using the 5% percentile of the low (RCP2.6) emissions scenario, the 50% percentile of the medium (RCP4.5) emissions scenario and the 95% percentile of the high (RCP8.5) emissions scenario from the UKCP18 user interface have been used in this assessment.

4.2 Historic Relative Sea-level Rise

Table 4.1 describes projected historic changes in relative sea-level at Hoylake using 1990 as the starting year.

Table 4.1. Projected historic changes in relative sea level (m) at Hoylake under the 5th percentile low, 50th percentile medium and 95th percentile high emissions scenarios using 1990 as the starting year

Year	Low emissions 5th percentile (m)	Medium emissions 50th percentile (m)	High emissions 95th percentile (m)
1990	0.0	0.0	0.0
2008	0.017	0.028	0.043
2010	0.021	0.034	0.053
2013	0.026	0.045	0.067
2018	0.038	0.061	0.094
2020	0.043	0.069	0.105
2021	0.045	0.073	0.111

Table 4.2 describes the projected rates of relative sea-level rise over the same time periods of analysis as the LiDAR data; 2002-2008 (note that 1990-2008 is used as a proxy because data before 2007 were not available), 2008-2013, 2013-2018, 2018-2021, 2002-2021 (1990-2021 proxy) and 2008-2021. The data shows that the highest projected rate of relative sea-level rise was 5.67mm/year for the 95% percentile of the high (RCP8.5) emissions scenario between 2018 and 2021.

Table 4.2. Projected relative sea-level rise (mm/year) at Hoylake under the 5th percentile low, 50th percentile medium and 95th percentile high emissions scenarios

Year	Low emissions 5th percentile (m)	Medium emissions 50th percentile (m)	High emissions 95th percentile (m)
1990-2008 (proxy for 2002-2008)	17/18 = 0.94	28/18 = 1.56	43/18 = 2.39
2008-2013	9/5 = 1.80	17/5 = 3.40	24/5 = 4.80
2013-2018	12/5 = 2.40	16/5 = 3.20	27/5 = 5.40
2018-2021	7/3 = 2.33	12/3 = 4.00	17/3 = 5.67
1990-2021 (proxy for 2002-2021)	45/31 = 1.45	73/31 = 2.35	111/31 = 3.58
2008-2021	28/13 = 2.15	45/13 = 3.46	68/13 = 5.23

As a basis for comparison, Woodworth (2017) used recent mean sea level information from the UK tide gauge network along with short records of sea level measurements by the Ordnance Survey in 1859-1860, to estimate the average rates of sea-level change around the coast since the mid-19th century. The nearest historic data to Hoylake analysed by Woodworth (2017) is at Liverpool Gladstone Dock, for 101 years of data between 1858 and 2011. The estimated long-term rate of sea-level rise between 1858 and 2011 was 1.75mm/year.

Woodworth *et al.* (1999) reviewed changes in mean sea level around the coast of the UK using data from tide gauges. The nearest historic data to Hoylake analysed by Woodworth *et al.* (1999) is at Liverpool Princes Pier. Here, 19 years between 1959 and 1983 had a complete record of mean sea-level, and these were used to estimate changes over this period. The estimated medium-term rate of sea-level rise between 1959 and 1983 was 2.58mm/year.

4.3 Future Relative Sea-level Rise

Table 4.3 describes projected future changes in relative sea-level at Hoylake using 1990 as the starting year.

Table 4.3. Projected future changes in relative sea level (m) at Hoylake under the 5th percentile low, 50th percentile medium and 95th percentile high emissions scenarios using 1990 as the starting year

Year	Low emissions 5th percentile (m)	Medium emissions 50th percentile (m)	High emissions 95th percentile (m)
1990	0.0	0.0	0.0
2022	0.047	0.076	0.117
2030	0.067	0.109	0.170
2032	0.072	0.117	0.185
2040	0.091	0.152	0.249
2042	0.096	0.161	0.267
2050	0.114	0.200	0.345
2060	0.134	0.249	0.455
2070	0.153	0.301	0.583
2072	0.156	0.311	0.611
2080	0.169	0.353	0.723
2090	0.184	0.402	0.877
2100	0.197	0.452	1.042

Using 2022 as the baseline for geomorphological change, and an assumption that the 32 years of relative sea-level rise between 1990 and 2022 has already taken place, then the projected relative sea-level rises using a 2022 baseline are shown in **Table 4.4** and **Figure 4-2**.

Table 4.4. Changes in relative sea level (m) at Hoylake under the 5th percentile low, 50th percentile medium and 95th percentile high emissions scenarios using a 2022 baseline

Year	Low emissions 5th percentile (m)	Medium emissions 50th percentile (m)	High emissions 95th percentile (m)
2022	0	0	0
2030	0.020	0.032	0.052
2032	**0.024**	**0.040**	**0.068**
2040	0.044	0.075	0.132
2042	**0.049**	**0.085**	**0.150**
2050	0.067	0.123	0.228
2060	0.086	0.173	0.338
2070	0.105	0.225	0.466
2072	**0.109**	**0.235**	**0.493**
2080	0.122	0.277	0.606
2090	0.137	0.326	0.760
2100	0.149	0.376	0.925

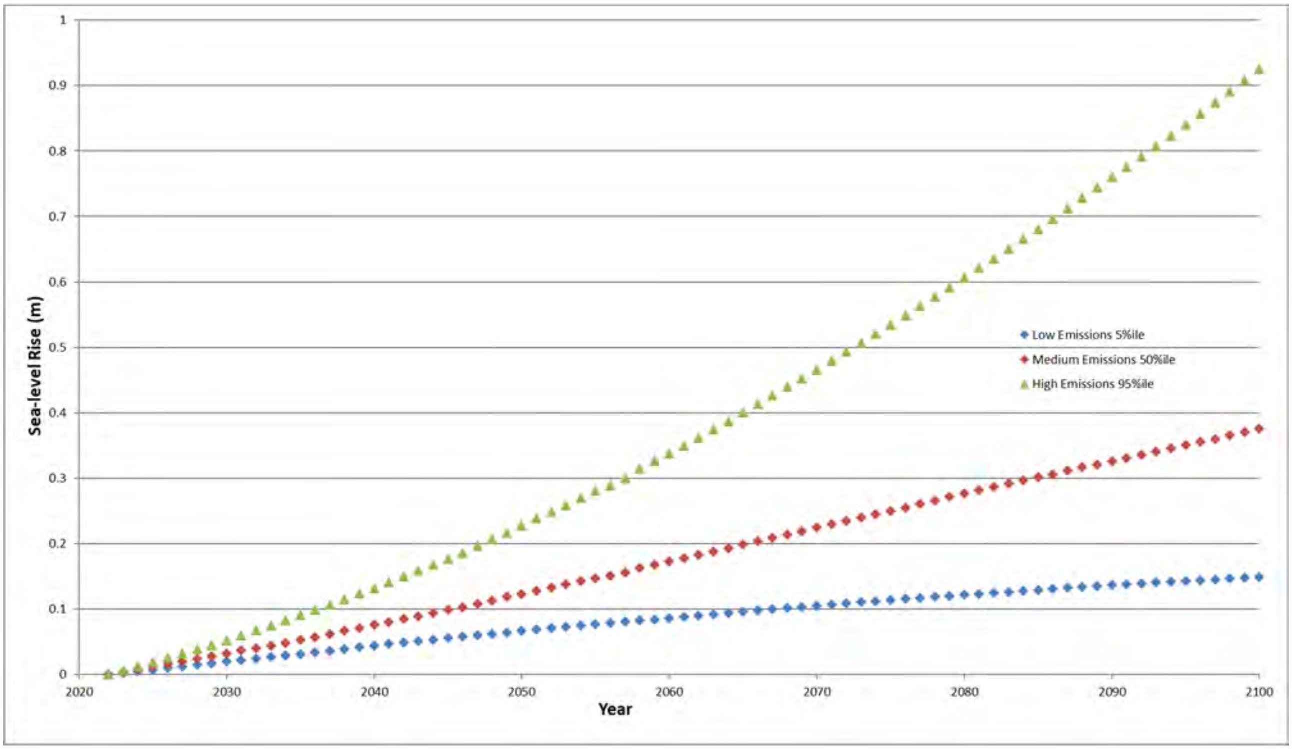


Figure 4-2. Changes in relative sea level (m) under the 5th percentile low, 50th percentile medium and 95th percentile high emissions scenarios using a 2022 baseline

Relative sea-level rises by 2032 (10 years), 2042 (20 years) and 2072 (50 years) for low (RCP2.6) emissions 5th percentile are estimated to be approximately 0.024m, 0.049m and 0.109m, respectively. These equate to average sea-level rises of 2.4mm/year over 10 years, 2.45mm/year over 20 years and 2.18mm/year over 50 years (**Table 4.5**).

Relative sea-level rises in 2032 (10 years), 2042 (20 years) and 2072 (50 years) for medium (RCP4.5) emissions 50th percentile are estimated to be approximately 0.040m, 0.085m and 0.235m, respectively. These equate to average sea-level rises of 4.0mm/year over 10 years, 4.25mm/year over 20 years and 4.7mm/year over 50 years.

Table 4.5. Changes in relative sea level (m) at Hoylake under the 5th percentile low, 50th percentile medium and 95th percentile high emissions scenarios using a 2022 baseline for years 10, 20 and 50

Year	Low emissions 5th percentile		Medium emissions 50th percentile		High emissions 95th percentile	
	Rise (m)	Rate of rise (mm/year)	Rise (m)	Rate of rise (mm/year)	Rise (m)	Rate of rise (mm/year)
2032	0.024	2.4	0.040	4.0	0.068	6.8
2042	0.049	2.45	0.085	4.25	0.150	7.5
2072	0.109	2.18	0.235	4.7	0.493	9.86

Relative sea-level rises in 2032 (10 years), 2042 (20 years) and 2072 (50 years) for high (RCP8.5) emissions 95th percentile are estimated to be approximately 0.068m, 0.150m and 0.493m, respectively. These equate to average sea-level rises of 6.8mm/year over 10 years, 7.5mm/year over 20 years and 9.86mm/year over 50 years.

5 Future Coastal Change and Potential Limits of Vegetation

The future evolution of Hoylake Beach will largely depend on the future beach topography (particularly the upper beach where the vegetation has developed) relative to the position of future water (sea) levels. Hence, the upper beach topography and historic and future sea levels are the principal issues considered in this section to predict how the beach may develop.

5.1 Morphological Change (Both Shoreline Management Scenarios)

To predict future geomorphological change requires consideration of how the site has developed historically. For the purposes of future prediction, the longest available datasets are used to take account of any shorter-term anomalies. Hence, a historic accretion rate of 22mm/year (the average of 18mm/year for 2002 to 2021 and 25mm/year for 2008 to 2021) has been used for extrapolation into the future.

The projected historic rate of relative sea-level rise over the 2008 to 2021 period was between 2.15mm/year (low emissions 5th percentile) and 5.23mm/year (high emissions 95th percentile). Even for the high emissions scenario, the average accretion rate of 22mm/year is about four times greater than the projected rate of relative sea-level rise. This means that historically, accretion has kept pace with and significantly exceeded relative sea-level rise and implies that sea-level rise has had a negligible controlling effect on accretion, which has been driven predominantly by sediment supply.

Projected future rates of relative sea-level rise for the next 50 years are between 2.18mm/year (low emissions 5th percentile) and 9.86mm/year (high emissions 95th percentile) (**Table 4.5**). Hence, it is likely, assuming sediment supply and therefore accretion remains constant into the future (given the very wide foreshore fronting Hoylake this is considered to be a robust assumption), that accretion rates on the upper beach will continue to exceed rates of relative sea-level rise into the future.

To predict future coastal change, the elevation of the beach was raised using a direct extrapolation of the average historical trend (22mm/year). Over 10, 20 and 50 years this equates to 0.22m, 0.44m and 1.1m, respectively. Coincident with this accretion would be potential rises in relative sea-level for the three emission scenarios over the three time periods. **Table 5.1** describes the average changes in elevation over 10, 20 and 50 years when the nine projected relative sea-level rises have been applied to the three average accretion rates.

Table 5.1. Elevation changes applied to the topography to predict future coastal change

Year	Average accretion (m)	Relative sea-level rise scenario	Relative sea-level rise (m)	Elevation change (m)
2032	0.22	Low emissions 5th percentile	0.02	0.20
		Medium emissions 50th percentile	0.04	0.18
		High emissions 95th percentile	0.07	0.15
2042	0.44	Low emissions 5th percentile	0.05	0.39
		Medium emissions 50th percentile	0.09	0.36
		High emissions 95th percentile	0.15	0.29
2072	1.1	Low emissions 5th percentile	0.11	0.99
		Medium emissions 50th percentile	0.24	0.87
		High emissions 95th percentile	0.49	0.61

5.2 Do Nothing Scenario

For the reasons explained in **Section 1.2**, the medium emissions 50th percentile sea level rise scenario was used to predict elevation changes which have then been used to identify the future positions of the dense and sparse vegetation boundaries in 10 years (2032, **Figure 5.1**), 20 years (2042, **Figure 5-2**) and 50 years (2072, **Figure 5-3**). The current vegetation boundaries at the 4.5m OD and 4.3m OD contours have been adjusted to fall along the predicted future 4.5m OD and 4.3m OD contours, respectively. Hence, the predicted positions of the vegetation boundaries are a balance between continued sediment accretion at the historic rate and the different relative sea-level rises projected for each year for the medium emissions 50th percentile scenario. The future position of HAT has also been identified using the predicted future 5.4m OD contour (denoted by the green line on **Figure 5-1** - **Figure 5-3**)

5.2.1 Ecological Change

The predicted positions of the boundaries of the dense and sparse vegetation and HAT for years 10, 20 and 50 would result in estimated increases in their areas as shown in **Table 5.2**.

Table 5.2. Predicted vegetated areas at years 10, 20 and 50

Habitat	Area (m^2)			
	Baseline (2021)	Year 10 (2032)	Year 20 (2042)	Year 50 (2071)
Dense Vegetation	48,500	105,600	203,600	707,200
Sparse Vegetation	68,500	123,100	160,400	264,600
Beach above HAT	0.00	2,100	6,600	52,900

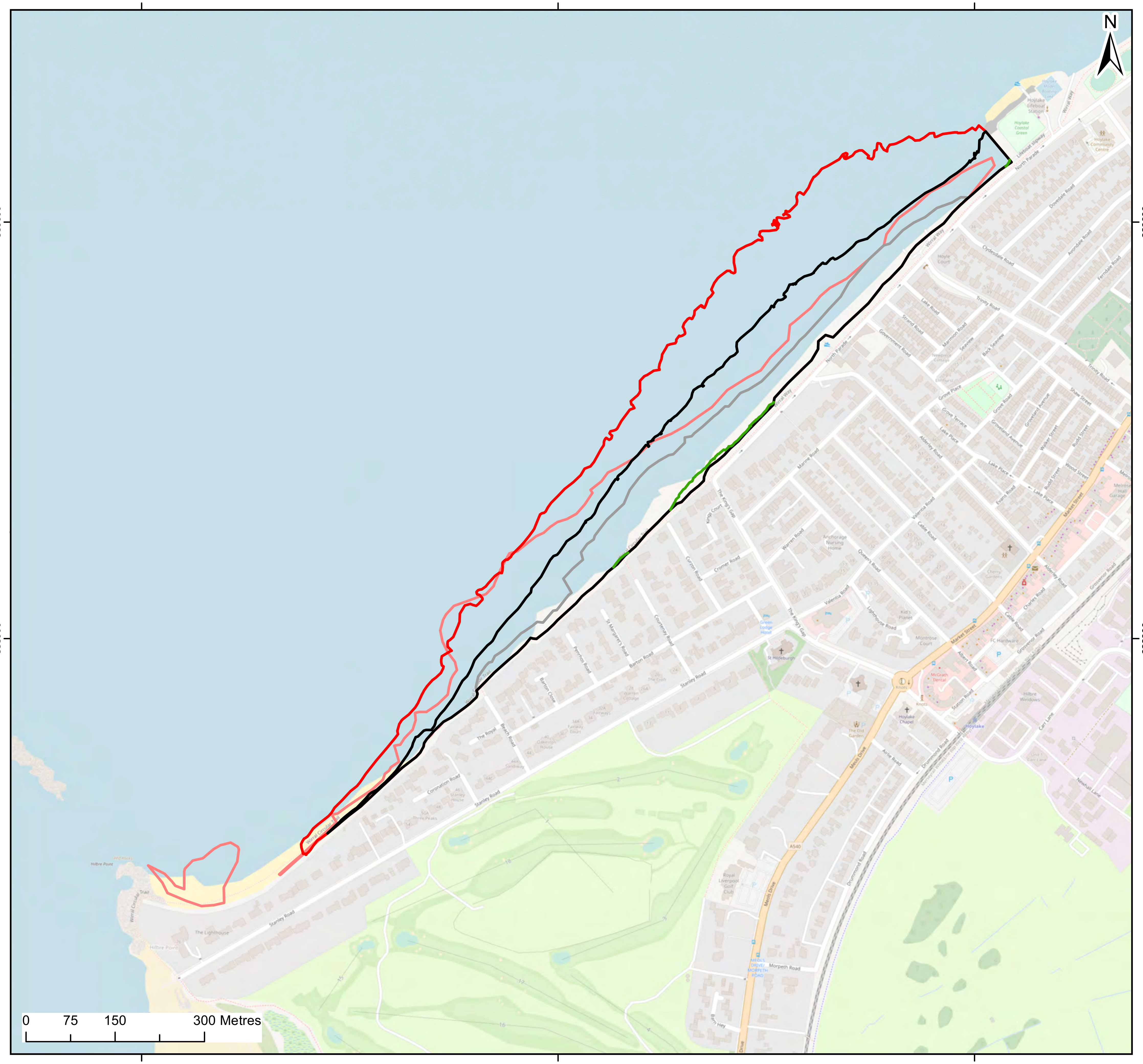
5.2.1.1 Potential Future Saltmarsh Development

Saltmarshes are categorised as low, medium or high marsh, depending on the underlying topography and characteristic plant assemblages (**Table 5.3**).

Table 5.3. Typical saltmarsh zonation

Saltmarsh Zonation	Tidal Range	Typical Species Present
Low Marsh	MHWN – MHW	*Spartina, Salicornia, Suaeda, Puccinellia, Aster* and *Atriplex*
Middle Marsh	MHW – MHWS	*Festuca, Juncus* and *Agrostis*
High Marsh	MHSW – HAT	*Elymus*, *Puccinellia* and *Armerial*

Pioneer and low marsh extends from MHWN to Mean High Water (MHW), and is typically characterised by species including *Spartina, Salicornia, Suaeda, Puccinellia, Aster* and *Atriplex*. Common saltmarsh-grass (*Puccinellia*) is a frequent pioneer species in northwest England on sandy marshes (Environment Agency, 2007), such as those at Hoylake and has been shown in saltmarsh stabilisation studies to both limit erosion and to significantly enhance accretion rates (Langlois *et al.,* 2001). Middle marsh extends between MHW and MHWS, where the topography reduces the inundation frequency compared to low marsh. Middle marsh is dominated by species such as *Festuca, Juncus* and *Agrostis.* Upper marsh is located above MHWS where species such as *Elymus*, *Puccinellia* and *Armerial* are generally present. Upper marsh is inundated less by sea water than both low and middle marsh and this is reflected in changes in species composition and increased diversity (Foster *et al.,* 2013). The distinction between zones is often blurred due to overlapping vertical ranges of individual species (Environment Agency, 2007).



Legend:

- Predicted boundary of dense vegetation for the medium emissions 50th percentile sea-level rise scenario in 10 years' time (2032)
- Predicted boundary of less dense vegetation for the medium emissions 50th percentile sea-level rise scenario in 10 years' time (2032)
- Dense vegetation boundary mapped by the National Vegetation Survey (NVC) 2021 survey
- Less dense vegetation boundary mapped by the National Vegetation Survey (NVC) 2021 survey
- Predicted highest astronomical tide for the medium emissions 50th percentile sea-level rise scenario in 10 years' time (2032)

Client:	Project:
Wirral Borough Council	Hoylake Beach Geomorphology and Ecology Study

Title:

Predicted positions of the dense and sparse vegetation, and HAT in 10 years (2032)

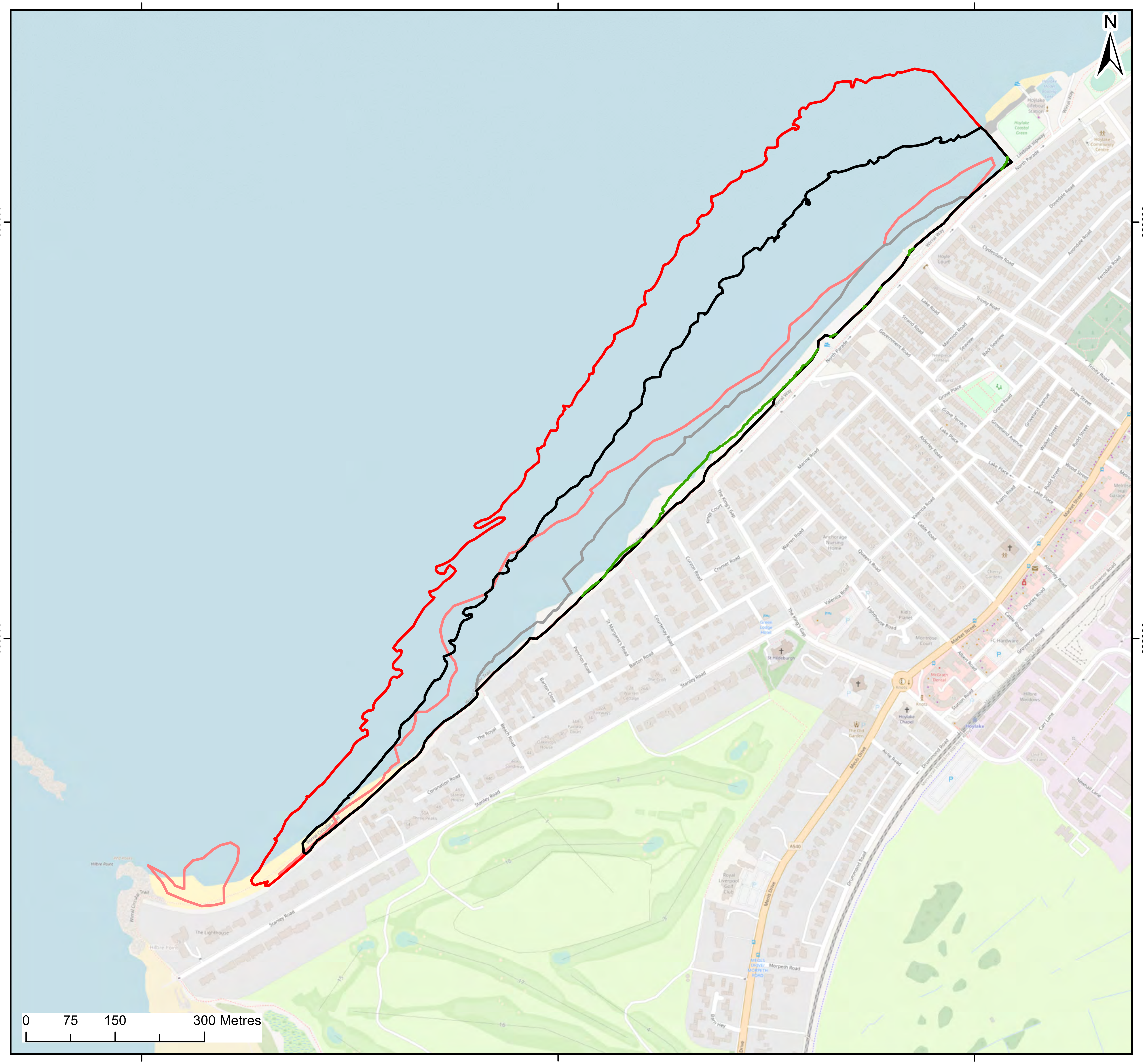
Figure: 5-1 Drawing No: PC2553-RHD-ZZ-XX-DR-Z-0011

