EASTERN SOLENT | COASTAL PARTNERSHIP

Hayling Island Coastal Management Strategy Coastal Processes Study

Report

Date: December 2020

Version: 6.0

Portsmouth City Council · Havant Borough Council · Fareham Borough Council www.fareham.gov.uk · Gosport Borough Council

Document Information

Project	Hayling Island FCERM Strategy
Technical Subject	Coastal Processes
Department	Eastern Solent Coastal Partnership now called Coastal Partners
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Document History

Date	Revision	Prepared	Reviewed	Notes
30/04/2020	0.0	EL/EH	SC	Draft for internal review
05/06/2020	1.0	EL/EH	SN/SC	
14/07/2020	2.0	EL/EH	SN/SC	Awaiting erosion zones
09/09/2020	3.0	EL/EH	SN/SC	Awaiting erosion zones
28/10/2020	4.0	EL/EH	SC	Awaiting erosion zones
04/11/2020	5.0	EL/EH	SC	Issued to AECOM
15/12/2020	6.0	EL/EH	SC	Final

Contents

Glossary

Term	Definition
Beach Nourishment	A term to describe the addition of material to areas of eroding shoreline, encompassing beach bypass, recharge and recycling.
Beach Profile	Cross-section perpendicular to the shoreline, usually repeatedly surveyed (from the same start point and bearing) for regional monitoring purposes or to describe the 1-dimensional characteristics of a beach.
Beach Recharge	Artificial process of replenishing a beach with material from another source outside of the local littoral system.
Beach Recycling	The movement of sediment along a beach area, typically from areas of accretion to areas of eroding shoreline within the same littoral system.
Bi-modal	In a bimodal sea state, both locally generated wind waves are present as well as swell waves. The potential for damage to the coastline is much greater than for each wind and swell waves alone.
BMP (Beach Management Plan)	This provides a basis for the management of a beach primarily for coastal defence purposes, taking into account coastal processes and the other uses of the beach.

Term	Definition
Climate Change	Long term changes in climate. The impact of climate change along the coast is usually associated with changes in sea level and wave climate
Coastal squeeze	The reduction in habitat area which can arise if the natural landward migration of a habitat under sea level rise is prevented by a fixation of the high water mark.
Crest	Highest point on a beach face, breakwater or seawall.
Crest width	A term adopted for the nourished frontage to describe the horizontal distance from the beach crest (where the beach slope angle drops down towards the sea) to the seaward edge of the promenade.
Do Minimum	When assessing erosion zones, this scenario assumes that there are ongoing ad hoc repairs or maintenance which extends the life of the defences and delays the onset of erosion.
Do Nothing	When assessing erosion zones, this means to assume that no further work is carried out on coastal defences. The Environment Agency guidance defines this as to 'walk away with no further intervention'.
Fetch length	The distance that a constant direction of wind can (or has already) pass across a water body (such as an ocean). Longer fetch creates higher energy waves. Fetch length, along with the wind speed (or wind strength), determines the size (sea state) of waves produced.
Geomorphology/ morphology	The scientific study of the nature and history of the landforms on the surface of the Earth and other planets, and of the processes that create them.
Inshore	Areas where waves are transformed by interaction with the seabed.
Joint probability	The probability of two (or more) variables (e.g. wave height and sea level) occurring simultaneously.
Joint Probability Analysis (JPA)	Method to generate joint probability values, by calculating the joint probability distribution of two (or more) variables – typically based on Extreme Value Theory
LiDAR (Light Detection and Ranging)	This is a remote (e.g. airborne) mapping technique which uses a laser and other instruments to measure ground elevation at high spatial resolution.
Longshore drift	Movement of material parallel to the shore, also referred to as longshore drift.
mCD (metres Chart Datum)	This is referenced to approximately the lowest astronomical tidal level at a given location. It is typically a reference datum used for navigation purposes.
mOD (metres Ordnance Datum)	A vertical datum used in the UK, equal to the mean sea level at Newlyn in Cornwall between 1915 and 1921. It is typically a reference datum used for terrestrial purposes.
Nearshore	The zone that extends from the swash zone to the position marking the start of the offshore zone.
Offshore	The zone beyond the nearshore zone where sediment motion induced by waves alone effectively ceases and where the influence of the seabed on wave action has become small in comparison with the effect of wind.
Overtopping	Water carried over the top of a coastal defence due to wave run-up exceeding the crest height.

Term	Definition
Recharge	Material brought in for beach nourishment from outside the sediment cell. For the purposes of the BMP, this includes material imported by road and material dredges from licenced offshore sites.
Recycling	Material brought in for beach nourishment from within the sediment cell. For the purposed of the BMP, this includes The Ness, West Beach, Open Beach, Coastguard Revetment and Gunner Point and Chichester Harbour Entrance Channel.
Return Period	A statistical measurement denoting the average probability of occurrence of a given event (e.g. sea level or wave height) over time (usually the annual probability per year).
(Mean) sea level change	The rise and fall of mean sea level in relation to the land level throughout geological and historic time in response to global climate and local tectonic changes.
Sediment transport	The movement of a mass of sedimentary material by the forces of currents, waves or wind.
SERCMP	South East Regional