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
P03	29/11/2021	JT	DB	A3	1:6,500
P02	15/11/2021	JT	DB	A3	1:6,500

Co-ordinate system: British National Grid

Royal HaskoningDHV
Enhancing Society Together

ROYAL HASKONINGDHV
INDUSTRY & BUILDINGS
2 ABBEY GARDENS
GREAT COLLEGE STREET
LONDON
SW1P 3NL
+44 (0)20 7222 2115
www.royalhaskoningdhv.com



Legend:

- Predicted boundary of dense vegetation for the medium emissions 50th percentile sea-level rise scenario in 20 years' time (2042)
- Predicted boundary of less dense vegetation for the medium emissions 50th percentile sea-level rise scenario in 20 years' time (2042)
- Dense vegetation boundary mapped by the National Vegetation Survey (NVC) 2021 survey
- Less dense vegetation boundary mapped by the National Vegetation Survey (NVC) 2021 survey
- Predicted highest astronomical tide for the medium emissions 50th percentile sea-level rise scenario in 20 years' time (2042)

Client: Wirral Borough Council

Project: Hoylake Beach Geomorphology and Ecology Study

Title: Predicted positions of the dense and sparse vegetation, and HAT in 20 years (2042)

Figure: 5-2

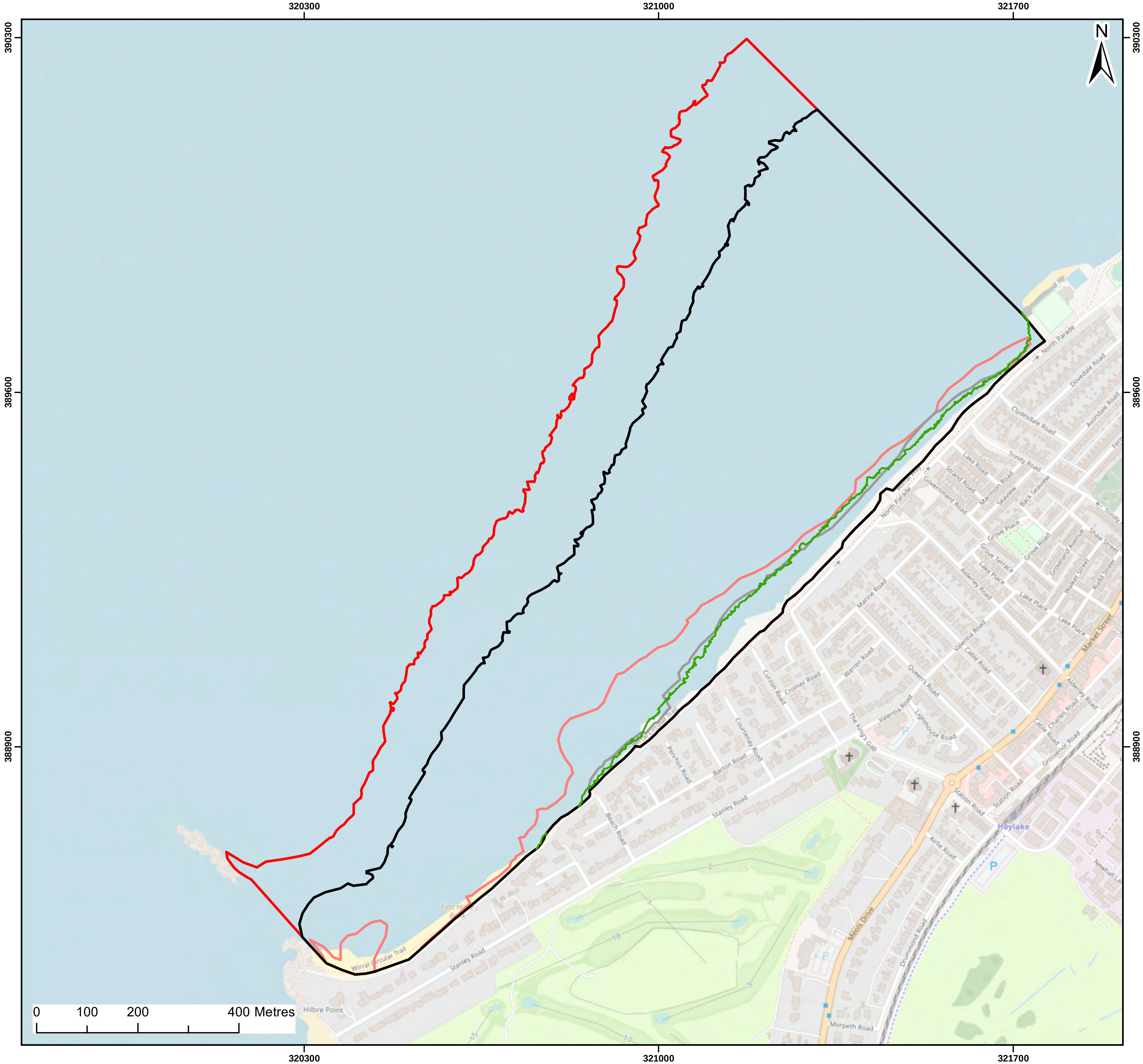
Drawing No: PC2553-RHD-ZZ-XX-DR-Z-0012

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
P03	29/11/2021	JT	DB	A3	1:6,500
P02	15/11/2021	JT	DB	A3	1:6,500

Co-ordinate system: British National Grid

Royal HaskoningDHV
Enhancing Society Together

ROYAL HASKONINGDHV
INDUSTRY & BUILDINGS
2 ABBEY GARDENS
GREAT COLLEGE STREET
LONDON
SW1P 3NL
+44 (0)20 7222 2115
www.royalhaskoningdhv.com



Legend:

- Predicted boundary of dense vegetation for the medium emissions 50th percentile sea-level rise scenario in 50 years' time (2072)
- Predicted boundary of less dense vegetation for the medium emissions 50th percentile sea-level rise scenario in 50 years' time (2072)
- Dense vegetation boundary mapped by the National Vegetation Survey (NVC) 2021 survey
- Less dense vegetation boundary mapped by the National Vegetation Survey (NVC) 2021 survey
- Predicted highest astronomical tide for the medium emissions 50th percentile sea-level rise scenario in 50 years' time (2072)

Client:	Project:
Wirral Borough Council	Hoylake Beach Geomorphology and Ecology Study

Title: Predicted positions of the dense and sparse vegetation, and HAT in 50 years (2072)

Figure: 5-3 | Drawing No: PC2553-RHD-ZZ-XX-DR-Z-0013

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
P03	29/11/2021	JT	DB	A3	1:7,500
P02	15/11/2021	JT	DB	A3	1:7,500

Co-ordinate system: British National Grid

Royal HaskoningDHV
Enhancing Society Together

ROYAL HASKONINGDHV
INDUSTRY & BUILDINGS
2 ABBEY GARDENS
GREAT COLLEGE STREET
LONDON
SW1P 3NL
+44 (0)20 7222 2115
www.royalhaskoningdhv.com

Vegetation communities (SM13 and SM6) and species associated with pioneer and low marsh are currently present at Hoylake, including Common saltmarsh-grass, Sea Aster, annual Glasswort agg, annual Sea-blite and Common Cordgrass. The migration of these plant community zones primarily depends on relative sea-level rise and accretion rates, and the availability of land at a suitable base elevation (Feagin *et al*, 2010).

Conversely to much of the UKs coastal habitats, which are being lost through a process of coastal squeeze, as the low water mark migrates landwards in response to sea-level rise, the beach at Hoylake is predicted to accrete by 0.22mm/year, resulting in a low water mark that will be seaward of its current position in future years. Therefore, as the future distribution of saltmarsh is largely predetermined by the accretion rate, it is likely that in years 10, 20 and 50 that the area suitable for colonisation of pioneer and low, middle, and high marsh zones (and comprising species) will increase in extent and migrate seaward (**Figure 5-1**, **Figure 5-2** and **Figure 5-3**).

What is less certain is how the zonation of saltmarsh will develop over time, as saltmarsh zones may fluctuate in location and land cover due to variations in underlying topography (Davey, 2002). At a finer scale, variations in vertical zonation and species composition may also be present should there be variations in microtopography (hummocks and hollows) (Mossman *et al*., 2019; Stribling *et al.,* 2007).

The historic recorded plant communities and coastal evolution between Birkdale and Ainsdale, located on the Sefton shoreline between Liverpool and Southport, may have similarities with Hoylake's common saltmarsh-grass dominated vegetation and can be used as an analogy as to how the ecology at Hoylake Beach could develop over time. From 1986 onwards, the area between Birkdale and Ainsdale began to be vegetated by common saltmarsh-grass, which in turn trapped sand, eventually forming a zone of embryo dune, with the area becoming known as 'Birkdale Green Beach'. This change in habitat from scattered common saltmarsh-grass to embryo dune 30-35m wide occurred over a period of two- to three-years, and was 0.5-1m in high in five years (Smith and Lockwood, 2021) (**Figure 5-4** and **Figure 5-5**).

Figure 5-4. New Green Beach at Birkdale in May 2005, showing initial colonisation by P. maritima (Smith and Lockwood, 2021)

Figure 5-5. Proto-dunes forming around P. maritima with Cakile maritima at New Green Beach, September 2008 (Smith and Lockwood, 2021)

5.2.2 Potential Future Sand Dune Development

The formation of sand dunes requires a supply of dry sand and wind to transport it (Defra, 2007). Onshore winds transport sand particles downwind of the strand line, where it accumulates, forming embryo dunes. These embryo dunes grow and extend if the accumulation of sand outpaces the rate of erosion. Dune plant species, which can tolerate high salinity levels, such as Sand couch, Sea Sandwort *Honckenya peploides*, Sea rocket, Prickly saltwort *Salsola kali*, Sea mayweed and Orache Spp. are able to colonise these embryo dunes. Although not essential for the formation of sand dunes, vegetation can greatly affect the morphology and movement of dune systems (Defra, 2007). Behind developing embryo dunes, foredunes can establish. With comparatively more vegetation cover than embryo dunes stabilising the foredune, these can stay in position for a number of years. Further stages of dune succession can form semi-fixed and fixed dune systems, and dune slacks, which support varying plant communities.

At Hoylake, the area of land above HAT is predicted to increase as HAT moves seaward as a result of accretion (**Table 5.2**). Protected from the effects of wave action and erosion, similar habitats to Birkdale could begin to develop between HAT and the seawall, particularly given that many of the species associated with strandline and embryo dunes are already present.

The oldest areas of habitat above HAT would be nearest to the current seawall, with new embryo and proto-dune likely to extend seaward as land above HAT increases in area and the interface between saltmarsh and early dune systems shifts with changes in season tidal levels over time. How these habitats will develop temporally will be influenced by a multitude of abiotic and biotic factors, including disturbance and erosion, climatic conditions, changes in soil chemistry and composition, and impacts of species present on their environment.

Wind-blown sand accretion would occur on the upper beach at Hoylake, and the presence of sand dune vegetation can further increase the accumulation of sand as it is trapped around both living and dead plant matter. Whilst this, and the development of saltmarsh, may reduce wind-blown sand nuisance, sand dune development has the potential to result in higher beach levels than that predicted by this study. Should dune height exceed that of the existing sea wall, there is the potential that the dune could migrate landwards, affecting local roads and houses.

5.3 Morphological and Ecological Change for the Do Everything Scenario

For the Do Everything scenario, Hoylake Beach would be managed over 10, 20 and 50 years, so that all vegetation is removed, i.e. there would be no ecological change; hence, the morphological development of the beach would be similar to the Do Nothing scenario because the rate of accretion would not be significantly altered by the management practices (**Table 3.1**).

The clearing of vegetation (by whatever means is determined) would be completed without removal of the sediment. Hence, the future accretion rate for Do Everything would be broadly similar to Do Nothing, and the elevation of the beach would rise and expand seaward relative to future sea level. However, the removal of sand dune vegetation would reduce the rate of sand accumulated by dune formation, meaning that the higher beach levels resulting from dune formation would not occur.

Wind-blown sand nuisance could increase due to the non-vegetated beach providing a larger surface area for wind to dry intertidal sand and transport it landward, without the trapping efficiency of the vegetation under the Do Nothing scenario. This source of sand and its transport onshore by wind could overtop the seawall and enter the areas landward affecting local roads and houses.

6 Natural Capital Value

A Natural Capital Value assessment was carried out on the shoreline management scenarios by Liverpool John Moores University (see **Appendix C**).

Natural capital is defined as the "elements of nature that directly or indirectly produce value or benefits to people, including ecosystems, species, freshwater, land, minerals, the air and oceans, as well as natural processes and functions"[3]. Ecosystem services are defined as being "the aspects of ecosystems utilized (actively or passively) to produce human well-being"[4].

The major benefits of natural capital to humans include ecosystem services such as: the supply of timber from trees, the supply of fish for consumption, erosion control, crop pollination, water filtration, carbon storage to reduce the impact of climate change, noise reduction, air pollution reduction and the maintenance of greenspaces and biodiversity for the benefit of ecosystems and human recreation, with benefits to mental and physical health. Natural capital is therefore critically important for the maintenance of a high quality of life for human populations.

In this study, ecosystem service models have been used to examine the change in ecosystem service provision from Hoylake Beach in its current state compared to projected future states of the beach caused by climate change-induced sea level rise, natural sediment accretion and possible future beach management scenarios.

The findings of the Natural Capital Value assessment are as follows:

- Carbon sequestration and storage potential are expected to increase strongly under the Do Nothing scenario as vegetation colonises the study area, with an additional 245 tC sequestered every year and a 50% increase of current carbon stocks after 50 years.
- Carbon sequestration and storage potential are expected to decrease slightly under the Do Everything scenario, with a 6% lower sequestration capacity and a loss of around 326 tC from current carbon stocks.
- The provision of ecosystem services is broadly predicted to increase under the Do Nothing scenario, with green space access, air purification, noise pollution reduction and pollination showing increasing capacity over time.
- The provision of ecosystem services is broadly predicted to decrease under the Do Everything scenario, with pollination, noise pollution reduction and air purification showing a decreasing trend over time. The exception is access to nature which is expected to increase.

[3] *Natural Capital Committee. 2014. Towards a Framework for Defining and Measuring Changes in Natural Capital. Working Paper 1, Natural Capital Committee.*

[4] *Fisher, B., Turner, R. K., Morling, P. 2009. Defining and classifying ecosystem services for decision making. Ecological Economics, 68(3): 643-653.*

7 Flood Risk Assessment

This section assesses the future flood risk at Hoylake due to climate change by determining how the Annual Exceedance Probability (AEP) of the flood extent according to the Flood Zone 3 dataset (FZ3) is predicted to change into the future for both management scenarios (Do Nothing / Do Everything).

Although detailed flood risk assessments are available (e.g. AECOM, 2016), a review highlights that these do not make use of the most recent data (e.g. an update to the Coastal Flood Boundary Dataset has since been published by the Environment Agency, 2018) and do not cover the entire Hoylake frontage in detail (i.e. overtopping calculations have been performed using a topographic profile that is not representative for the whole frontage).

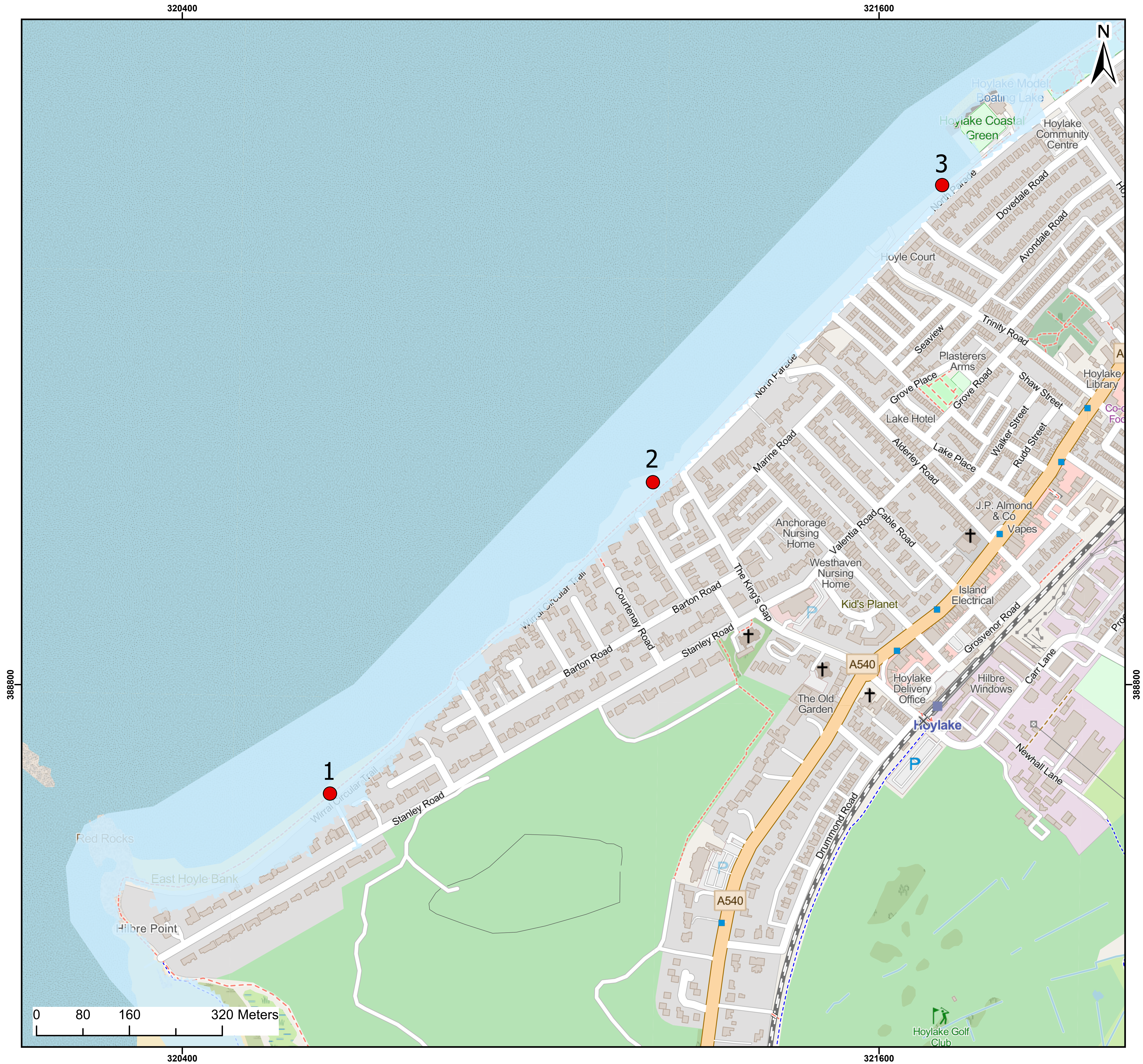
The most consistent and complete overview of the areas in Hoylake with a 1 in 200 (0.5% AEP) or greater chance of flooding from the sea each year is presented in the Environment Agency's FZ3. This dataset was initially based on a coarse nationwide model but has since been updated locally with more detailed flood modelling. It ignores the presence of flood defences; this implicitly means wave overtopping is not included. The reliability of this review is directly linked to the quality of the dataset used. Due to the nature of the FZ3 dataset, it is not clear from which initial study the flood extent at Hoylake originates, or which water level conditions were used to drive the modelling. It is recommended that a detailed flood risk assessment, informed by the latest data, focussed locally on Hoylake, is performed as part of any future BMP.

7.1 Sources of Flood Risk

For the purpose of this flood risk assessment in the context of beach management, the dominant source of tidal flooding at Hoylake is Still Water Level (SWL) flooding. Typically, coastal flooding can be caused by either SWL flooding, wave overtopping, or a combination of the two. Although wave run-up and overtopping of the seawall at Hoylake is likely to occur, especially along the promenade, it will not be a major source of flooding for the area behind the seawall. There is little opportunity for the overtopped volume to accumulate behind the defences as the topography is sloping upwards in a landward direction, and the water will flow back to the sea instead. Apart from some local areas along the western part of the coast and along North Parade, this is the case along the whole frontage, justifying the use of the FZ3 dataset for this study. **Figure 7-1** and **Figure 7-2** highlight the areas at risk of flooding from a 1 in 200 year event (FZ3). They show that flooding is mainly confined to the frontage just behind the sea wall; however, wave run-up can cause a direct hazard or nuisance for the road and its users, and for the lower lying parts of properties.

Groundwater flooding is caused when the water table within the underlying strata rises to above ground level, causing flooding to occur at the surface. The areas most at risk can be low-lying areas or where the ground water table is at a naturally shallow depth. The Environment Agency's Areas Susceptible to Ground Water Flooding (AStGWF) map[5] suggests that the coastal fringes to the east and northeast together with the northwest of the Wirral could be susceptible to groundwater flooding (see **Figure 7.3**). However, the production of these maps was based on limited geological information and does not take account of groundwater rebound following reductions in water abstraction. In addition, the maps show 1km grid squares where geological and hydrogeological conditions show that groundwater might emerge but it is likely that only isolated locations within the overall susceptible area are actually likely to suffer the consequence of groundwater flooding (Wirral Council, 2011).

[5] *https://data.gov.uk/dataset/f0329412-b46a-49b0-9f30-abef8c4b807e/groundwater-flooding-susceptibility*



Legend:

- Flood Zone 3
- 3D Image Points

Source: © Haskoning DHV UK Ltd, 2021;
Contains OS data © Crown copyright and database right, 2021.
Map data © OpenStreetMap contributors, Microsoft, Esri Community Maps contributors, Map layer by Esri
Contains OS data © Crown Copyright and database right 2020

Client:	Project:
Wirral Borough Council	Hoylake Beach Geomorphological Review

Title: Hoylake Flood Zone 3

Figure: 7.1 | Drawing No: Project code or BIM number

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
P01	10/01/2022	OB	RMB	A3	1:6,554

Co-ordinate system: British National Grid

Royal HaskoningDHV
Enhancing Society Together

ROYAL HASKONINGDHV
RESILIENCE UK
WESTPOINT
PETERBOROUGH BUSINESS PARK
PETERBOROUGH
PE2 6FZ
+44 (0)1733 334455
www.royalhaskoningdhv.com

Figure 7-2. 3D Images taken from ground-level view function in Google Earth. Locations are shown on Figure 7.1.

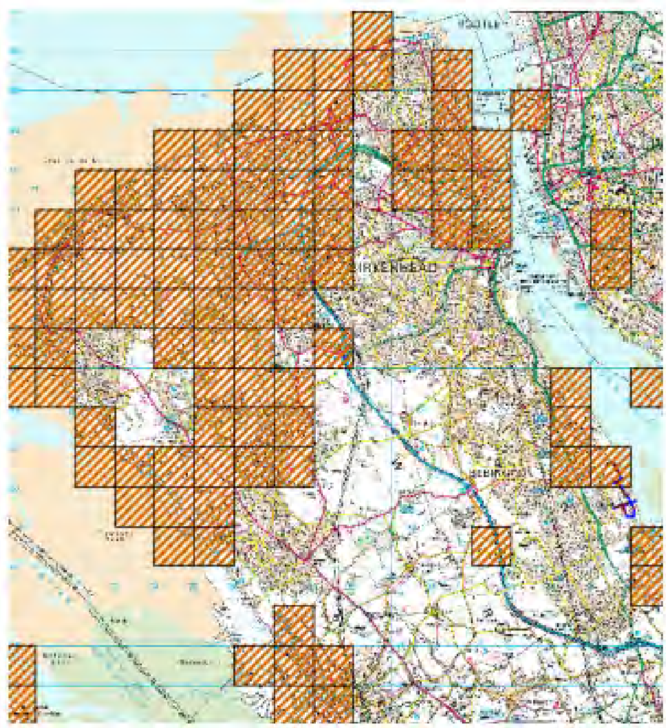


Figure 7-3 Environment Agency AStGWF Map for the Wirral (Source: Wirral Council, 2011)

7.2 Do Nothing and Do Everything Scenarios

The Do Nothing scenario involves leaving the beach to develop naturally without any human interference. In this scenario, there is predicted accretion leading to an increase in the vegetated area along the beach and development of sand dunes. In the Do Everything scenario, total removal of all vegetation would occur.

In both scenarios the beach has no influence on SWL flooding. In the Do Nothing scenario the developing dune system could start to have a flood defence function, should the dunes potentially grow higher than the sea wall, reducing the impact of waves. This would however not affect the scale of the flood zone because that would require a continuous, uninterrupted row of dunes; any gap in the alongshore arrangement of the dunes would lead to a breach, in which case the risk of SWL flooding is similar. Therefore, in both scenarios, changes in future flood risk are expected to be similar, and SWL flooding will continue to be the dominant source of tidal flooding.

Although it is not considered as a source of flooding, it is worth noting the potential impact of the changing beach on the likelihood and impact of wave overtopping and run-up. The Do Nothing scenario would likely decrease the wave impact at the defences due to the extensively vegetated beach, which is known to effectively dampen wave energy. The Do Nothing scenario would reduce the direct hazard and nuisance of wave run-up on the road, its users and the lower lying parts of properties; however, there is also a risk that a developing dune system could form a barrier against any overtopped water flowing back to the sea, and could thus enhance flooding in some locations and under certain conditions.

Should the Do Nothing and/or Do Everything scenarios affect groundwater levels, e.g. from changing beach levels, this has the potential to affect groundwater flooding behind the sea wall.

7.3 Annual Exceedance Probability

The AEP of FZ3 is 0.5%; it has a 200-year return period. For the purposes of this study, and given the nature of the flood risk in the area, it was not deemed necessary or appropriate to perform advanced modelling of overtopping and 2D flood spreading modelling. Alternatively, a constant SWL flood extent has been selected (FZ3). In the future, and assuming no other changes, this same flood extent will occur due to the same high sea-level conditions; however, with climate change (sea-level rise) these high sea-level conditions will become more likely. Extreme sea levels are expected to become more common and therefore the return period of the expected flood extent is expected to reduce.

The change in return period is based on same climate change scenario used in the morphological change predictions (medium emissions 50th percent confidence level)[6]. In accordance with common practice, it was assumed that the distribution of extreme sea levels does not change, and that all values in the extreme sea-level distribution are affected equally by sea-level rise. Therefore, all extreme values taken from the Coastal Flood Boundary Dataset (CFDB) of the Environment Agency (2018), can be projected into the future by adding sea-level rise. The extreme sea levels from the CFDB at Hoylake (point 1886) are presented in **Table 7.1** alongside their future values.

[6] It should be noted that current EA guidance is to use the 95th Percentile medium emissions scenario, with appropriate sensitivity analysis in flood and coastal erosion risk management considerations.

Table 7.1. Coastal Flood Boundary Dataset (CFBD) return period levels applicable at Hoylake (ref point 1886) in metres OD, projected into the future under a medium emissions 50th percentile climate change scenario

Return Period	2017	2032	2042	2072
1	5.33	5.39	5.43	5.58
2	5.43	5.49	5.53	5.68
5	5.57	5.63	5.67	5.82
10	5.67	5.73	5.77	5.92
20	5.77	5.83	5.87	6.02
25	5.80	5.86	5.90	6.05
50	5.88	5.94	5.98	6.13
75	5.95	6.01	6.05	6.20
100	5.98	6.04	6.08	6.23
150	6.03	6.09	6.13	6.28
200	6.08	6.14	6.18	6.33
250	6.11	6.17	6.21	6.36
300	6.13	6.19	6.23	6.38
500	6.20	6.26	6.3	6.45
1000	6.29	6.35	6.39	6.54
10000	6.64	6.70	6.74	6.89

Figure 7-4 (blue line) shows the relationship between the return periods and the extreme water levels. In the current situation (point 1), conditions with a 35-year return period cause a 5.8m OD water level. With sea-level rise of 0.25m (50 years into the future), these same conditions will cause a 6.02m OD water level (point 2). That water level is the current 200-year return period water level (point 3), which would cause the FZ3 flood extent.

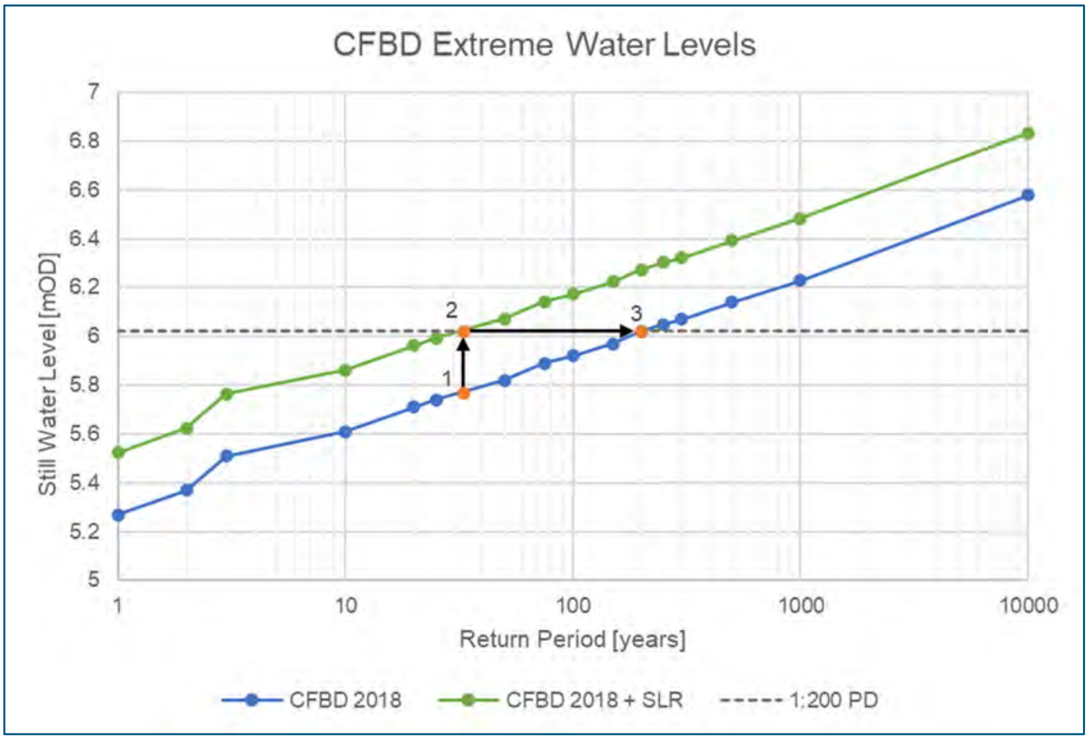


Figure 7-4. Extreme still water levels from the Coastal Flood Boundary dataset for Hoylake (blue line). Green line indicates the future effect of sea-level rise

Figure 7-5 shows the application of this approach for a 200-year return period and the chosen sea-level rise scenario. In both the Do Nothing and Do Everything scenarios, the return period associated with the flood extent in FZ3 will reduce from 200 years to 36 years in 2072. **Table 7.2** presents the AEPs in 10, 20 and 50 years.

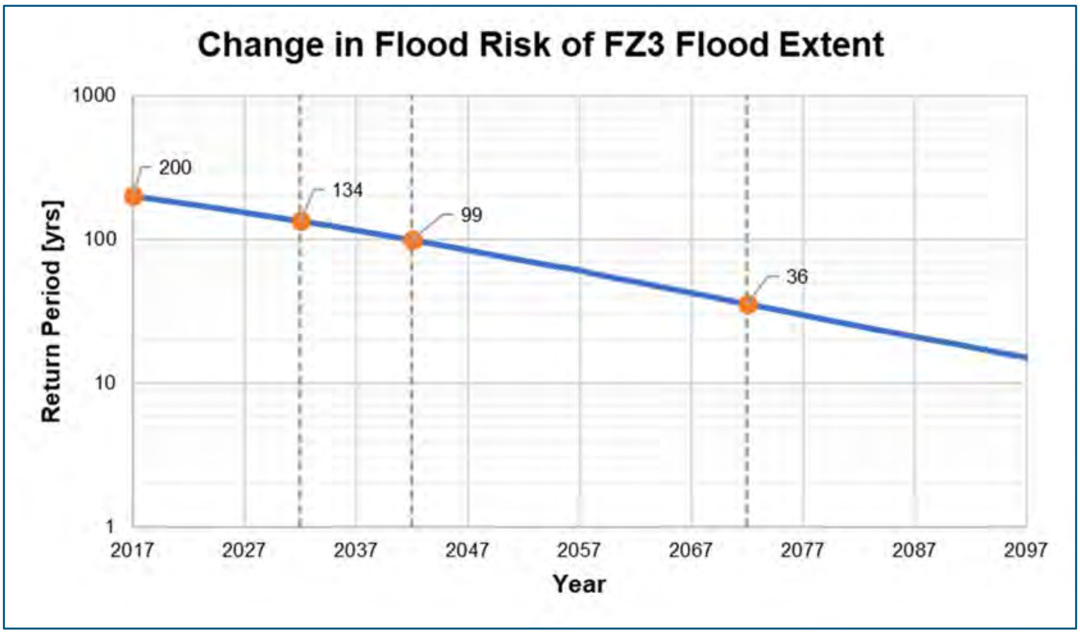


Figure 7-5. Estimated future flood risk associated with FZ3, based on sea-level rise under a medium emissions climate change scenario. Dashed grey lines indicate 10, 20 and 50 years from the present day, and the orange dots indicate the corresponding future return periods

Table 7.2. Estimated return period of the FZ3 flood extent in 10, 20 and 50 years

Year	Return Period (years)
2017	200
2032	134
2042	99
2072	36

8 Opportunities and Constraints

There is a critical balance to achieve between the need for management and the need to maintain the ability of the natural shoreline to adjust to change. This section appraises the opportunities and constraints of the Do Nothing and Do Everything scenarios using criteria included in four appraisal elements:

- environment: potential impacts on morphological and ecological systems;
- flood and coastal erosion risk: issues of flooding and coastal erosion related to sea-level rise;
- Natural Capital Value: potential impacts to ecosystem services; and
- beach use: implications for visitors and public access.

The method that was adopted is a RAG (Red, Amber, Green) traffic-light assessment (**Table 8.1**). For each scenario, the table provides the appraisal element and criteria, and columns where the results of the appraisal are summarised. The colours represent the following:

- Red shading: approach does not meet defined criterion;
- Amber shading: approach does meet defined criterion in some aspects, but there are aspects which are negative or undesirable; and
- Green shading: approach fully meets defined criterion.

Table 8.1. RAG assessment for Do Nothing and Do Everything scenarios at Hoylake

Element	Criteria	Do Nothing	Do Everything
Environment	Working with natural processes	Maintains the evolving nature of the coastal landscape	Significantly alters the natural development of the coastal landscape
	Biological diversity and longevity	Increased through the development of more complex saltmarsh and sand dunes	Significant decrease from the prevention of vegetation growth
	Wind-blown sand hazards for adjacent road and properties	Increase if sand dune system develop close to the seawall	Increase due non-vegetated beach providing a larger source of wind-blown sand
Flood and coastal erosion risk	Flood zone extent	Area unchanged	Area unchanged
	Flood defence function	Developing dune system could have a flood defence function	No sand dunes that would perform a potential flood defence function
	Wave attenuation/dissipation	Vegetated beach would increase attenuation and/or dissipation of waves	Non-vegetated beach would provide less attenuation and/or dissipation of waves
Natural Capital Value	Carbon sequestration and storage potential	Increase due to vegetation colonisation	Decrease if vegetation is prevented from establishing
	Ecosystem services	Increase due to increased vegetation, green space access, air purification, noise pollution reduction and pollination	Decrease due to prevention of vegetation growth, with pollination, noise pollution reduction and air purification decreasing. Access to nature is expected to increase
Beach use	Recreational use	Decrease due to reduced beach area	Increase due to maintained sandy beach
	Impact on access to and along the coast	Development of saltmarsh and dunes could impede access	No change to access
	Management zoning	No management zoning in this scenario	No management zoning in this scenario

9 Conclusions and Recommendations

9.1 Conclusions

This study has predicted that Hoylake Beach will accrete into the future, based on historical morphological change and projected sea-level rise using the medium emissions climate change scenario 50% confidence level. The beach accretion is predicted to outpace projected sea-level rise, and consequently beach levels will rise and tidal datums, including MHWN, MHWS and HAT, will migrate seawards.

Due to this progressive movement of the tidal datums, if no management takes place (Do Nothing scenario), the existing dense and sparse vegetation boundaries (as mapped by an NVC survey in 2021) will also migrate seawards, concomitantly increasing their areas across the beach. The predicted seaward movement of HAT would create space landward of HAT for development of sand dunes in front of the seawall, which would increase in area over time.

For a fully managed system (Do Everything scenario), Hoylake Beach would be managed to remove all vegetation. The accretionary evolution of the beach would be similar to the Do Nothing scenario but without any vegetation. The vegetation would be cleared without loss of the underlying sediment. Wind-blown sand nuisance could increase due to the non-vegetated beach providing a larger surface area for wind to dry intertidal sand and transport it landward, without the trapping efficiency of the vegetation under the Do Nothing scenario. This source of sand and its transport onshore by wind could overtop the seawall and enter the areas landward affecting local roads and houses

However, the presence of sand dune vegetation under the Do Nothing scenario can further increase the accumulation of sand as it is trapped around both living and dead plant matter. Whilst this, and the development of saltmarsh, may reduce wind-blown sand nuisance, sand dune development has the potential to result in higher beach levels than that predicted by this study. Should dune height exceed that of the existing sea wall, there is the potential that the dune could migrate landwards, affecting local roads and houses.

In terms of Natural Capital Value, there are differences depending on the scenario. For Do Nothing, carbon sequestration and storage potential would increase, whereas for Do Everything they would decrease. The provision of ecosystem services is likely to increase for Do Nothing, whereas there is a predominantly decreased provision for Do Everything. The exception is access to nature which is expected to increase.

From a flood-risk perspective, the beach would have no influence on still water level flooding, regardless of the scenario. The Do Nothing scenario would reduce the direct hazard and nuisance of wave run-up on the road, its users and the lower lying parts of properties; however, there is also a risk that a developing dune system could form a barrier against any overtopped water flowing back to the sea, and could thus enhance flooding in some locations. Should the Do Nothing and/or Do Everything scenarios affect groundwater levels, e.g. from changing beach levels, this has the potential to affect groundwater flooding behind the sea wall.

9.2 Recommendations

The following additional studies are considered necessary to support the development of the BMP:

- Before the BMP is developed it is recommended that a botanical survey be carried out in spring, summer, and early autumn to ensure that a full list of species growing on the site is generated.
- Should future beach management include for continuing Green beach development, a yearly botanical survey should be repeated to monitor the progress of colonisation. An NVC survey should be repeated in five years, to map the progress of vegetation communities colonising the site and document their evolution.
- Due to the nature of the FZ3 dataset, it is not clear from which initial study the flood extent at Hoylake originates, or which water level conditions were used to drive the modelling. It is recommended that a detailed flood risk assessment, informed by the latest data, focussed locally on Hoylake, is performed as part of any future BMP.
- A review of groundwater behaviour behind the sea wall and how potential future beach management actions could impact on behaviour should be undertaken to inform the BMP.
- Beach levels and sediment accretion rates should be continued to be monitored to validate the assumptions made in this study and to inform future management of the beach.
- Further investigation of the effects of wind blown sand and sand dune development should be undertaken to understand how this could affect future beach levels.

10 References

AECOM. (2016). Habitats Regulations Screening Assessment and Application for SSSI Assent Relating to Beach Management Operations at Wirral Beaches. March 2016.

Brown, J.M., Souza, A.J. and Wolf, J. (2010). An 11-year validation of wave-surge modelling in the Irish Sea, using a nested POLCOMS-WAM modelling system. Ocean Modelling, 33, 118-128.

Brown, J.M., Amoudry, L.O., Mercier, F.M. and Souza, A.J. (2013). Intercomparison of the Charnock and COARE bulk wind stress formulations for coastal ocean modelling. Ocean Science, 9, 721-729.

Coastal Engineering. (2015). North West Strategic Monitoring Regional Sediment Analysis and Reporting 2015. Intertidal Report November 2015.

Davy, A. (2002). Development and Structure of Salt Marshes: Community Patterns in Time and Space. In: Weinstein M.P., Kreeger D.A. (eds) Concepts and Controversies in Tidal Marsh Ecology. Springer, Dordrecht.

Defra. (2007). Sand dune processes and management for flood and coastal defence. Part 2: Sand dune processes and morphology. R&D Technical Report FD1392/TR.

Environment Agency. (2007). Saltmarsh Management Manual – R&D Technical Report SC030220.

Environment Agency. (2018). Coastal Design Sea Levels - Coastal Flood Boundary Extreme Sea Levels (2018). Update 22 June 2021. Retrieved from: https://data.gov.uk/dataset/73834283-7dc4-488a-9583-a920072d9a9d/coastal-design-sea-levels-coastal-flood-boundary-extreme-sea-levels-2018

Feagin, R.A., Luisa Martinez, M., Mendoza-Gonzalez, G. and Costanza, R. (2010). Salt marsh zonal migration and ecosystem service change in response to global sea level rise: a case study from an urban region. Ecology and Society. Volume 15, 14.

Foster, N.M., Hudson, M.D., Bray, S. and Nicholls, R.J. (2013). Intertidal mudflat and saltmarsh conservation and sustainable use in the UK: A review. Journal of Environmental Management, 126, 96-104.

Halcrow. (2010). North West England and North Wales Shoreline Management Plan SMP2. Report to the North West and North Wales Coastal Group in July 2010.

Halcrow. (2018). Wirral Coastal Processes Report. Report to Wirral Metropolitan Borough Council.

Jemmett, A., and Smith, T. (2000). The Beaches at West Kirby and Hoylake – Option for Managing Wind Blown Sand and Habitat Change. January 2000.

Joint Nature Conservation Committee. (2004). Common Standards Monitoring Guidance for Sand Dune Habitats (August 2004).

Langlois, E., Bonis, A. and Bouzillé, J.B. (2001). The response of Puccinellia maritima to burial: A key to understanding its role in salt-marsh dynamics? Journal of Vegetation Science, 12.

Mossman, H., Grant, A. and Davy, A. (2019). Manipulating saltmarsh microtopography modulates the effects of elevation on sediment redox potential and halophyte distribution. Journal of Ecology, 108.

Pye, K. (1996). Evolution of the shoreline of the Dee Estuary, United Kingdom. In: Nordstrom, K.F. and Roman, C.T. (Eds.) Estuarine Shores: Evolution, Environments and Human Alterations. John Wiley & Sons Ltd, 14-37.

Pye, K. and Blott. S. (2009). Potential implications of future sea level rise for estuarine sediment budgets and morphology in Northwest England and North Wales. Report to Halcrow Group Limited, Cell Eleven Tidal and Sediment Transport Study (CETaSS) Stage 2, October 2009, Swindon, UK.

Rodwell, J.S. (2006). National Vegetation Classification: Users' Handbook. JNCC. Peterborough.

Ruffino, L. (2021). National Vegetation Classification (NVC) Survey Hoylake Shore.

Stace, C. (2019). New Flora of the British Isles. Fourth Edition. Cambridge University Press.

Smith, P.H. and Lockwood, P.A. (2021). Fifteen years of habitat, floristic and vegetation change on a pioneer sand-dune and slack system at Ainsdale, north Merseyside, UK. British & Irish Botany, 3, 232-262.

Stribling, J. M., Cornwell, J.C. and Glahn, O.A. (2007). Microtopography in Tidal Marshes: Ecosystem Engineering by Vegetation? Estuaries and Coasts, 30, 1007–1015.

Styles, J. (2021). North Wirral Foreshore [Hoylake] Botanical Survey.

Wirral Borough Council. (2003). Annual Coastal Process Inspection – October 2002. Shoreline Management Partnership.

Wirral Council. (2009). Annual Coastal Process Inspection – October 2008. Coastal Engineering UK Ltd.

Wirral Council. (2011). Preliminary Flood Risk ASSESSMENT REPORT file:///C:/Users/303543/Box/PC2553%20Hoylake%20Beach%20Ecology%20and%20Geomorphology%20Study/PC2553%20Hoylake%20Team/PC2553%20%20TECHNICAL%20DATA/Incoming%20Data/Preliminary%20Flood%20Risk%20Assessment%20.pdf

Wirral Council. (2014). Annual Coastal Process Inspection – July 2013. Coastal Engineering UK Ltd.

Wirral Council. (2019). Annual Coastal Process Inspection – July 2018. Coastal Engineering UK Ltd.

Wirral Council. (2022 – in press). Annual Shoreline Inspection - June 2021. Coastal Engineering UK Ltd.

Woodworth, P.L., Tsimplis, M.N., Flather, R.A. and Shennan, I. (1999). A review of the trends observed in British Isles mean sea level data measured by tide gauges. Geophysical Journal International, 136, 651–670.

Woodworth, P.L. (2017). Sea level change in Great Britain between 1859 and the present. Geophysical Journal International, 18, 15pp.

Appendix A: Natural England Advice to Wirral Council Regarding Beach Management

Natural England advice to Wirral Council regarding beach management

Natural England's statutory purpose, as set out in the Natural Environment and Rural Communities Act 2006, is to ensure that the natural environment is conserved, enhanced and managed for the benefit of present and future generations, thereby contributing to sustainable development. Our role includes providing advice to others, being a regulator and working in partnership with others including public bodies.

The following information forms the basis of Natural England's advice related to the challenges Wirral Council are facing in managing the Wirral coastline. In providing this we recognise the environment is dynamic, there are statutory requirements and strong interests and views which are often in conflict. It should also be noted that in the intertidal area there may be other statutory bodies that may need to be consulted, such as the Environment Agency and Marine Management Organisation.

Natural England's advice is provided in the following sections:

- Summary of statutory sites on the Wirral coastline
- Statutory sites at Hoylake
- Coastal dynamics
- Factors driving growth of foreshore vegetation
- Vegetation control
- Drainage
- Wider values and opportunities
- Issues that could be picked up within a wider plan
- Ideas for way forward

Natural England advice is provided from the perspective of its statutory role in giving advice on protected sites.

<u>Summary of statutory sites on the Wirral coastline</u>

- Nearly the whole of the Wirral coastline is covered by a range of overlapping statutory designations including nationally important Sites of Special Scientific Interest (SSSIs) and international Special Protection Areas (SPA), Special Areas of Conservation (SAC) and Ramsar Wetland sites.
- The SSSIs of Wirral coastline are: Mersey Estuary, Mersey Narrows, North Wirral Foreshore, Dee Estuary and Red Rocks. These sites are all important for their non-breeding birds with some important for features including saltmarsh, intertidal sediment communities, sand dunes and breeding birds.

- The SPAs and Ramsar sites are: Mersey Estuary, Mersey Narrows and North Wirral Foreshore, Dee Estuary and Liverpool Bay (SPA only). These are all important for non-breeding birds with Dee Estuary also being important for some breeding birds.
- The SAC: Dee Estuary, note this extends on to the North Wirral Foreshore. This is important for a range of features including its intertidal sediments, reefs, saltmarsh and sand dunes.
- Information relating to the designated sites including Conservation Objectives, Supplementary Advice on Conservation Objectives and the Advice on Operations are available on Natural England's designated sites view system. Geographic information on the designated sites and other information relating the natural environment can be found on the following website: magic.defra.gov.uk
- Wirral Council, Natural England and other public bodies have several statutory conservation duties:
    - To further the conservation and enhancement of SSSIs – Section 28G of the Wildlife and Countryside Act 1981 (as amended),
    - Statutory duty to conserve biodiversity - Section 40 of the Natural Environment and Rural Communities Act 2006 (NERC Act). Specific habitats and species are identified, through Section 41 (NERC Act 2006) identified as being of principle importance for conserving biodiversity. Lists of Priority habitats
    - The Conservations of Habitats and Species Regulations 2017 (as amended) (aka the Habitat Regulations) includes a duty of competent authorities (as defined in Regulation 7) to have regard for the requirements of the Habitats and Wild Birds Directive in the exercise of their statutory functions (Regulation 9(3)).
    - Further guidance on public bodies responsibilities for SSSIs can be found from the following webpage: https://www.gov.uk/guidance/sites-of-special-scientific-interest-public-body-responsibilities

Statutory sites at Hoylake (see Annex 1 for some further detail)

- The foreshore at Hoylake is included in the following statutory sites: North Wirral Foreshore SSSI (unit 1 East Hoyle Bank), Mersey Narrows and North Wirral Foreshore SPA/Ramsar site and Dee Estuary SAC.
- North Wirral Foreshore SSSI is designated for the following features: aggregations of non-breeding water birds and especially bar-tailed godwit, dunlin, knot and turnstone, intertidal sediments and saltmarshes.
- Wetland Bird Survey (WeBS) Alerts (using WeBS data from 2014/15 to 2018/19) indicate bar-tailed godwit, knot and turnstone on North Wirral Foreshore SSSI have significant declines which would lead to these features and so the site to be in unfavourable condition.
- Liverpool Bay SPA, a marine site is located off Hoylake but it is below mean low water.

Coastal dynamics

- Sea level rise and coastal change are inevitable. Sustainable coastal management needs to take account of natural coastal change.
- Coastal conservation is often about understanding the way in which the physical system underpins the presence of individual habitats or species. Management for habitat and species features must to take account of coastal dynamics.

- As the coast changes so the mosaic of habitats and species as well as the landscape and its 'local distinctiveness' will change and evolve. Understanding the reasons for change must be factored into management decisions to ensure the best possible outcomes for the natural environment. Reasons for change will include the wider geomorphological processes, sources of sediment supply, constraints on sediment movements, wider scale sediment dredging or disposal and climate change.
- Development of pioneer vegetation that will eventually develop in to sand dunes or saltmarsh is a natural stage in the coastal change process. It is probably not possible to fully predict how the habitats will develop, however the situation at this location is likely to be different to that at Parkgate eg due to levels of exposure to winds, tides and waves and differences in sediment supply. It may be more likely that there is more development of dune habitats than saltmarshes.
- Management of the coastline should focus upon working with coastal processes that enable a dynamic environment resilient sea level rise.
- There is a need to conserve, manage and sustain sediment supplies that feed coastal systems and the landscapes and habitats they support.
- Management interventions such as raking and spraying will impact on the natural development of habitats and so geomorphological processes and sediment movement.
- Sustainable coastal management will need to incorporate adaptation measures in both short and long-term.
- Further information on the geomorphological regime and influences may be obtainable from the NW Coastal Group and the Shoreline Management Plan 2 provides information on the coastal processes. Appendix C: Baseline Process Understanding indicates a long-term trend of sediment accretion for the period of the SMP, potentially leading to a complex of dunes and intertidal habitats in front of maintained sea defences, although channel movements and offshore sandbank evolution will influence the pattern of habitats.
- The Dee estuary is currently continuing to import sediment with saltmarshes showing vertical accretion. The rate of marsh expansion near the estuary mouth has decreased in recent decades but accumulation of windblown sand continues to occur near the Point of Ayr and at Hoylake (Halcrow, 2013). Such accretion is important in supporting the function of the defences. Moore. *et al* (2009), however, suggests that the Dee could be reaching a morphological equilibrium and the rate of accretion may decrease in the future.
- The Dee estuary is a drowned, glacially over-deepened valley bounded by Triassic sandstone and Carboniferous coal measures, extensively mantled by glacial till and outwash sands and gravels. A glacial till forms an eroding cliff along part of the east shore of the estuary near Thurstaston. The glacial till overlies Triassic red mudstones and sandstones, with sandstone ridges and outcrops. The harder coarse Triassic sandstone reaches the surface to create ridges and outcrops in many part of the Wirral. There are three sandstone islands which comprise the Hilbre Island Complex, the only natural hard rock coast within the estuary (Natural England, 2014).
- The main source of sediment to the estuary is the Irish Sea, although the erosion of the glacial till cliffs and the suspended load of the River Dee provide secondary sources (Appendix 2 and 3) (Halcrow, 2013).

- Planning for any coastal development including critical coastal infrastructure and access routes needs to take account of how the coast will respond to the action of coastal processes and sea level rise.
- There is a need to consider the facilitation, migration or adaptation of key natural environment assets as the coast evolves.
- The long term vision in the SMP2 is to maintain protection to assets where necessary but to provide more accommodation space where practical to do so. Along the east bank of the Dee saltmarsh should be allowed to roll back where possible and undefended cliffs should be allowed to erode naturally (Halcrow, 2010b) (Appendix 4).
- You may need or wish to commission a specific review or advice from coastal geomorphologists regarding the geomorphological regimes and influences.

<u>Factors driving growth of foreshore vegetation</u>

- Coastal habitats should be allowed to establish in line with ‘natural change’ as a dynamic response to the changing physical environment. Changes can be long term such as sea level rise or short term such as winter storms.
- At the current time, changes to the physical environment (e.g. accretion and drainage inputs) are encouraging vegetation establishment. Physical factors such as sediment type and water quality will influencing the speed of establishment and the character of the developing habitats.
- ‘Natural changes’ to the balance of intertidal sediments and vegetation communities (pioneer plants, saltmarsh and embryo-dunes) is acceptable, indeed should be actively allowed. Beach raking to prevent the establishment of foreshore habitats can impact on the natural coastal processes and so would generally not be welcome from a ‘Natural change’ perspective.
- As habitats form naturally in new locations within the statutory designated sites they will considered as conservation features of the statutory designated sites and will therefore be covered by the sites’ conservation objectives. For example developing pioneer saltmarsh and sand dunes on north Wirral foreshore are protected as features of the Dee Estuary SAC.
- In response to dynamic change Natural England can also consider if the features of SSSIs need to be amended to account for developing habitats to ensure their continued protection. Nb - North Wirral Foreshore Site of Special Scientific Interest was last revised in 1986. There are currently no plans to revise this SSSI.

<u>Vegetation control</u>

- Some vegetation control may be acceptable to arrest pioneer establishment in some locations subject to adequate assessment and consents and would need to be very targeted, tightly controlled and monitored. This would be restricted by the sites conservation objectives in seeking to maintain coastal processes and habitat development.
- Habitats that regularly establish or are able to succeed to more mature forms will have value so potential control needs careful consideration.
- Vegetation control across the whole coast would not be acceptable as this is likely to be contrary to the site’s conservation objectives, it is also unlikely to be economic or sustainable.
- Smaller areas of vegetation control may have scope to be consented but there should be clear justifications for requests to control vegetation establishment. It is unlikely that such control

could be considered 'directly connected with or necessary for the conservation management of the protected sites' – the first Habitat Regulations Assessment test.

- Raking control should only be focused on patches of single species such as the invasive *Spartina anglica* or possibly some limited areas of *Puccinellia maritima*, rather than raking of large areas of beach
- There needs to be a thorough ecological survey of any areas to be proposed for targeting of vegetation control.
- Mechanical methods of control should be considered as the primary means, herbicide use as a last resort and with clear objectives and practice, and only requested where supported by evidence to demonstrate lack of environmental impact, being used in line with permits from Environment Agency and MMO (where required).
- The application of herbicides on the intertidal is a concern regarding impact on non-target plant species, wider impacts on intertidal invertebrates and so to predator species such as shorebirds and seabirds, shell fisheries and wider environmental risks. The risks may not be fully known and a precautionary approach should be taken and therefore Natural England is currently unlikely to support herbicide use.
- The Council should be clear that only vegetation control that is permitted by itself and other consenting bodies will be allowed and action taken by third parties (eg private companies, stakeholder groups and members of the public) without adequate consent carries the risk of enforcement.

<u>Drainage</u>

- Natural England is concerned about the land drainage being discharged to the foreshore along the promenade and that it may not be regulated. This is with regard to the quality of the water and risks of contamination, the ability to maintain the drainage due to natural accretion, the influence this is having on vegetation development and beach amenity.
- Natural England advises that the water quality should be tested to understand the contamination risks, better managed and regulated.
- Natural England advises that it would be better for the local environment for land drainage/ run off to be collected treated and then discharged via a regulated discharge point. There may be opportunities for wetland creation landward of Hoylake or further along the coast and these areas could receive this treated water.

<u>Wider values and opportunities</u>

- The development of pioneer vegetation starts a natural succession that further accretes and stabilises sediment, this then develops a vegetation community that becomes more diverse.
- Pioneer vegetation is likely to lead to development of saltmarsh and/or dunes; this is of conservation interest and value. Given the more exposed location *Puccinellia* patches are more likely to lead embryo dunes, these will then develop into dune and slack habitats. This has been seen and well recorded between Birkdale and Ainsdale on the Sefton Coast.
- Natural England recognises that vegetation may be seasonal however where they are allowed to persist, sand dune and saltmarsh habitats provide important 'natural capital assets' that provide valuable ecosystem services. These habitats can develop in front of existing defences. Examples of the services include provision of :

- Protection of the current defences and communities behind from coastal erosion and flooding by providing a barrier and habitat to absorb wave and tidal energy.
- Carbon storage into vegetation and sediments thus contributing to mitigation for climate change and the aspirations of Wirral Council the Liverpool City Region to achieve Net Zero Carbon by 2040.
- Developing habitats to support important biodiversity.
- Health and wellbeing benefits – there is significant evidence available to show the health and wellbeing benefits from people's interaction with a biodiverse natural environment.
- Alternative visitor attraction. Development of important natural habitats provide an opportunity to develop a sustainably managed visitor economy focussed on the natural environment.

- There is an opportunity to assess the natural capital value of the coastal environment and how this might be influenced by coastal change in a range of scenarios. Liverpool John Moores University (LJMU) with Nature Connected (the Local Nature Partnership for the Liverpool City Region) have completed a Natural Capital Baseline for the Liverpool City Region. LJMU would be willing to model a change to this baseline under different management scenarios. This would help inform an appropriate and sustainable management solution for the long term. Contact details for the lead at LJMU can be supplied.

<u>Issues that could be picked up within a wider plan</u>

- Natural England recommends and supports the development of a more holistic beach management plan.
- This plan could be developed through an inclusive engagement process with a wide range of stakeholders that presents and accounts for a variety of constraints such as conservation, economic, legal and sustainability.
- A more holistic plan would ideally be inclusive of the range of activities and users on the intertidal and coastal zone eg local communities, range of recreational users, shell fisheries, life boat operations and land yachting etc. It should also account for improvement in the land drainage on to the foreshore and future coastal defence planning.
- Recreational disturbance is a recognised issue impacting non-breeding birds, especially during autumn, winter and early spring. It is known that recreational activities can disturb important non-breeding birds that are feeding or roosting on the North Wirral Foreshore (and elsewhere). Wirral Council with others currently undertake some work that seeks to manage this disturbance eg interpretation events, signage and wardening but more action may be required. A holistic beach management plan should incorporate measures to limit and manage recreational disturbance.
- A beach management plan will need to be subject to relevant consents and relevant assessments eg a Habitat Regulations Assessment.
- A range of activities and operations have the opportunity to have an environmental effect in combination with each other or cumulatively. This should be considered and this is a good reason for having a more holistic inclusive plan. A beach management plan that has been agreed with Natural England can be considered for an overarching consent/ assent (to cover all the activities within the plan), rather than consent/ assent for individual activities.

- A wider consideration of the benefits and value that changes to the natural environment can have on the area's socio-economic prosperity eg green tourism, well-being, ecosystem services such as coastal protection.

Ideas for way forward

- Development of an engagement process/consultation to enable a wider evidenced based debate to formulate a holistic beach management plan.
- It is for Wirral Council to determine the extent of stakeholder engagement or consultation on determining proposals or plans for coastal management. However, Natural England would recommend that local communities are engaged to understand the options and constraints and their views considered in determining sustainable approaches to the management of the coast. Although Natural England has an advisory and regulatory role it would also be a stakeholder in an engagement/consultation process.
- There needs to be more understanding of the coastal change, habitat development and the value that this brings.
- If amenity beach provision is required then this needs to be considered in the context of the changing coastal environment and how this could be done in a complimentary way. What area of amenity beach is required and what locations, how will this be sustainably managed. Are there options to where and how the amenity beaches are accessed? For example does an amenity beach need to be against the sea defence or could it be further out in front of developed habitats?

Annex 1 Further details regarding designated sites on North Wirral Foreshore

What are the interest features of the sites?

SSSI: Saltmarsh development on North Wirral Foreshore has been recognised for some time with the 1986 North Wirral Foreshore SSSI citation stating:

“North Wirral Foreshore is located between the outer Dee and Mersey Estuaries. This site is an area of intertidal sand and mudflats and embryonic saltmarsh which is of considerable importance as a feeding and roosting site for passage and wintering flocks of waders, wildfowl, terns and gulls.

The embryonic mixed saltmarsh is formed principally from common saltmarsh-grass *Puccinellia maritima* and glasswort *Salicornia europaea*, together with some common cord-grass *Spartina anglica*.”

The Favourable Condition Table (FCT) also lists saltmarsh as a notified feature and includes a 2014 estimate of 12.8 ha. The FCT also notes the SAC dune features but these haven’t been identified for the SSSI, although are present close by at Red Rocks SSSI.

Natural England’s Views About Management document also covers saltmarsh as a notified feature.

The last recorded condition assessment (23 October 2012) assessed this part of the SSSI as Unfavourable Declining due to declines in non-breeding birds – currently considered due to recreational disturbance. The condition assessment did not appear to consider the condition of the habitat features ie saltmarsh and intertidal sediments.

Wetland Bird Survey (WeBS) Alerts (using WeBS data from 2014/15 to 2018/19) indicate bar-tailed godwit, knot and turnstone on North Wirral Foreshore SSSI have significant declines which would lead to these features and so the site to be in unfavourable condition. The site requires formal re-assessment.

Un-consented damage to the habitats features is likely to lead to an unfavourable condition assessment eg through loss of indicator species, habitat structure or habitat area.

Changes in proportions of habitat types due to ‘natural change’ will be acceptable with regards to condition.

Natural England is required to keep its understanding of interest features under review and this could lead to changes to the designation.

Natural England will consider any proposals with regard to risks to the conservation and enhancement of the SSSI features.

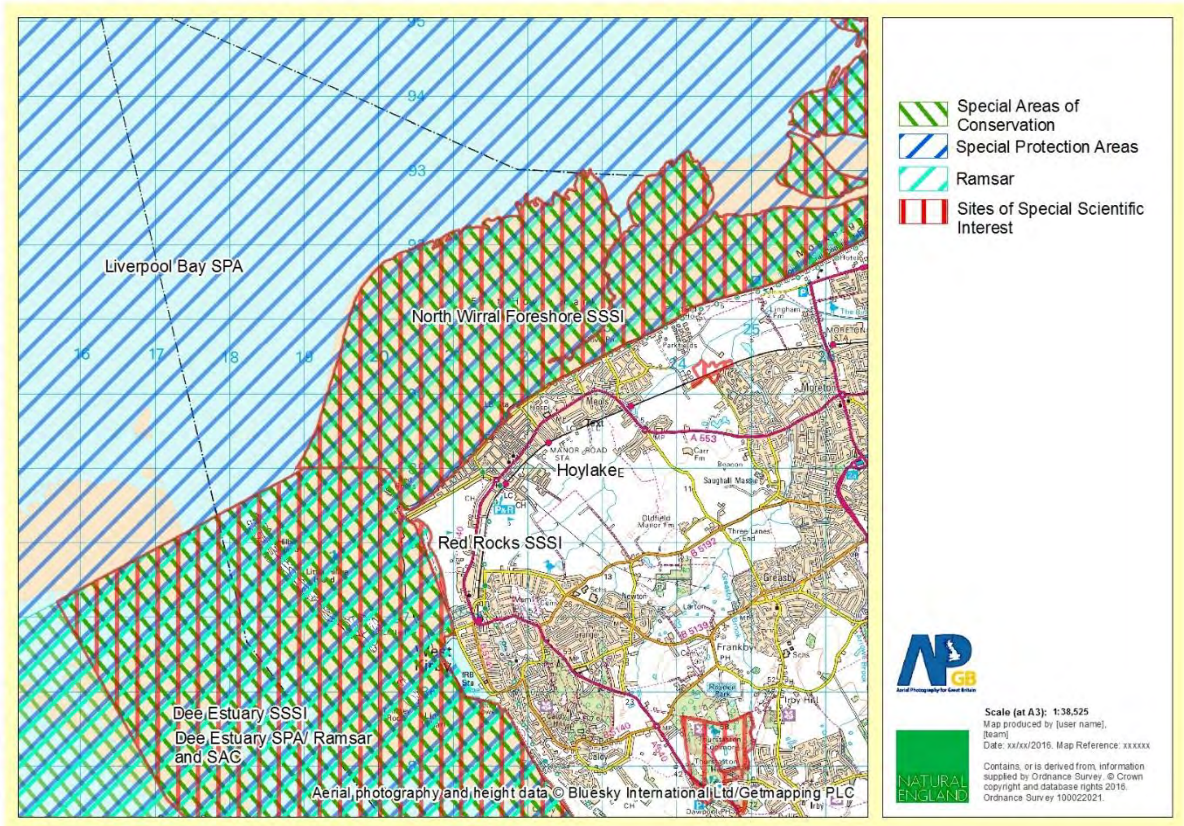
Natural England will consider a review of condition and pressures that may be influencing condition, such as bird disturbance, inappropriate vegetation control and inappropriate drainage/water quality or wider external effects that may be accelerating change.

Ramsar: The Ramsar Information Sheet also refers to embryonic saltmarsh:

“The site comprises intertidal habitats at Egremont foreshore on the south bank of the Mersey, man-made saline and freshwater lagoons at Seaforth on the north bank and the extensive intertidal flats at North Wirral Foreshore. ……….. North Wirral Foreshore supports large numbers of feeding waders at low tide and also includes important high tide roost sites, it is an area of intertidal sands and mudflats with embryonic saltmarsh.”

Natura 2000: For the SAC, the ‘supporting processes’ will include those that sustain and allow development of the Annex I features for which the site is designated. The SPA and the SAC conservation objectives both have the caveat ‘subject to natural change’, suggesting that where coastal processes are driving the shift in habitats, we would not conclude such changes to result in an unfavourable condition assessment. There is no information in the SIP for the relevant N2k sites suggesting any major problem from saltmarsh or dune evolution for any of the designated features.

Map indicating the overlapping designations of the North Wirral Foreshore



<u>Diagram showing sediment movements for Shoreline Management Plan sub-cell 11a</u>

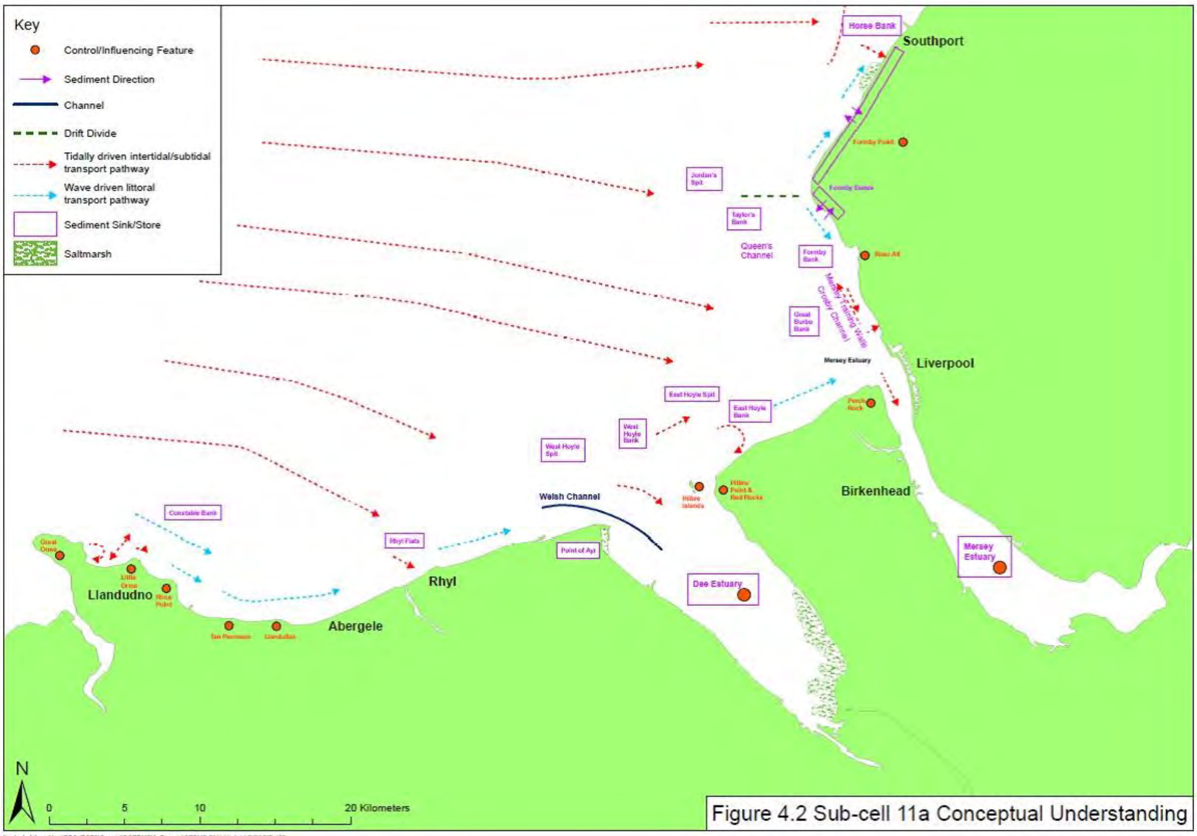


Figure 4.2 Sub-cell 11a Conceptual Understanding

Appendix B: NVC Survey Report

National Vegetation Classification

(NVC) Survey

Hoylake Shore

Client:	FAO: Jamie Gardiner
	HaskoningDHV UK Limited
	Edmund Street
	Liverpool
	L3 9NG
Surveyor:	Lucia Ruffino MSc,
	Bryn Afon, Byn Du,
	Ty Croes, LL63 5RN
	Telephone 07830177564
	Email: luciaruffino65@gmail.com

Date of survey:	23rd to 26th August 2021
Date of report:	14th October 2021
Version:	Final 01

Summary

- An NVC habitat survey of an area of shore at Hoylake, Wirral was commissioned as part of a wider ecological and geomorphological study of the area. The survey area is approx. 2km long, between Red Rocks and the Hoylake Lifeboat station.
- The site is subject to the following, overlapping designations:
  - North Wirral Foreshore SSSI, designated for features such as non-breeding birds, intertidal sediments, and saltmarshes.
  - Mersey Narrows and North Wirral Foreshore SPA/Ramsar site, designated for non-breeding birds.
  - Dee Estuary SAC, designated for features including intertidal sediments, reefs, saltmarsh and sand dunes.

  These designations make this site of particular importance from a conservation perspective.
- The vegetation at Hoylake shore has recently appeared, as natural processes have caused sand to raise the level of the site above mean low water. This has allowed plants that are salt tolerant to form pioneer vegetation on Hoylake shore.
- The NVC survey recorded two vegetation communities within the survey area: SM13a *Puccinellia maritima* saltmarsh community, sub-community with *Puccinellia maritima* dominant (the majority of the vegetation) and smaller stands of SM6 *Spartina anglica* saltmarsh community.
- A total of 103 vascular plant species and 1 bryophyte species were recorded during the NVC survey.
- From a conservation perspective, the vegetation communities on site are of high conservation value: SM13 *Puccinellia maritima* saltmarsh community is of importance for conservation at international level, as it is one of the vegetation communities included within Annex I Habitat 1330 'Atlantic salt meadows (*Glauco-Puccinellitalia maritimae*)'. This habitat is also the primary reason for selection of the Dee Estuary as an SAC. At national level, Section 41 of the Natural Environment and Rural Communities (NERC) Act 2006 lists coastal saltmarsh as a habitat of principal importance in England.
- Many of the species recorded on site are also rare and/or notable, including: *Catabrosa aquatica,* classified as vulnerable in England, *Triglochin palustris*, classified as Near Threatened in England, *Crithmum maritimum* and *Polygonum oxyspermum*, both considered Locally Rare in VC58 Cheshire.
- In view of the high conservation value of the site it is recommended that a thorough botanical survey be carried out next year in spring, summer, and early autumn to ensure that a full list of species growing on the site is generated. In addition, a botanical survey should be repeated on a yearly basis to monitor the progress of colonisation. An NVC habitat survey should be repeated in 5 years, to map the progress of vegetation communities colonising the site and document their evolution.

Contents

1. Introduction

1.1. Background and site description

The client, HaskoningDHV UK Limited, commissioned Lucia Ruffino MSc to carry out an NVC habitat survey of an area of shore at Hoylake, Wirral, as part of a wider ecological and geomorphological study. The survey area is approximately 2km long, between Red Rocks and the Hoylake Lifeboat station. The site is subject to the following, overlapping designations:

- North Wirral Foreshore SSSI, designated for features such as non-breeding birds, intertidal sediments, and saltmarshes.
- Mersey Narrows and North Wirral Foreshore SPA/Ramsar site, designated for non-breeding birds.
- Dee Estuary SAC, designated for features including intertidal sediments, reefs, saltmarsh and sand dunes.

Recent natural coastal changes at Hoylake have led to the formation of pioneer vegetation within the survey area and Wirral Council have requested a survey of such vegetation to inform future management of the area.

Figure 1: Survey area: any vegetation between Red Rocks and the Lifeboat station both landwards and seawards of the red line.

1.2. Objectives of the NVC survey

The aims of the survey are as follows:

- To classify and map habitats within the survey area in accordance with the National Vegetation Classification protocol.
- To give a conservation assessment of the vegetation communities in order to inform future management of Hoylake shore.

2. Methodology

An NVC survey was carried out by Lucia Ruffino, between 23rd and 26th August 2021, in good weather conditions, with good visibility. Habitats were recorded and classified following the standard NVC protocol[1].

A Garmin 62st GPS was used to record locations. Maps were produced using QGIS 3.4 Madeira (2018).

Nomenclature of higher plant species follows Stace (2019)[2].

In accordance with the NVC methodology, five or more quadrats were recorded for most vegetation communities. However, for vegetation communities which covered smaller areas, fewer quadrats were recorded. In this case, each quadrat was analysed separately, and the community was assigned on the basis of the components of each quadrat.

For very small, fragmentary stands of vegetation, a full species list was made, and abundance was noted using the DAFOR scale. The whole stand was then compared to the NVC descriptions and assigned to a community on this basis.

3. Results

3.1. Overview

A total of 27 quadrats, 103 vascular plant species and 1 bryophyte species were recorded throughout the survey area. Location of quadrats is shown on the map at Figure 2, overleaf.

[1] J. S. Rodwell (2006) National Vegetation Classification: Users' Handbook. JNCC. Peterborough.
[2] Stace, C (2019) New Flora of the British Isles. Fourth Edition. Cambridge University Press.

Figure 2: Location of quadrats throughout survey area.

A list of all plant species recorded on site and all quadrat data (in Excel format) are collated in Appendix 4. For ease of reference, the whole-site species list is also reproduced in table format in Appendix 1 at the end of this report. In addition, a list of plant species growing along the sea wall, and therefore not forming part of the main stand of vegetation, was also compiled, and is included in table form in Appendix 1.

It should be noted that annual *Salicornia* species were not identified to species for the purposes of the NVC survey. Identification to species is not necessary, as original NVC surveys only recorded annual *Salicornia* species as 'annual *Salicornia* agg'. However, at the time of the survey a few specimens of *Salicornia* from the site had anthers showing and were therefore identified to species for sake of completeness. All specimens were identified as *S. europaea.*

Target notes to the NVC survey, together with the relevant maps, are included in Appendix 2.

The main semi-natural vegetation community recorded on site is SM13 *Puccinellia maritima* saltmarsh community, a generally species-poor grassland dominated by the grass *Puccinellia maritima* (Common Saltmarsh-grass), with associates such as T*ripolium pannonicum* (Sea Aster), annual *Salicornia* agg (annual Glasswort agg), and *Suaeda maritima* (Annual Sea-blite). Approximately 10ha of this vegetation was recorded within the survey area.

Approximately 0.6ha of SM6 *Spartina anglica* saltmarsh community were also recorded, at the western end of the site, by Red Rocks. These vegetation communities are described in more detail at section 3.6 below and photographs are shown in Appendix 2.

3.2. Vegetation extents

As vegetation has only recently colonised this site, an aerial photograph sufficiently recent as to show the extents of the vegetation was not available. Therefore, the vegetation extents were mapped using a GPS. It should be noted that not all vegetation within the mapped area is dense and continuous. Vegetation tended to be denser towards the shore and become sparser seawards.

The map at Figure 3 below shows the outer limits of vegetation (the red line), i.e. where vegetation is present but is sparse. The hatched black area indicates stands of denser vegetation.

Figure 3: Vegetation extents map

To add to the complexity of the site, a strip of vegetation is also growing along the sea wall, clearly separate in nature from the main stand of vegetation on the beach. As mentioned above, a separate species list was created for this strip of vegetation (see Appendix 1).

3.3. Rare and/or notable species

No European protected plant species[3]; Schedule 8[4] or Section 41[5] plant species were recorded during the survey.

The following rare and/or notable species were recorded during the survey:

- *Catabrosa aquatica*: classified as vulnerable (VU) in England[6]
- *Triglochin palustris*: classified as Near Threatened (NT) in England
- *Crithmum maritimum*: Locally Rare in VC58 Cheshire[7]
- *Polygonum oxyspermum*: Locally Rare in VC58 Cheshire

The following species which occur on site are also considered scarce in VC58 Cheshire (Kay, 2015) as they only occur in 4-16 sites in the vicecounty:

Ammophila arenaria
Armeria maritima
Atriplex littoralis
Beta vulgaris ssp *maritima*
Cakile maritima
Carex extensa
Catapodium marinum
Elymus junceiformis
Juncus gerardii
Juncus ranarius
Leymus arenarius
Parapholis strigosa
Raphanus raphanistrum ssp *maritimus*
Spergularia media
Triglochin maritima

[3]These are species protected under the Conservation of Habitats and Species Regulations 2010.
[4] Species protected under Schedule 8 of the Wildlife and Countryside Act 1981 (as amended).
[5] Species included under Section 41 of the Natural Environment and Rural Communities (NERC) Act 2006.
[6] Stroh, P A; Leach, S J; August, T A; Walker, K J; Pearman, D A; Rumsey, F J; Harrower, C A; Fay, M F; Martin, J P; Pankhurst, T; Preston, C D; Taylor I (2014). A Vascular Plant Red List for England. Botanical Society of Britain and Ireland, Bristol
[7] Kay, G M (2015). Cheshire VC58. County Rare Plant Register 2015.

The following species recorded on site are also considered of Conservation Importance in North West England, and specifically in Wirral[8]:

Armeria maritima
Crithmum maritimum
Puccinellia distans
Raphanus raphanistrum ssp *maritimus*

3.4. Non-native invasive species

No plant species listed under Schedule 9 of the Wildlife and Countryside Act 1981 were recorded on this site.

3.5. NVC Maps

NVC habitat maps covering the survey area are shown below.

[8] Regional Biodiversity Steering Group for North West England (1999). Wild About the North West – A Biodiversity Audit of North West England. Volume 1 and 2.

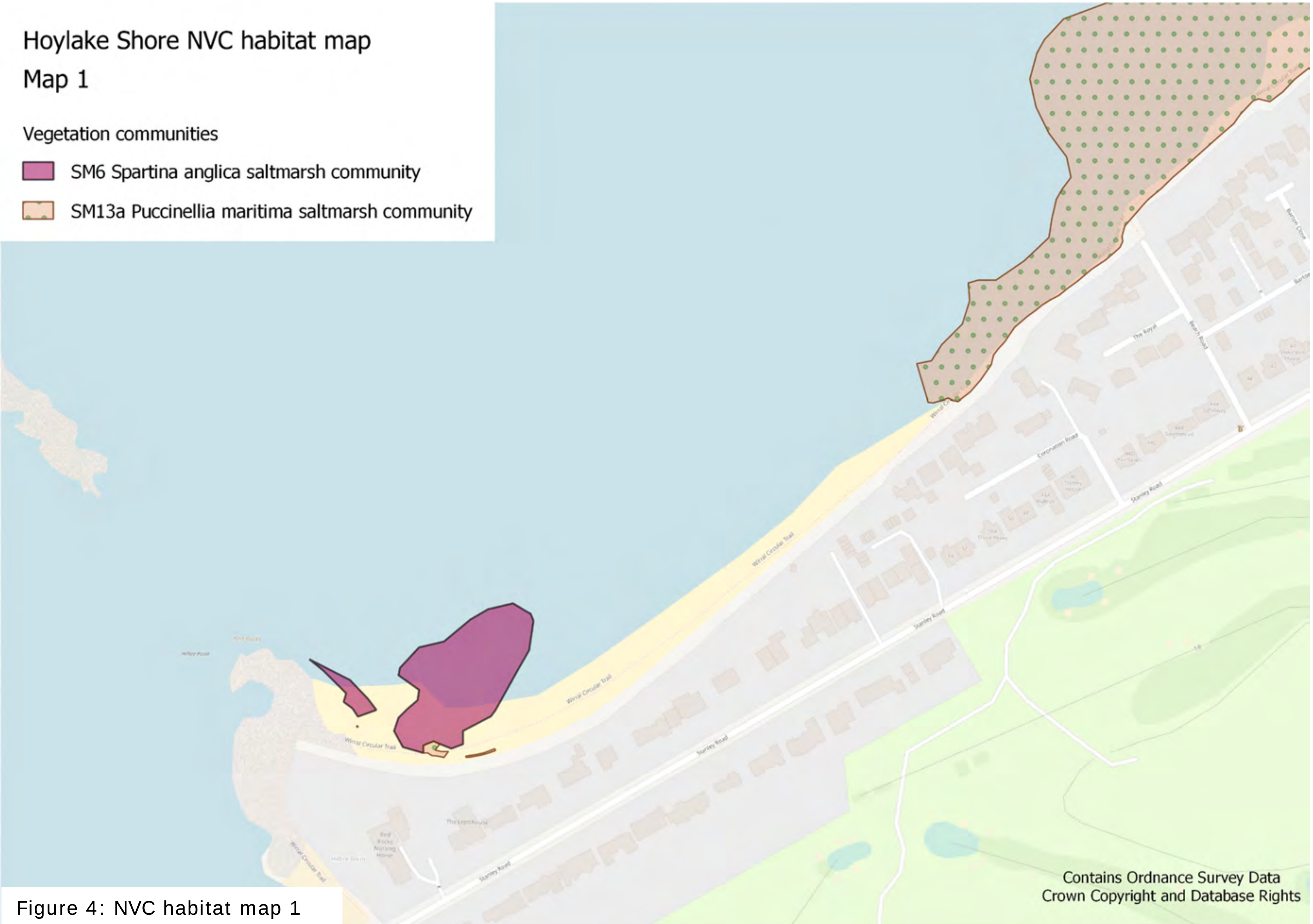


Figure 4: NVC habitat map 1

Figure 5: NVC habitat map 2

Figure 6: NVC habitat map 3

3.6. Community descriptions

3.6.1. SM13a *Puccinellia maritima* saltmarsh community, sub-community with *Puccinellia maritima* dominant

This is a low-mid saltmarsh community which can be described as a species-poor grassland dominated by the grass *Puccinellia maritima*. Other associates, such as T*ripolium pannonicum*, annual *Salicornia* species, *Suaeda maritima* are present but they are usually at low cover. On this site, the vegetation fits within SM13a, the sub-community with *Puccinellia maritima* dominant.

Although the vegetation on this site is generally a good fit to this sub-community, it differs from the national NVC data as follows: *Armeria maritima*, *Atriplex portulacoides*, *Limonium* sp and *Spergularia media*, all recorded in the national NVC data (albeit at low frequency and/or cover), are absent from the site quadrats. *Salicornia* spp. are under-represented in the site data, whereas *Triglochin palustris*, *Juncus ranarius*, *Bolboschoenus maritimus* and *Cotula coronopifolia* are recorded here but not recorded in the NVC national data.

It should be noted that *Armeria maritima* is rare on the overall site, as only 1 plant was seen during the survey. *Spergularia media* was recorded within the overall site but was rare. The same applies to *Atriplex portulacoides*. *Limonium* spp have not been recorded at all on this site.

The quadrat data has been summarised in Table 1, which shows the constancy table for this vegetation community.

Table 1. Constancy table for quadrats of SM13a *Puccinellia maritima* saltmarsh community, sub-community with *Puccinellia maritima* dominant.

Species	**Constancy**	**Domin range**		
Puccinellia maritima	V	5	-	9
Triglochin palustris	IV	2	-	5
Triglochin maritima	III	1	-	4
Spartina anglica	II	1	-	4
Tripolium pannonicum	II	1	-	1
Lysimachia maritima	II	1	-	5
Juncus ranarius	II	1	-	5
Bolboschoenus maritimus	II	1	-	3
Cotula coronopifolia	II	1	-	3

Species	Constancy	Domin range		
Suaeda maritima	I	1	-	1
Plantago maritima	I	1	-	1
Salicornia sp.	I	1	-	1
Phragmites australis	I	1	-	1
Atriplex prostrata	I	1	-	4
Spergularia marina	I	2	-	5
Parapholis strigosa	I	1	-	3
Agrostis stolonifera	I	3	-	3
Plantago coronopus	I	1	-	1
Poa annua	I	1	-	2
Carex extensa	I	1	-	1
Ranunculus sceleratus	I	1	-	1
Rumex crispus	I	1	-	1
Taraxacum agg	I	1	-	1
Catabrosa aquatica	I	4	-	4
Elymus repens	I	3	-	3
Atriplex sp seedling	I	1	-	1
Unidentifiable small seedlings (monocotyledons)				
No of species per quadrat - range		1	-	11
Mean no of species per quadrat	5.04			
No of samples:	24			

3.6.2. Description of other communities

Another vegetation community was recorded within the survey area: SM6 *Spartina anglica* saltmarsh community. Three quadrats were taken in this pioneer saltmarsh community, which is dominated by *Spartina anglica* (Common Cord-grass) with associates such as annual *Salicornia* species, *Suaeda maritima* and *Puccinellia maritima,* all found at low cover. Stands of this community were recorded at the southwestern end of the site, where the substrate is more silty.

The presence of *Bolboschoenus maritimus* in stands of SM13a *Puccinellia maritima* saltmarsh community mentioned at paragraph 3.6.1 above could be indicative of future development of stands of S21 *Scirpus maritimus* (now *Bolboschoenus maritimus*) swamp, a plant community frequently found in the higher reaches of saltmarshes, furthest away from the sea. There is already a small, well-developed stand of this vegetation at approx. SJ2165 8961. However, most stands where this species is frequent consisted of young, developing plants at the time of survey. These were recorded and described in the target notes (see Appendix 2), so that future development of this vegetation can be monitored.

4. Discussion

4.1. Assessment criteria for conservation value of vegetation communities

Vegetation communities and habitats are assessed for their conservation value as follows:

- Habitats of importance at international level - referring to habitats listed under Annex 1 of the EU Habitats Directive.
- Habitats of importance at national level - within the framework of the Natural Environment and Rural Communities (NERC) Act 2006, commenting on whether they are included within Section 41 as 'habitats of principal' in England

In addition, as the vegetation communities surveyed are within an area designated as an SAC, a further assessment is made as to whether the communities fall within Annex I habitat categories which are a primary reason for selection of the SAC.

4.2. Conservation assessment

SM13 *Puccinellia maritima* saltmarsh community is of importance for conservation at international level, as it is one of the vegetation communities included within Annex I Habitat 1330 'Atlantic salt meadows (*Glauco-Puccinellitalia maritimae*)'.

It should be noted that this habitat is the primary reason for selection of the Dee Estuary as an SAC.

At national level, Section 41 of the Natural Environment and Rural Communities (NERC) Act 2006 lists coastal saltmarsh as a habitat of principal importance in England.

4.3. Survey limitations

- As a recent aerial photograph of the area to be surveyed was not available, the extents of the vegetation were mapped using a GPS, which has an accuracy of +/- 3 (rarely 4) metres and therefore the extents shown in Figures 3, 4 and 5 have to be considered as being + /- 3m.
- It is known that scattered plants of *Spartina anglica* occur a long way seaward of the vegetation mapped for the purposes of this survey. However, for practical reasons,

the survey was limited to areas where the vegetation forms recognisable stands and a note was made of the fact that beyond that point scattered plants of *Spartina anglica* do occur further out and are visible at low tide.

5. Conclusions

The vegetation at Hoylake shore has only recently appeared as natural processes have caused sand to raise the level of the site above mean low water. This has allowed plants that are salt tolerant to form pioneer vegetation on Hoylake shore.

Hoylake shore is subject to the following, overlapping designations:

- North Wirral Foreshore SSSI, designated for features such as non-breeding birds, intertidal sediments, and saltmarshes
- Mersey Narrows and North Wirral Foreshore SPA/Ramsar site, designated for non-breeding birds
- Dee Estuary SAC, designated for features including intertidal sediments, reefs, saltmarsh and sand dunes

These designations make this site of particular importance from a conservation perspective.

The vegetation communities at Hoylake shore can be classified as saltmarsh vegetation. Applying the NVC survey protocol, two vegetation communities have been recorded within the survey area: SM13a *Puccinellia maritima* saltmarsh community, sub-community with *Puccinellia maritima* dominant (the majority of the vegetation) and smaller stands of SM6 *Spartina anglica* saltmarsh community.

The site can be considered species-rich, with a total of 103 vascular plant species and 1 bryophyte species recorded during the NVC survey throughout the survey area.

From a conservation perspective, the vegetation on site is of high conservation value:

- SM13 *Puccinellia maritima* saltmarsh community is of importance for conservation at international level, as it is one of the vegetation communities included within Annex I Habitat 1330 ‘Atlantic salt meadows (*Glauco-Puccinellitalia maritimae*)’. This habitat is also the primary reason for selection of the Dee Estuary as an SAC.

- At national level, Section 41 of the Natural Environment and Rural Communities (NERC) Act 2006 lists coastal saltmarsh as a habitat of principal importance in England.

Many of the species recorded on site are also rare and/or notable, including:

- *Catabrosa aquatica,* classified as vulnerable (VU) in England
- *Triglochin palustris*, classified as Near Threatened (NT) in England
- *Crithmum maritimum* and *Polygonum oxyspermum*, both considered Locally Rare in VC58 Cheshire

Finally, it should be noted that the vegetation on this site is of a pioneer nature and is likely to be subject to change over time, as geomorphological processes continue to modify the shore.

6. Recommendations

Considering the high conservation value of both the habitats and species at Hoylake shore, the following recommendation are made:

- A thorough botanical survey should be carried out next year in spring, summer, and early autumn to ensure that a full list of species growing on the site is generated.
- A botanical survey should then be repeated on a yearly basis to monitor the progress of colonisation.
- An NVC habitat survey should be repeated in 5 years' time to map the progress of vegetation communities colonising the site and document their evolution.

References

Kay, G M (2015). Cheshire VC58. County Rare Plant Register 2015 https://bsbi.org/wp-content/uploads/dlm_uploads/Cheshire_RDB_2015.pdf Accessed 12/10/2021

Regional Biodiversity Steering Group for North West England (1999). Wild About the North West – A Biodiversity Audit of North West England. Volume 1 and 2.

Rodwell, J S (2000). British Plant Communities Volume 5. Maritime communities and vegetation of open habitat. Cambridge University Press.

Rodwell, J S (2006) National Vegetation Classification: Users' Handbook. JNCC.

Stace, C (2019) New Flora of the British Isles. Fourth Edition. Cambridge University Press.

Stroh, P A; Leach, S J; August, T A; Walker, K J; Pearman, D A; Rumsey, F J; Harrower, C A; Fay, M F; Martin, J P; Pankhurst, T; Preston, C D; Taylor I (2014). A Vascular Plant Red List for England. Botanical Society of Britain and Ireland, Bristol.

Appendix 1

Table A1.1: Whole-site species list, including abundances noted using the DAFOR scale.

Common name	Taxon	Abundance
Creeping Bent	*Agrostis stolonifera*	R
Marsh Foxtail	*Alopecurus geniculatus*	R
Marram	*Ammophila arenaria*	O
Barren Brome	*Anisantha sterilis*	R
Thrift	*Armeria maritima*	R
False Oat-Grass	*Arrhenatherum elatius*	R
Grass-leaved Orache	*Atriplex littoralis*	R
Common Orache	*Atriplex patula*	R
Sea-purslane	*Atriplex portulacoides*	R
Spear-leaved Orache	*Atriplex prostrata*	F
Oat	*Avena sativa*	R
Sea Beet	*Beta vulgaris subsp. maritima*	O
Trifid Bur-marigold	*Bidens tripartita*	O
Sea Club-rush	*Bolboschoenus maritimus*	F
a Cabbage	*Brassica sp*	R
a Butterfly-bush	*Buddleja sp*	R
Sea Rocket	*Cakile maritima*	R
Shepherd's-purse	*Capsella bursa-pastoris*	R
Long-bracted Sedge	*Carex extensa*	O
False Fox-sedge	*Carex otrubae*	R
Whorl-grass	*Catabrosa aquatica*	O
Sea Fern-grass	*Catapodium marinum*	R
Red Valerian	*Centranthus ruber*	R
Fat-hen	*Chenopodium album*	R
Creeping Thistle	*Cirsium arvense*	R
a Scurvygrass	*Cochlearia sp*	R
Buttonweed	*Cotula coronopifolia*	O/LF
Rock Samphire	*Crithmum maritimum*	R
Ivy-leaved Toadflax	*Cymbalaria muralis*	R
Cock's-foot	*Dactylis glomerata*	R
Annual Wall-rocket	*Diplotaxis muralis*	O
Sand Couch	*Elymus junceiformis*	O
Common Couch	*Elymus repens*	O
Great Willowherb	*Epilobium hirsutum*	O
Hoary Willowherb	*Epilobium parviflorum*	O
Field Horsetail	*Equisetum arvense*	R
Sea-holly	*Eryngium maritimum*	R
Red Fescue	*Festuca rubra*	R
Floating Sweet-grass	*Glyceria fluitans*	R
Sunflower	*Helianthus annuus*	R
Hoary Mustard	*Hirschfeldia incana*	R
Yorkshire-fog	*Holcus lanatus*	R

Common name	Taxon	Abundance
Wall Barley	*Hordeum murinum*	R
Cat's-ear	*Hypochaeris radicata*	R
Common Ragwort	*Jacobaea vulgaris*	R
Saltmarsh Rush	*Juncus gerardii*	R
Frog Rush	*Juncus ranarius*	F
Lyme-grass	*Leymus arenarius*	O
Purple Toadflax	*Linaria purpurea*	R
Perennial Rye-grass	*Lolium perenne*	O/LF
Duke of Argyll's Teaplant	*Lycium barbarum*	R
Gypsywort	*Lycopus europaeus*	O
Sea-milkwort	*Lysimachia maritima*	F
Pineappleweed	*Matricaria discoidea*	R
Black Medick	*Medicago lupulina*	R
a Watercress	*Nasturtium sp*	R/LA
Red Goosefoot	*Oxybasis rubra*	R
Long-headed Poppy	*Papaver dubium*	R
Common Poppy	*Papaver rhoeas*	R
Hard-grass	*Parapholis strigosa*	R
Pellitory-of-the-Wall	*Parietaria judaica*	R
Water-pepper	*Persicaria hydropiper*	R
Redshank	*Persicaria maculosa*	R
Reed Canary-grass	*Phalaris arundinacea*	R
Common Reed	*Phragmites australis*	R
Buck's-horn Plantain	*Plantago coronopus*	O
Ribwort Plantain	*Plantago lanceolata*	R
Greater Plantain	*Plantago major*	R
Sea Plantain	*Plantago maritima*	O
Annual Meadow-grass	*Poa annua*	O/LF
Knotgrass	*Polygonum aviculare*	O
Ray's Knotgrass	*Polygonum oxyspermum*	O
Water Bent	*Polypogon viridis*	R
Silverweed	*Potentilla anserina*	R
a cherry seedling	*Prunus sp seedling*	R
Reflexed Saltmarsh-grass	*Puccinellia distans*	R
Common Saltmarsh-grass	*Puccinellia maritima*	A
Creeping Buttercup	*Ranunculus repens*	R
Celery-leaved Buttercup	*Ranunculus sceleratus*	R
Sea Radish	*Raphanus raphanistrum subsp. maritimus*	R
Clustered Dock	*Rumex conglomeratus*	R
Curled Dock	*Rumex crispus*	O
Procumbent Pearlwort	*Sagina procumbens*	R
a Glasswort	*Salicornia sp.*	F
Common Glasswort	*Salicornia europaea*	R
a willow seedling	Salix sp (seedling)	O
White Stonecrop	*Sedum album*	R
Groundsel	*Senecio vulgaris*	O

Common name	**Taxon**	**Abundance**
Perennial Sow-thistle	*Sonchus arvensis*	R
Smooth Sow-thistle	*Sonchus oleraceus*	R
Common Cord-grass	*Spartina anglica*	F
Lesser Sea-spurrey	*Spergularia marina*	O
Greater Sea-spurrey	*Spergularia media*	R
Common Chickweed	*Stellaria media*	R
Annual Sea-blite	*Suaeda maritima*	O
Dandelion	*Taraxacum agg.*	R
Sea Arrowgrass	*Triglochin maritima*	F
Marsh Arrowgrass	*Triglochin palustris*	F
Sea Mayweed	*Tripleurospermum maritimum*	O
Sea Aster	*Tripolium pannonicum*	F
a Wheat	*Triticum sp*	R
Colt's-foot	*Tussilago farfara*	R
a Bulrush	*Typha sp* (seedling)	R
	Bryophytes	
	Marchantia polymorpha	

Table A1.2: List of species growing along the sea wall and immediately below, clearly not forming part of the main stands of vegetation on the beach area. Abundances refer to the whole 'strip' of vegetation, and are noted using the DAFOR scale. Please note: this is a sub-set of species which are all included in the whole-site species list at Table A1.1 above.

Taxon	**Abundance**
Poa annua	F
Puccinellia maritima	F
Rumex crispus	F
Senecio vulgaris	F
Sonchus oleraceus	F
Tripleurospermum maritimum	F
Tripolium pannonicum	F
Nasturtium sp	O/LA
Agrostis stolonifera	O/LF
Lolium perenne	O/LF
Plantago coronopus	O/LF
Ammophila arenaria	O
Atriplex littoralis	O
Atriplex patula	O
Atriplex portulacoides	O
Atriplex prostrata	O
Beta vulgaris subsp maritima	O
Bidens tripartita	O
Buddleja sp (sapling)	O
Cakile maritima	O
Capsella bursa-pastoris	O
Carex extensa	O
Catabrosa aquatica	O
Cochlearia sp	O
Cotula coronopifolia	O
Crithmum maritimum	R
Diplotaxis muralis	O
Elymus junceiformis	O
Elymus repens	O
Epilobium hirsutum	O
Epilobium parviflorum	O
Helianthus annuus	O
Juncus ranarius	O
Leymus arenarius	O
Lycopus europaeus	O
Lysimachia maritima	O
Parietaria judaica	O
Persicaria maculosa	O
Phragmites australis	O

Taxon	Abundance
Plantago major	O
Plantago maritima	O
Polygonum aviculare	O
Polygonum oxyspermum	O
Ranunculus sceleratus	O
Salix sp (seedlings)	O
Sonchus arvensis	O
Stellaria media	O
Suaeda maritima	O
Taraxacum agg.	O
Triglochin maritima	O
Triglochin palustris	O
Anisantha sterilis	R
Arrhenatherum elatius	R
Avena sativa	R
Brassica sp	R
Catapodium marinum	R
Centranthus ruber	R
Chenopodium album	R
Cirsium arvense	R
Cymbalaria muralis	R
Dactylis glomerata	R
Equisetum arvense	R
Eryngium maritimum	R
Festuca rubra	R
Hirschfeldia incana	R
Holcus lanatus	R
Hordeum murinum	R
Hypochaeris radicata	R
Jacobaea vulgaris	R
Linaria purpurea	R
Lycium barbarum	R
Matricaria discoidea	R
Medicago lupulina	R
Oxybasis rubra	R
Papaver dubium	R
Papaver rhoeas	R
Persicaria hydropiper	R
Polypogon viridis	R
Prunus sp seedling	R
Ranunculus repens	R
Raphanus raphanistrum subsp maritimus	R
Rumex conglomeratus	R
Sagina procumbens	R
Sedum album	R

Taxon	Abundance
Triticum sp.	R

Bryophytes
Marchantia polymorpha

National Vegetation Classification

(NVC) Survey

Hoylake Shore

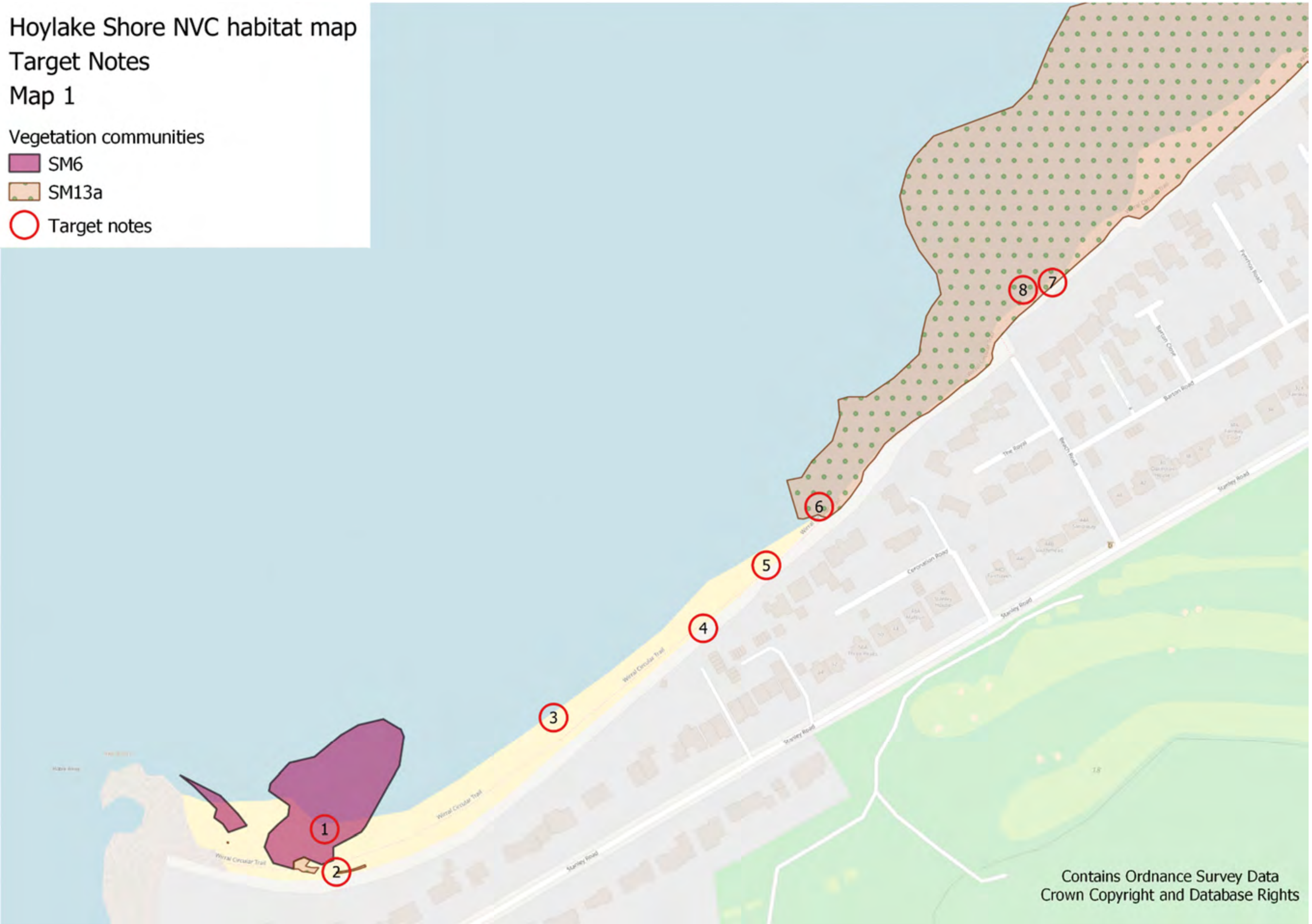
APPENDIX 2 – TARGET NOTES

Client:	FAO: Jamie Gardiner HaskoningDHV UK Limited Edmund Street Liverpool L3 9NG
Surveyor:	Lucia Ruffino MSc, Bryn Afon, Byn Du, Ty Croes, LL63 5RN Telephone 07830177564 Email: luciaruffino65@gmail.com
Date of survey:	23rd to 26th August 2021
Date of report:	14th October 2021
Version:	Final 01

Appendix 2 – Target Notes

TN NO	Eastings	Northings	Description
1	320410	388482	*Puccinellia maritima* is establishing in stand of *Spartina anglica*. One plant of *Armeria maritima* is present here, with *Salicornia* sp O and *Tripolium pannonicum* R.
2	320418	388453	Band of *Puccinellia maritima* 1m to 1.5m wide.
3	320566	388558	At this point there is no obvious vegetation seaward and only sparse vegetation by sea wall.
4	320668	388619	Sparse vegetation. *Spartina anglica* tussocks, *Plantago coronopus* R, *Puccinellia maritima* R, *Triglochin palustre* R, *Bolboschoenus maritimus* (young, developing plants) R.
5	320711	388662	Very sparse vegetation - not exactly a stand or community. *Triglochin maritima O, Salicornia sp O, Puccinellia maritima O, Tripolium pannonicum R, Lysimachia maritima R, Suaeda maritima R, Spartina anglica R, Juncus ranarius R, Phragmites australis R*.
6	320747	388702	Stand of dead *Puccinellia maritima*. Tussocks of *Puccinellia maritima* appear to have died - not clear whether naturally or due to human intervention. The issue seems to be confined to a stretch of the beach approximately 220m long northeast and southwest of Beach Road.
7	320906	388855	End of dead *Puccinellia maritima*.
8	320886	388850	Small stand of young developing *Bolboschoenus maritimus*.
9	321180	389173	Stand of *Lysimachia maritima* 3m x 2m.
10	321186	389166	Small stand of young developing *Bolboschoenus maritimus* with *Triglochin palustris, Puccinellia maritima* and *Triglochin maritima* also present.
11	321189	389162	Small stand of dense *Lysimachia maritima* (3m x 1.5m). Instead of being constant throughout, L maritima tends to occur in dense stands in a matrix of SM13a.
TN NO	**Eastings**	**Northings**	**Description**
12	321225	389168	Stand of grassier vegetation in SM13a, with abundant *Poa annua* and frequent *Lolium perenne*. *Puccinellia maritima* is still present, at lower abundance.
13	321269	389252	Small stand of *Bolboschoenus maritimus*.
14	321265	389191	On slipway *Catabrosa aquatica* A, *Nasturtium* sp (no flowers) A.

15	321411	389416	Vegetation here is sparser. *Puccinellia maritima F, Suaeda maritima R, Spartina anglica R, Atriplex prostrata R*.
16	321524	389487	Area with *Bolboschoenus maritimus A, Atriplex prostrata A, Suaeda maritima O, Elymus repens O, Triglochin maritima O, Triglochin palustris O, Tripleurospermum maritimum R, Spartina anglica R, Beta vulgaris subsp maritima R*.
17	321650	389611	Area with *Bolboschoenus maritimus D, Triglochin palustris A, Puccinellia maritima F, Juncus ranarius F, Tripolium pannonicum F, Triglochin maritima F, Juncus gerardii cf O, Cotula coronopifolia R*. This is the largest stand of developing *Bolboschoenus* swamp and here *B. maritimus* is fully grown and flowering (approx 60cm high) and vegetation is dense.


Hoylake Shore NVC habitat map
Target Notes
Map 1
Vegetation communities
SM6
SM13a
Target notes
1
2
3
4
5
6
7
8
Contains Ordnance Survey Data
Crown Copyright and Database Rights

Hoylake Shore NVC habitat map
Target Notes
Map 2
Vegetation communities
SM6
SM13a
Target notes
16
15
13
14
9
11
12
Contains Ordnance Survey Data
Crown Copyright and Database Rights


Hoylake Shore NVC habitat map
Target Notes
Map 3
Vegetation communities
SM6
SM13a
Target notes
9
11
12
13
14
15
16
17
Contains Ordnance Survey Data
Crown Copyright and Database Rights

Appendix 3 - Photographs

Photograph 1: Stand of SM13a *Puccinellia maritima* saltmarsh community, sub-community with *Puccinellia maritima* dominant (outlined in red). Photograph also shows strip of vegetation by the sea wall which is developing separately from the main stand of saltmarsh vegetation (outlined in yellow).

Photograph 2: SM13a *Puccinellia maritima* saltmarsh community, sub-community with *Puccinellia maritima* dominant.

Appendix 3 - Photographs

Photograph 3: SM6 *Spartina anglica* saltmarsh community at the southwestern end of the site.

Photograph 4: Young developing plants of *Bolboschoenus maritimus*.

Appendix 3 - Photographs

Photograph 5: stand of vegetation with abundant, fully grown *Bolboschoenus maritimus* in main stand of SM13a *Puccinellia maritima* saltmarsh community – see Target Note 17, Appendix 2.

Appendix 3 - Photographs

Photograph 6: Dead *Puccinellia maritima* seen during the NVC survey. Tussocks of *Puccinellia maritima* appear to have died - not clear whether naturally or due to human intervention. The issue seems to be confined to a stretch of the beach approximately 220m long northeast and southwest of Beach Road. See Target Note 6, Appendix 2.

Photograph 7: Dead *Puccinellia maritima* seen during the NVC survey. See Target Note 6, Appendix 2.

Community: SM13a Puccinellia maritima saltmarsh community, sub-community with Puccinellia maritima dominant. Data differs from NVC data as follows: Armeria maritima, Atriplex portulacoides, Limonium sp and Spergularia media are absent from the site data, while they are recorded in the national NVC data, though at low frequency and/or cover. Salicornia sp are under-represented in the site data, whereas Triglochin palustris, Juncus ranarius, Bolboschoenus maritimus and Cotula coronopifolia are recorded here but not recorded in the NVC national data. Armeria maritima is rare on this site (only 1 plant seen during the survey).

Quadrat No	2	3	4	5	6	7	8	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	26	27			
Eastings	320344	320344	320837	320914	320981	320995	321045	321089	321153	321195	321181	321234	321289	321295	321346	321363	321357	321389	321429	321478	321506	321706	321626	321557			
Northings	388473	388473	388786	388869	388918	389018	389045	389037	389106	389144	389191	389209	389230	389303	389317	389306	389372	389361	389389	389434	389477	389676	389588	389533			
Community	SM13a																										
Date	23/08/2021	23/08/2021	23/08/2021	23/08/2021	23/08/2021	23/08/2021	24/08/2021	24/08/2021	24/08/2021	24/08/2021	24/08/2021	24/08/2021	24/08/2021	24/08/2021	24/08/2021	24/08/2021	24/08/2021	24/08/2021	24/08/2021	24/08/2021	24/08/2021	25/08/2021	26/08/2021	26/08/2021			
Species	**Domin value**	**Domin value**	**Domin value**	**Domin value**	**Domin value**	**Domin value**	**Domin value**	**Domin value**	**Domin value**	**Domin value**	**Domin value**	**Domin value**	**Domin value**	**Domin value**	**Domin value**	**Domin value**	**Domin value**	**Domin value**	**Domin value**	**Domin value**	**Domin value**	**Domin value**	**Domin value**	**Domin value**	**No of occurrences**	**Constancy**	**Domin range**
Puccinellia maritima	7	8	7	9	7	8	7	5	5	8	9	6	8	5	7	9	6	8	7	8	7	5	6	8	24	V	5 - 9
Triglochin palustris			3	2	4			3	3	2		5	3	2	5	3		3	4	2	3		5		16	IV	2 - 5
Triglochin maritima					2			2	1	4	2	3	1	1	2	1								2	11	III	1 - 4
Spartina anglica	1	2												1	3			4		3	2				7	II	1 - 4
Tripolium pannonicum	1	1					1			1						1				1			1		7	II	1 - 1
Lysimachia maritima		3						3	5	3		1			4										6	II	1 - 5
Juncus ranarius				2	5				1	4	3		3		2	1							3		9	II	1 - 5
Bolboschoenus maritimus				1					2			3				2				3		3			6	II	1 - 3
Cotula coronopifolia												2	3		1	2					2				5	II	1 - 3
Suaeda maritima	1					1	1													1					4	I	1 - 1
Plantago maritima		1																							1	I	1 - 1
Salicornia sp.			1		1		1												1						4	I	1 - 1
Phragmites australis			1																			1			2	I	1 - 1
Atriplex prostrata						1														4					2	I	1 - 4
Spergularia marina									5				2												2	I	2 - 5
Parapholis strigosa									1							3									2	I	1 - 3
Agrostis stolonifera										3						3									2	I	3 - 3
Plantago coronopus										1															1	I	1 - 1
Poa annua													2							1		2			3	I	1 - 2
Carex extensa													1												1	I	1 - 1
Ranunculus sceleratus																				1					1	I	1 - 1
Rumex crispus																				1					1	I	1 - 1
Taraxacum agg																						1			1	I	1 - 1
Catabrosa aquatica																							4		1	I	4 - 4
Elymus repens																				3					1	I	3 - 3
Atriplex sp seedling																							1		1	I	1 - 1
Unidentifiable small seedlings (monocotyledons)									3														3				
Bare sand %	60%	40%	60%	5%	20%	35%	55%	75%	45%	1%	5%	40%	25%	80%	50%	10%	70%	45%	50%	20%	55%	50%	0	40%			
Litter cover Domin (including algae fragments and other debris)	2	4	2	3	0	1	3	0	0	3	0	2	0	3	1	0	3	2	0	5	0	5	7 *	0			
Vegetation height cm	50	20	10	20	15	15	15	15	10	15	15	15	10	10	15	10	20	20	15	25	20	20	15	20			
No of species per quadrat	4	5	4	4	5	3	4	4	8	8	3	6	8	4	7	9	1	3	3	11	4	5	6	2			
Mean no of species per quadrat / range																										5.04	1 - 11
No of samples:																										24	

* includes standing water with algae

1-20%	I
21-40%	II
41-60%	III
61-80%	IV
81-100%	V

1	4%	I
2	8%	I
3	13%	I
4	17%	I
5	21%	II
6	25%	II
7	29%	II
8	33%	II
9	38%	II
10	42%	III
11	46%	III
12	50%	III
13	54%	III
14	58%	III
15	63%	IV
16	67%	IV
17	71%	IV
18	75%	IV
19	79%	IV
20	83%	V
21	88%	V
22	92%	V
23	96%	V
24	100%	V

Species	Constancy	Domin range		
Puccinellia maritima	V	5	-	9
Triglochin palustris	IV	2	-	5
Triglochin maritima	III	1	-	4
Spartina anglica	II	1	-	4
Tripolium pannonicum	II	1	-	1
Lysimachia maritima	II	1	-	5
Juncus ranarius	II	1	-	5
Bolboschoenus maritimus	II	1	-	3
Cotula coronopifolia	II	1	-	3
Suaeda maritima	I	1	-	1
Plantago maritima	I	1	-	1
Salicornia sp.	I	1	-	1
Phragmites australis	I	1	-	1
Atriplex prostrata	I	1	-	4
Spergularia marina	I	2	-	5
Parapholis strigosa	I	1	-	3
Agrostis stolonifera	I	3	-	3
Plantago coronopus	I	1	-	1
Poa annua	I	1	-	2
Carex extensa	I	1	-	1
Ranunculus sceleratus	I	1	-	1
Rumex crispus	I	1	-	1
Taraxacum agg	I	1	-	1
Catabrosa aquatica	I	4	-	4
Elymus repens	I	3	-	3
Atriplex sp seedling	I	1	-	1
Unidentifiable small seedlings (monocotyledons)				
No of species per quadrat - range		1	-	11
Mean no of species per quadrat	5.04			
No of samples:	24			

SM13a Constancy table

Community: SM6 Spartina anglica saltmarsh community. Data is a good fit with the national NVC data.

Quadrat No	1	9	25
Eastings	320351	320985	320409
Northings	388486	389078	388482
Community	SM6	SM6	SM6
Comments	23/08/2021	24/08/2021	26/08/2021
Species	**Domin value**	**Domin value**	**Domin value**
Spartina anglica	5	7	7
Suaeda maritima	1		
Puccinellia maritima		3	5
Salicornia sp.			1

Bare sand %	80%	60%	60%	
Litter cover Domin (including algae fragments and other debris)	3	3	3	
Vegetation height cm	40	25	50	
No of species per quadrat	2	2	3	
Mean no of species per quadrat / range				2.33 2 - 3
No of samples:				3

Eastings	Northings	Description	Label as	
320351	388486	Q1 SM6	SM6	23/08/2021
320344	388473	Q2 SM13a	SM13a	23/08/2021
320395	388454	Q3 SM13a	SM13a	23/08/2021
320837	388786	Q4 SM13a - in dead Puccinellia maritima	SM13a	23/08/2021
320914	388869	Q5 SM13a	SM13a	23/08/2021
320981	388918	Q6 SM13a	SM13a	23/08/2021
320995	389018	Q7 SM13a	SM13a	23/08/2021
321045	389045	Q8 SM13a	SM13a	24/08/2021
320985	389078	Q9 SM6	SM6	24/08/2021
321089	389037	Q10 SM13a	SM13a	24/08/2021
321153	389106	Q11 SM13a	SM13a	24/08/2021
321195	389144	Q12 SM13a	SM13a	24/08/2021
321181	389191	Q13 SM13a	SM13a	24/08/2021
321234	389209	Q14 SM13a	SM13a	24/08/2021
321289	389230	Q15 SM13a	SM13a	24/08/2021
321295	389303	Q16 SM13a	SM13a	24/08/2021
321348	389317	Q17 SM13a	SM13a	24/08/2021
321363	389306	Q18 SM13a	SM13a	24/08/2021
321357	389372	Q19 SM13a	SM13a	24/08/2021
321389	389361	Q20 SM13a	SM13a	24/08/2021
321429	389389	Q21 SM13a	SM13a	24/08/2021
321478	389434	Q22 SM13a	SM13a	24/08/2021
321506	389477	Q23 SM13a	SM13a	24/08/2021
321706	389676	Q24 SM13a	SM13a	25/08/2021
320409	388482	Q25 SM6	SM6	25/08/2021
321626	389588	Q26 SM13a	SM13a	26/08/2021
321557	389533	Q27 SM13a	SM13a	26/08/2021

Eastings	Northings	Description	Date	TN NO
320410	388482	Puccinellia maritima is establishing in stand of Spartina anglica. One plant of Armeria maritima is present here, with Salicornia sp O and Tripolium pannonicum R.	25/08/2021	1
320418	388453	Band of Puccinellia maritima 1m to 1.5m wide.	25/08/2021	2
320566	388558	At this point there is no obvious vegetation seaward and only sparse vegetation by sea wall.	25/08/2021	3
320668	388619	Sparse vegetation. Spartina anglica tussocks, Plantago coronopus R, Puccinellia maritima R, Triglochin palustre R, Bolboschoenus maritimus (young, developing plants) R	23/08/2021	4
320711	388662	Very sparse veg - not exactly a stand or community. Triglochin maritima O, Salicornia sp O, Puccinellia maritima O, Tripolium pannonicum R, Lysimachia maritima R, Suaeda maritima R, Spartina anglica R, Juncus ranarius R, Phragmites australis R.	23/08/2021	5
320747	388702	Stand of dead Puccinellia maritima. Tussocks of Puccinellia maritima appear to have died - not clear whether naturally or due to human intervention. The issue seems to be confined to a stretch of the beach approximately 220m long northeast and southwest of Beach Road.	23/08/2021	6
320906	388855	End of dead Puccinellia maritima	23/08/2021	7
320886	388850	Small stand of young developing Bolboschoenus maritimus.	23/08/2021	8
321180	389173	Stand of Lysimachia maritima 3m x 2m	24/08/2021	9
321186	389166	Small stand of young developing Bolboschoenus maritimum with Triglochin palustris, Puccinellia maritima and Triglochin maritima also present	24/08/2021	10
321189	389162	Small stand of dense Lysimachia maritima (3m x 1.5m). Instead of being constant throughout, L maritima tends to occur in dense stands in a matrix of SM13a.	24/08/2021	11
321225	389168	Stand of grassier vegetation in SM13a, with abundant Poa annua and frequent Lolium perenne. Puccinellia maritima is still present, at lower abundance.	24/08/2021	12
321269	389252	Small stand of Bolboschoenus mar	24/08/2021	13
321265	389191	On slipway Catabrosa aquatica A, Nasturtium sp (no flowers) A.		14
321411	389416	Vegetation here is sparser. Puccinellia maritima F, Suaeda maritima R, Spartina anglica R, Atriplex prostrata R.	24/08/2021	15
321524	389487	Area with Bolboschoenus maritimum A, Atriplex prostrata A, Suaeda maritima O, Elymus repens O, Triglochin maritima O, Triglochin palustris O, Tripleurospermum maritimum R, Spartina anglica R, Beta vulgaris subsp maritima R.	24/08/2021	16
321650	389611	Area with Bolboschoenus maritimum D, Triglochin palustris A, Puccinellia maritima F, Juncus ranarius F, Tripolium pannonicum F, Triglochin maritima F, Juncus gerardii cf O, Cotula coronopifolia R. This is the largest stand of developing Bolboschoenus swamp and here B maritimum is fully grown and flowering (approx 60cm high) and vegetation is dense.	25/08/2021	17

Taxon	Abundance
Poa annua	F
Puccinellia maritima	F
Rumex crispus	F
Senecio vulgaris	F
Sonchus oleraceus	F
Tripleurospermum maritimum	F
Tripolium pannonicum	F
Nasturtium sp	O/LA
Agrostis stolonifera	O/LF
Lolium perenne	O/LF
Plantago coronopus	O/LF
Ammophila arenaria	O
Atriplex littoralis	O
Atriplex patula	O
Atriplex portulacoides	O
Atriplex prostrata	O
Beta vulgaris subsp maritima	O
Bidens tripartita	O
Buddleja sp (sapling)	O
Cakile maritima	O
Capsella bursa-pastoris	O
Carex extensa	O
Catabrosa aquatica	O
Cochlearia sp	O
Cotula coronopifolia	O
Crithmum maritimum	R
Diplotaxis muralis	O
Elymus junceiformis	O
Elymus repens	O
Epilobium hirsutum	O
Epilobium parviflorum	O
Helianthus annuus	O
Juncus ranarius	O
Leymus arenarius	O
Lycopus europaeus	O
Lysimachia maritima	O
Parietaria judaica	O
Persicaria maculosa	O
Phragmitis australis	O
Plantago major	O
Plantago maritima	O
Polygonum aviculare	O
Polygonum oxyspermum	O
Ranunculus sceleratus	O
Salix sp (seedlings)	O
Sonchus arvensis	O
Stellaria media	O
Suaeda maritima	O
Taraxacum agg.	O
Triglochin maritima	O

Taxon	Abundance
Triglochin palustris	O
Anisantha sterilis	R
Arrhenatherum elatius	R
Avena sativa	R
Brassica sp	R
Catapodium marinum	R
Centranthus ruber	R
Chenopodium album	R
Cirsium arvense	R
Cymbalaria muralis	R
Dactylis glomerata	R
Equisetum arvense	R
Eryngium maritimum	R
Festuca rubra	R
Hirschfeldia incana	R
Holcus lanatus	R
Hordeum murinum	R
Hypochaeris radicata	R
Jacobaea vulgaris	R
Linaria purpurea	R
Lycium barbarum	R
Matricaria discoidea	R
Medicago lupulina	R
Oxybasis rubra	R
Papaver dubium	R
Papaver rhoeas	R
Persicaria hydropiper	R
Polypogon viridis	R
Prunus sp seedling	R
Ranunculus repens	R
Raphanus raphanistrum subsp maritimus	R
Rumex conglomeratus	R
Sagina procumbens	R
Sedum album	R
Triticum sp.	R

Bryophytes
Marchantia polymorpha

Vegetation along sea wall

Common name	Taxon	Abundance
Creeping Bent	*Agrostis stolonifera*	R
Marsh Foxtail	*Alopecurus geniculatus*	R
Marram	*Ammophila arenaria*	O
Barren Brome	*Anisantha sterilis*	R
Thrift	*Armeria maritima*	R
False Oat-Grass	*Arrhenatherum elatius*	R
Grass-leaved Orache	*Atriplex littoralis*	R
Common Orache	*Atriplex patula*	R
Sea-purslane	*Atriplex portulacoides*	R
Spear-leaved Orache	*Atriplex prostrata*	F
Oat	*Avena sativa*	R
Sea Beet	*Beta vulgaris subsp. maritima*	O
Trifid Bur-marigold	*Bidens tripartita*	O
Sea Club-rush	*Bolboschoenus maritimus*	F
a Cabbage	*Brassica sp*	R
a Butterfly-bush	*Buddleja sp*	R
Sea Rocket	*Cakile maritima*	R
Shepherd's-purse	*Capsella bursa-pastoris*	R
Long-bracted Sedge	*Carex extensa*	O
False Fox-sedge	*Carex otrubae*	R
Whorl-grass	*Catabrosa aquatica*	O
Sea Fern-grass	*Catapodium marinum*	R
Red Valerian	*Centranthus ruber*	R
Fat-hen	*Chenopodium album*	R
Creeping Thistle	*Cirsium arvense*	R
a Scurvygrass	*Cochlearia sp*	R
Buttonweed	*Cotula coronopifolia*	O/LF
Rock Samphire	*Crithmum maritimum*	R
Ivy-leaved Toadflax	*Cymbalaria muralis*	R
Cock's-foot	*Dactylis glomerata*	R
Annual Wall-rocket	*Diplotaxis muralis*	O
Sand Couch	*Elymus junceiformis*	O
Common Couch	*Elymus repens*	O
Great Willowherb	*Epilobium hirsutum*	O
Hoary Willowherb	*Epilobium parviflorum*	O
Field Horsetail	*Equisetum arvense*	R
Sea-holly	*Eryngium maritimum*	R
Red Fescue	*Festuca rubra*	R
Floating Sweet-grass	*Glyceria fluitans*	R
Sunflower	*Helianthus annuus*	R
Hoary Mustard	*Hirschfeldia incana*	R
Yorkshire-fog	*Holcus lanatus*	R
Wall Barley	*Hordeum murinum*	R
Cat's-ear	*Hypochaeris radicata*	R
Common Ragwort	*Jacobaea vulgaris*	R
Saltmarsh Rush	*Juncus gerardii*	R
Frog Rush	*Juncus ranarius*	F
Lyme-grass	*Leymus arenarius*	O
Purple Toadflax	*Linaria purpurea*	R
Perennial Rye-grass	*Lolium perenne*	O/LF
Duke of Argyll's Teaplant	*Lycium barbarum*	R
Gypsywort	*Lycopus europaeus*	O
Sea-milkwort	*Lysimachia maritima*	F
Pineappleweed	*Matricaria discoidea*	R

Common name	Taxon	Abundance
Black Medick	*Medicago lupulina*	R
a Watercress	*Nasturtium sp*	R/LA
Red Goosefoot	*Oxybasis rubra*	R
Long-headed Poppy	*Papaver dubium*	R
Common Poppy	*Papaver rhoeas*	R
Hard-grass	*Parapholis strigosa*	R
Pellitory-of-the-Wall	*Parietaria judaica*	R
Water-pepper	*Persicaria hydropiper*	R
Redshank	*Persicaria maculosa*	R
Reed Canary-grass	*Phalaris arundinacea*	R
Common Reed	*Phragmites australis*	R
Buck's-horn Plantain	*Plantago coronopus*	O
Ribwort Plantain	*Plantago lanceolata*	R
Greater Plantain	*Plantago major*	R
Sea Plantain	*Plantago maritima*	O
Annual Meadow-grass	*Poa annua*	O/LF
Knotgrass	*Polygonum aviculare*	O
Ray's Knotgrass	*Polygonum oxyspermum*	O
Water Bent	*Polypogon viridis*	R
Silverweed	*Potentilla anserina*	R
a cherry seedling	*Prunus sp seedling*	R
Reflexed Saltmarsh-grass	*Puccinellia distans*	R
Common Saltmarsh-grass	*Puccinellia maritima*	A
Creeping Buttercup	*Ranunculus repens*	R
Celery-leaved Buttercup	*Ranunculus sceleratus*	R
Sea Radish	*Raphanus raphanistrum subsp. maritimus*	R
Clustered Dock	*Rumex conglomeratus*	R
Curled Dock	*Rumex crispus*	O
Procumbent Pearlwort	*Sagina procumbens*	R
a Glasswort	*Salicornia sp.*	F
Common Glasswort	*Salicornia europaea*	R
a willow seedling	Salix sp (seedling)	O
White Stonecrop	*Sedum album*	R
Groundsel	*Senecio vulgaris*	O
Perennial Sow-thistle	*Sonchus arvensis*	R
Smooth Sow-thistle	*Sonchus oleraceus*	R
Common Cord-grass	*Spartina anglica*	F
Lesser Sea-spurrey	*Spergularia marina*	O
Greater Sea-spurrey	*Spergularia media*	R
Common Chickweed	*Stellaria media*	R
Annual Sea-blite	*Suaeda maritima*	O
Dandelion	*Taraxacum agg.*	R
Sea Arrowgrass	*Triglochin maritima*	F
Marsh Arrowgrass	*Triglochin palustris*	F
Sea Mayweed	*Tripleurospermum maritimum*	O
Sea Aster	*Tripolium pannonicum*	F
a Wheat	*Triticum sp*	R
Colt's-foot	*Tussilago farfara*	R
a Bulrush	*Typha sp* (seedling)	R
	Bryophytes	
	Marchantia polymorpha	

Community	Area m2	Area ha
SM13a	107860.69	10.79
SM6	6006.58	0.60

Appendix C: Natural Capital Value Assessment

Ecosystem service modelling assessment for Hoylake Beach

Authors: Luke Bentley, Sandra Angers-Blondin, Colm Bowe (Liverpool John Moores University)

8th February 2022

Context

Natural capital is defined as the "elements of nature that directly or indirectly produce value or benefits to people, including ecosystems, species, freshwater, land, minerals, the air and oceans, as well as natural processes and functions"[1]. Ecosystem services are defined as being "the aspects of ecosystems utilized (actively or passively) to produce human well-being"[2].

The major benefits of natural capital to humans include ecosystem services such as: the supply of timber from trees, the supply of fish for consumption, erosion control, crop pollination, water filtration, carbon storage to reduce the impact of climate change, noise reduction, air pollution reduction and the maintenance of greenspaces and biodiversity for the benefit of ecosystems and human recreation, with benefits to mental and physical health. Natural capital is therefore critically important for the maintenance of a high quality of life for human populations.

In this study, we use ecosystem service models to examine the change in ecosystem service provision from Hoylake Beach in its current state compared to projected future states of the beach caused by climate change-induced sea level rise, natural sediment accretion and possible future beach management scenarios.

Methodology

Natural capital baseline

EcoservR is a natural capital mapping toolkit that measures ecosystem services from a habitat map generated from national datasets which are openly accessible to the public or available under public

[1] Natural Capital Committee. 2014. Towards a Framework for Defining and Measuring Changes in Natural Capital. Working Paper 1, Natural Capital Committee.
[2] Fisher, B., Turner, R. K., Morling, P. 2009. Defining and classifying ecosystem services for decision making. Ecological Economics, 68(3): 643-653.

sector agreements. The tool is a modernised version of Ecoserv-GIS, which was originally developed at the Durham Wildlife Trust in 2013 but had become obsolete.

The original documentation for Ecoserv-GIS contains literature reviews and step-by-step explanations for the data processing of the natural capital baseline and ecosystem service models[3], which have been summarised in this document.

The baseline map used for this exercise is an updated version of the Liverpool City Region Natural Capital Baseline[4] which draws on the following datasets to derive an ecological habitat classification:

- OS MasterMap Topography
- OS MasterMap Greenspace
- OS Open Greenspace
- CORINE Land Cover 2018
- National Forest Inventory 2019
- Priority Habitat Inventory
- Crop Map of England 2019
- Digital terrain model (5-m resolution)
- Hedgerows

The baseline (habitat) map was manually updated with the extents of dense and less dense saltmarsh as recorded during a NVC habitat survey in 2021, to reflect the current coastal habitats at Hoylake beach more accurately.

Mapping scenarios

The natural capital baseline (habitat map) was modified based on the predictions for future vegetation and tideline locations in 10, 20 and 50 years' time under a medium emissions 50th percentile sea-level rise UKCP18 scenario. This was carried out on two hypothetical shoreline management scenarios: a "do nothing" scenario where the shoreline is left to develop naturally, and a "do everything" scenario whereby the shoreline is kept free of all vegetation. All analyses were undertaken for the area of beach accretion and potential management (white box, Figure 1).

For the "do nothing" scenario, the predicted extent of dense and less dense saltmarsh (at t = 10y, 20y and 50y) were merged onto the baseline map to reflect projected changes in the landscape (Figure 1B). Furthermore, all sandy ground between the high astronomical tide line and the sea wall was converted to sand dunes (open dunes for t = 10 and t = 20, grassy dunes for t = 50) to reflect natural succession if no vegetation controls were applied.

For the "do everything" scenario, the area classified as saltmarsh and sand dune in the "do nothing" scenario are classified as intertidal sand / mudflat habitat to reflect the outcome of intensive management designed to remove vegetation on the beach (Figure 1C).

[3] Winn, J.P., Bellamy, C.C. & Fisher, T. 2018. EcoServ-GIS: a toolkit for mapping ecosystem services. Scottish Natural Heritage Research Report No. 954. https://www.nature.scot/doc/naturescot-research-report-954-ecoserv-gis-v33-toolkit-mapping-ecosystem-services-gb-scale

[4] Holt, A., Rouquette, J., Bowe, C., Busdieker, K., Angers-Blondin, S. 2020. Baseline natural capital assessment for the Liverpool City Region.

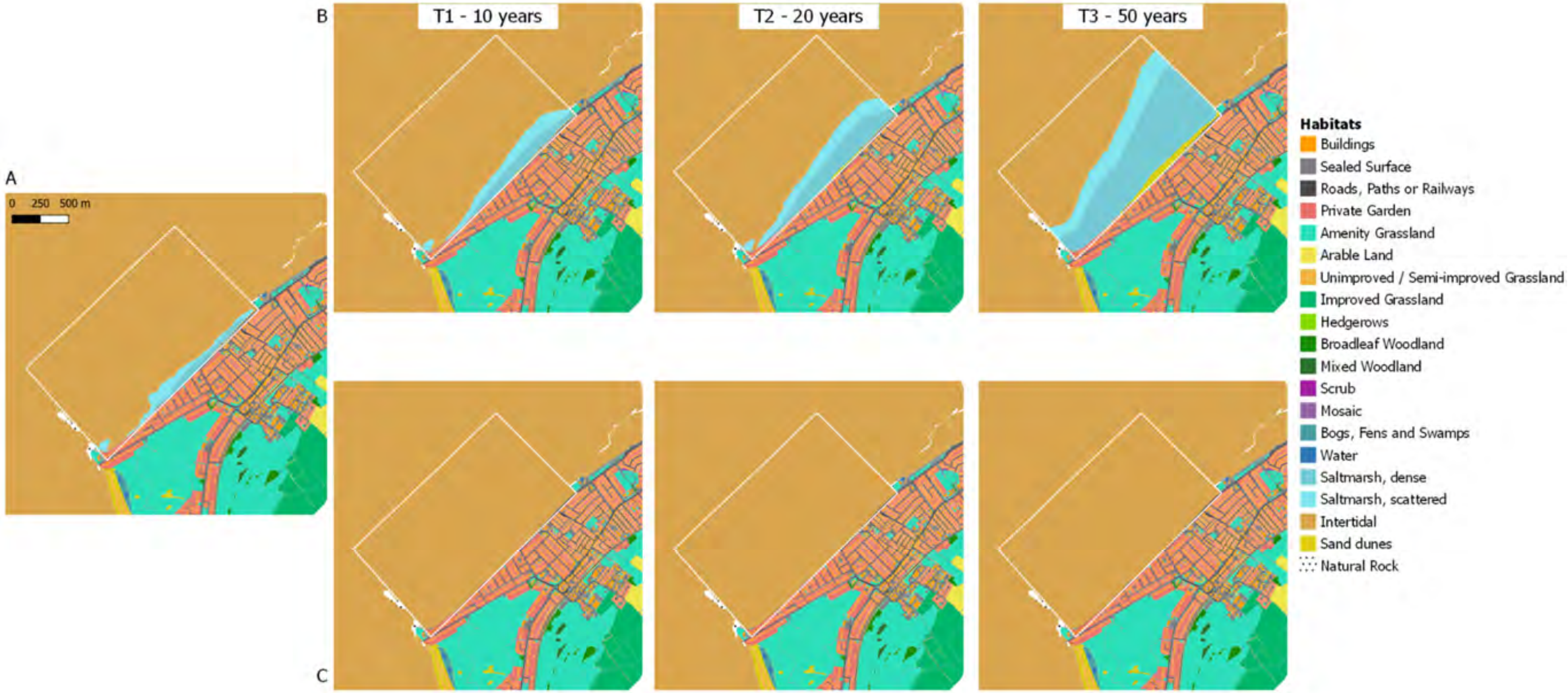


Figure 1. Current habitat baseline for Hoylake beach (A) and predicted evolution over time under “do nothing” (B) and “do everything” (C) scenarios. The white box denotes the region within which beach accretion and potential management will occur in the future, and all results are reported for this area.

Modelling ecosystem service provision

Carbon sequestration

Vegetation captures CO_2 through photosynthesis. Carbon sequestration refers to the net rate (amount of carbon per unit area and per unit of time) of uptake. Creating and maintaining natural sinks of carbon is important in tackling climate change.

Semi-natural habitats are assigned a carbon (C) sequestration value (tons C (tC) per ha per year) representing the amount of carbon that is drawn down or released annually per unit area. Negative values represent sequestration (sinks) and positive values represent emission (sources). These values are averages taken from the scientific literature, and do not consider habitat condition, land management, or the specific soil type at the location. The model does not consider emissions from built-up areas.

Average values for carbon sequestration capacity in coastal habitats are presented in Table 1. A rate of sequestration for less dense saltmarsh of 70% the rate of denser marsh was assumed.

Table 1. Carbon storage and sequestration values for coastal habitats

Habitat	Carbon storage (tC ha^{-1})	Carbon sequestration (tC ha^{-1} y^{-1})	Source
Intertidal sediments	11.9	-2.0	Gregg *et al.* 2021[5], Armstrong *et al*. 2020 [6]
Salt marsh, less dense	39.1	-3.6	Ford *et al.* 2019[7], Gregg *et al.* 2021
Salt marsh, dense	40.8	-5.2	Ford *et al.* 2019, Gregg *et al.* 2021
Sand dunes, open	0.01	-2.18	Gregg *et al.* 2021
Sand dunes, grassy	6.01	-2.18	Gregg *et al.* 2021

Carbon storage

Part of the carbon drawn up by vegetation accumulates in plant tissues and is incorporated into the soil over time.

Semi-natural habitats are assigned a carbon storage value (tC per ha) representing the amount of carbon that can be stored by this vegetation type and the top 30cm of soil. These values are averages taken from the scientific literature, and do not consider habitat condition, land management, or the specific soil type at the location.

[5] Gregg, R., Elias, J. L., Alonso, I., Crosher, I.E. , Muto, P., and Morecroft, M.D. 2021. Carbon storage and sequestration by habitat: a review of the evidence (second edition) Natural England Research Report NERR094. Natural England, York.

[6] Armstrong, S., Hull, S., Pearson, Z., Wilson, R. and Kay, S. 2020. Estimating the Carbon Sink Potential of the Welsh Marine Environment. NRW, Cardiff, 74p

[7] Ford, H., Garbutt, A., Duggan-Edwards, M., Harvey, R., Ladd, C., and Skov, M. W. 2019. Large-scale predictions of salt-marsh carbon stock based on simple observations of plant community and soil type. *Biogeosciences*, *16*(2), 425-436.

Average values for carbon storage capacity (Table 1) in saltmarshes were obtained from a study in Wales with similar saltmarshes and for which carbon stock and root density measurements were available. We used the values for *Puccinellia maritima* communities (the dominant community at Hoylake) and extracted the linear prediction of carbon stock using the 25th and 75th percentile of root density (for less dense and dense saltmarsh, respectively) from a linear regression.

Carbon storage was only estimated for the T3 –50 year time period. This was due to the uncertainty of the rate of carbon accumulation over the other time periods.

Air purification

Air pollution is a major health concern. Vegetation can trap particulate matter and other airborne pollutants and therefore improve air quality locally.

This model assigns scores (0-100) to habitat types based on their relative capacity to trap pollutants and improve air quality. Taller, denser vegetation (especially evergreen) scores the highest. Therefore the best habitats for this service are woodland (especially coniferous), with scrubland and other semi-natural habitats scoring lower. Built-up areas are considered to have a score of 0. Because the benefits that a habitat provides may be felt a certain distance away from the habitat itself, focal statistics sum the scores at A) a short (20 m) and B) local (100 m) range. The two are then combined (summed) to produce the final capacity map. Patches smaller than 100m^2 are removed as they are unlikely to provide the service to any meaningful extent.

Access to nature

Access to greenspaces is important for physical and mental wellbeing. People are more likely to visit sites close to their place of residence and are more attracted to greenspaces with a higher perceived naturalness.

This model extracts pavements and greenspace features deemed publicly accessible from the habitat map, and supplements them with Public Rights of Way, Open Country and Registered Common Land (CRoW Act 2000), Local Nature Reserves and National Nature Reserves locations. Naturalness scores are assigned to each habitat so that "wilder" or more complex habitats are rated as more attractive. Because the benefits that a habitat provides may be felt a certain distance away from the habitat itself, focal statistics sum the scores at a local (300m) range. Patches smaller than 500m^2 are removed as they are unlikely to provide the service to any meaningful extent.

High and equal naturalness scores were assumed for saltmarsh and sandflats, as both habitats are attractive to people for various reasons (recreation, exercise, wildlife watching, etc). It was assumed that there were no access restrictions in place for either saltmarsh or sandflats under either scenario. In practice, some areas might not be accessible to the public for safety reasons, or future management plans may set aside areas for conservation, which may limit access provision.

Pollination

Wild pollinators can contribute to the pollination of crops, and form part of a place's biodiversity.

This model provides a probability of pollinators visiting based on the proximity of suitable habitats. Core habitats (semi-natural grasslands, heathlands, scrub, hedgerows, gardens) and edge habitats (woodlands; suitable for nesting when within 20m of core habitats) are selected from the habitat map. Distances to habitats are calculated (up to 668m which is considered the maximum flight distance) and converted to a visitation probability score (which decreases with increasing distance to habitats). For this study saltmarsh and sand dunes are assumed to be core habitats.

Noise regulation

Major roads, railways, airports, and industrial areas can create substantial amounts of noise, which in turn is an environmental health hazard. Vegetation can dampen and block noise, improving conditions for people living near noise sources.

This model assigns relative scores (0-100) to habitat types based on their relative capacity to reduce noise. Built-up areas are considered to have a score of 0. Because the benefits that a habitat provides may be felt a certain distance away from the habitat itself, focal statistics sum the scores at A) a short (30m) and B) local (300m) range. The two are then combined (summed) to produce the final capacity map. Patches smaller than $500m^2$ are removed as they are unlikely to provide the service to any meaningful extent.

Climate regulation

Heat waves pose risk to human health, especially in urban areas where a heat island effect may develop. Landscape features which provide shade or are able to absorb heat can help mitigate this effect.

This model assigns relative scores (0-100) to habitat types based on their relative capacity to cool down their surroundings. Areas with trees (shade) and bodies of water are especially good at this. Because the benefits that a habitat provides may be felt a certain distance away from the habitat itself, focal statistics sum the scores at a local (300m) range. Because smaller patches will have less of an impact on their surroundings than large patches, a series of buffers are then used as masks to constrain the cooling scores around the features that provide them (< 2ha: 20m | 2-5ha: 40m | 5-10ha: 80m | > 10ha: 100m).

Results

Habitat change

Under the 'do nothing' scenario, sand is predicted to progressively give way to saltmarsh and sand dune habitats (Table 2).

Under the 'do everything' scenario, the area of sand is predicted to remain the same, as vegetation is continually removed (Table 3).

Table 2. Change in area in hectares of the four habitat types under the 'do nothing' scenario at t = 10, 20 and 50 years.

		Area (ha) *(and change from baseline)*					
Habitat	**Baseline**	**t1**		**t2**		**t3**	
Sand / mud flats	183.36	171.99	*(-11.38)*	158.02	*(-25.34)*	92.62	*(-90.74)*
Salt marsh, less dense	6.85	12.31	*(+5.46)*	16.04	*(+9.19)*	26.46	*(+19.60)*
Salt marsh, dense	4.85	10.56	*(+5.72)*	20.36	*(+15.52)*	70.72	*(+65.87)*
Sand dunes	0.00	0.21	*(+0.21)*	0.66	*(+0.66)*	5.29	*(+5.29)*

Table 3. Change in area in hectares of four important habitat types under the 'do everything' scenario at t = 10, 20 and 50 years.

		Area (ha) *(and change from baseline)*					
Habitat	**Baseline**	**t1**		**t2**		**t3**	
Sand / mud flats	183.36	195.06	*(+11.70)*	195.07	*(+11.71)*	195.08	*(+11.72)*
Salt marsh, less dense	6.85	0.00	*(-6.85)*	0.00	*(-6.85)*	0.00	*(-6.85)*
Salt marsh, dense	4.85	0.00	*(-4.85)*	0.00	*(-4.85)*	0.00	*(-4.85)*

Change in ecosystem services

Carbon sequestration

Under the "do nothing" scenario, the carbon sequestration rate is predicted to increase progressively over time as the vegetation communities develop, and to be 59% higher (additional 245 tC per year) in 50 years compared to the current-day baseline (Table 4, Figure 2).

Table 4. Predicted current and future annual rate of carbon sequestration (tC per year) by the main habitat types at Hoylake beach under a "do nothing" scenario. (t1= after 10 years, t2= after 20 years, t3= after 50 years)

	Carbon sequestration (tonnes C / year)			
Habitat	**Baseline**	**t1**	**t2**	**t3**
Sand / mud flats	363.1	340.5	312.9	183.4
Saltmarsh	50.0	99.5	163.9	463.0
Sand dune	*NA*	0.5	1.4	11.5
Total	*413.1*	*440.5*	*478.2*	*658.0*

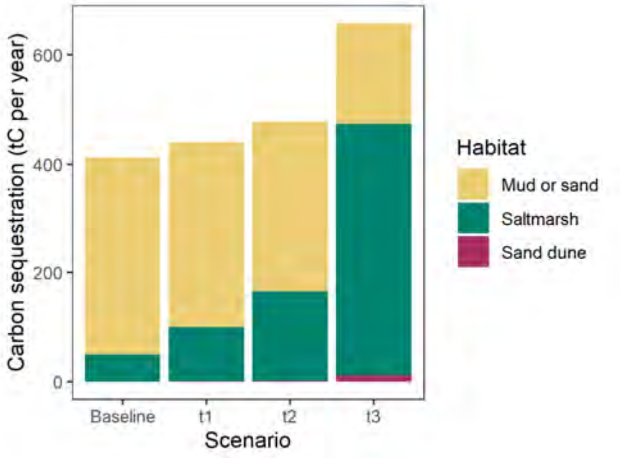


Figure 2. Predicted current and future annual rate of carbon sequestration (tC per year) by the main habitat types at Hoylake beach under a “do nothing” scenario. (t1= after 10 years, t2= after 20 years, t3= after 50 years) (NB: sand dunes are present at t1 and t2, but in such a small proportion that their contribution is very small compared to the other main habitats)

Under the “do everything” scenario, the carbon sequestration rate is predicted to decrease after the removal of saltmarsh, and then to remain constant. The future annual rate is expected to be around 6% lower (-27 tC/year) than the current-day baseline (Table 5, Figure 3).

Table 5. Predicted current and future annual rate of carbon sequestration (tC per year) by the main habitat types at Hoylake beach under a “do everything” scenario. (t1= after 10 years, t2= after 20 years, t3= after 50 years).

	Carbon sequestration (tonnes C / year)			
Habitat	**Baseline**	**t1**	**t2**	**t3**
Sand / mud flats	363.1	386.2	386.2	386.3
Saltmarsh	50.0	*0*	*0*	*0*
Total	*413.1*	*386.2*	*386.2*	*386.3*

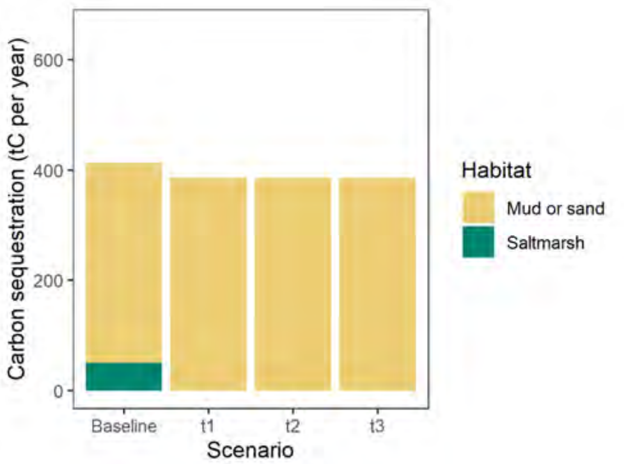


Figure 3. Predicted current and future annual rate of carbon sequestration (tC per year) by the main habitat types at Hoylake beach under a “do everything” scenario. (t1= after 10 years, t2= after 20 years, t3= after 50 years).

Carbon storage potential

Carbon storage refers to the stock of carbon locked in vegetation and soils over longer periods of time (at least 30 years in our models). Based on the final habitat map (landscape in 50 years' time) and assuming the habitats have by then reached a relatively mature state, carbon stocks have been predicted to increase by 2406 tonnes under the "do nothing" scenario, a 91% increase from the present stock (Table 6). Under the "do everything" scenario, a decrease of 326 tonnes has been predicted, translating into a loss of 12% of baseline stocks (Table 7).

Table 6. Projected carbon storage beyond t3 (50 years) under a "do nothing" scenario.

	Carbon storage (tC)	
Habitat	**Baseline**	**Long-term (50+ years)**
Sand / mud flats	2182.0	1102.2
Saltmarsh	465.6	3919.6
Sand dune	*0*	31.8
Total	*2647.6*	*5053.6*

Table 7. Projected carbon storage beyond t3 (50 years) under a "do everything" scenario.

	Carbon storage (tC)	
Habitat	**Baseline**	**Long-term (50+ years)**
Sand / mud flats	2182.0	2321.4
Saltmarsh	465.6	*0*
Total	*2647.6*	*2321.4*

Other ecosystem services

The provision of ecosystem services generally increased over time under the 'do nothing' scenario (Table 8). In particular, there were large score increases for the air purification, noise pollution reduction, green space access and pollination ecosystem services. Climate amelioration (cooling effect) had no change in score.

Table 8. Change in average ecosystem service score of five important ecosystem services under the 'do nothing' scenario at t = 10, 20 and 50 years. For each service, score maps were rescaled to a 0-100 range before calculating the average score over the study area, with 100 being the highest capacity.

	Average ES score *(and change from baseline)*						
Ecosystem service	**Baseline**	**t1**		**t2**		**t3**	
Green space access	4.85	9.04	*(+4.19)*	14.65	*(+9.80)*	44.23	*(+39.38)*
Air purification	6.28	11.78	*(+5.50)*	18.53	*(+12.25)*	50.81	*(+44.52)*
Climate amelioration	0.00	0.00	*(0)*	0.00	*(0)*	0.00	*(0)*
Noise pollution	7.07	11.27	*(+4.20)*	16.90	*(+9.83)*	46.86	*(+39.79)*
Pollination	55.38	60.94	*(+5.56)*	67.58	*(+12.20)*	89.53	*(+34.16)*

The provision of ecosystem services predominantly decreased under the ‘do everything’ scenario (Table 9). Green space access was the only service with a projected increase, while scores decreased for air purification, noise pollution reduction and pollination. Climate amelioration (cooling effect) had no change in score.

Table 9. Change in average ecosystem service score of six important ecosystem services under the ‘do everything’ scenario at t = 10, 20 and 50 years. For each service, score maps were rescaled to a 0-100 range before calculating the average score over the study area, with 100 being the highest capacity.

	Average ES score *(and change from baseline)*						
Ecosystem service	**Baseline**	**t1**		**t2**		**t3**	
Green space access	4.85	9.04	*(+4.19)*	14.65	*(+9.80)*	44.23	*(+39.38)*
Air purification	6.28	1.45	*(-4.84)*	1.45	*(-4.84)*	1.45	*(-4.84)*
Climate amelioration	0.00	0.00	*(0)*	0.00	*(0)*	0.00	*(0)*
Noise pollution	7.07	3.48	*(-3.60)*	3.48	*(-3.60)*	3.48	*(-3.60)*
Pollination	55.38	46.02	*(-9.35)*	46.02	*(-9.35)*	46.02	*(-9.35)*

Air purification change under a ‘do nothing’ scenario is provided in the following figure (Figure 4), giving an example of how ecosystem service scores spatially change over the study area. As expected, scores increase over the new saltmarsh habitat that establishes under a ‘do nothing’ scenario, leading to an overall increase in air purification capacity for Hoylake beach.

Take-away messages

- Carbon sequestration and storage potential are expected to increase strongly if areas of vegetation increase and it further colonises the site, with an additional 245 tC sequestered every year and a near doubling of current carbon stocks after 50 years.
- Carbon sequestration and storage potential are expected to decrease slightly if vegetation is prevented from establishing, with a 6% lower sequestration capacity and a loss of around 326 tC from current carbon stocks.
- The provision of ecosystem services is broadly predicted to increase if areas of vegetation increase and it further colonises the site, with green space access, air purification, noise pollution reduction and pollination showing increasing capacity over time.
- The provision of ecosystem services is broadly predicted to decrease if vegetation is prevented from establishing, with pollination, noise pollution reduction and air purification showing a decreasing trend over time. The exception is access to nature which is expected to increase.

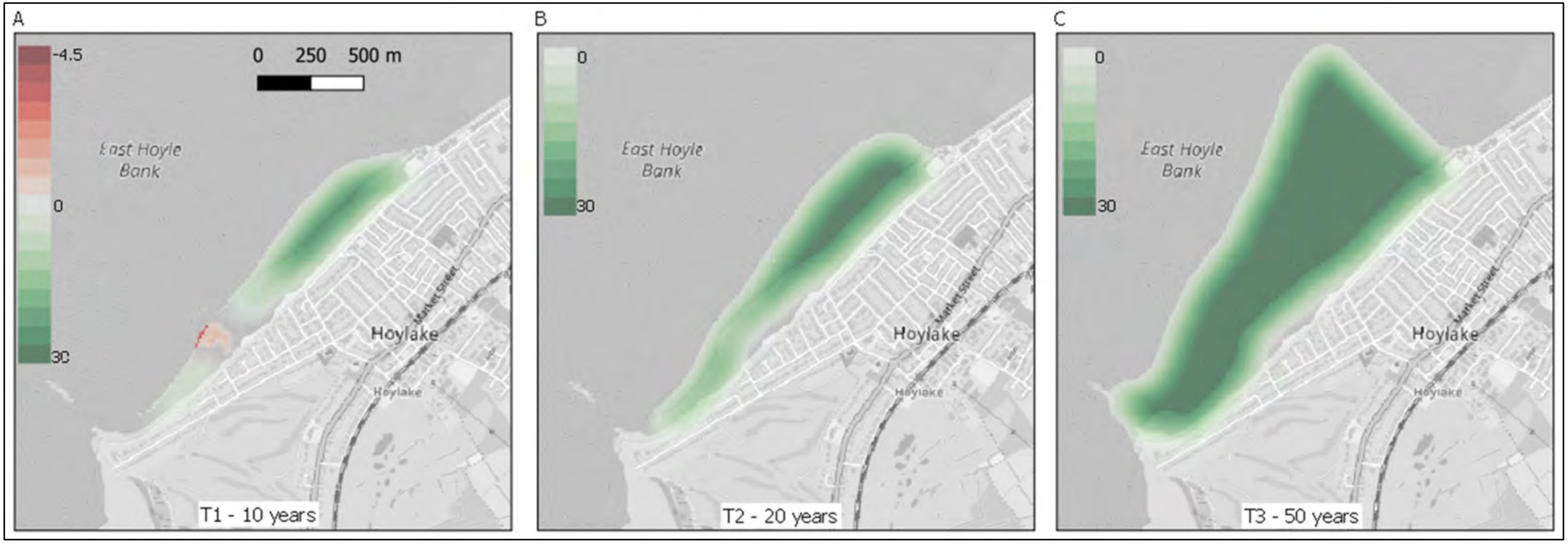


Figure 4. Change in air purification capacity score at (A) t1, (B) t2 and (C) t3. Greens denote an increase in air purification capacity, while reds denote a decrease.

Royal HaskoningDHV is an independent, international engineering and project management consultancy with over 138 years of experience. Our professionals deliver services in the fields of aviation, buildings, energy, industry, infrastructure, maritime, mining, transport, urban and rural development and water.

Backed by expertise and experience of 6,000 colleagues across the world, we work for public and private clients in over 140 countries. We understand the local context and deliver appropriate local solutions.

We focus on delivering added value for our clients while at the same time addressing the challenges that societies are facing. These include the growing world population and the consequences for towns and cities; the demand for clean drinking water, water security and water safety; pressures on traffic and transport; resource availability and demand for energy and waste issues facing industry.

We aim to minimise our impact on the environment by leading by example in our projects, our own business operations and by the role we see in “giving back” to society. By showing leadership in sustainable development and innovation, together with our clients, we are working to become part of the solution to a more sustainable society now and into the future.

Our head office is in the Netherlands, other principal offices are in the United Kingdom, South Africa and Indonesia. We also have established offices in Thailand, India and the Americas; and we have a long standing presence in Africa and the Middle East.

ETHIC Intelligence
CERTIFICATE ANTI-CORRUPTION COMPLIANCE SYSTEM

royalhaskoningdhv.com

Royal HaskoningDHV
Enhancing Society Together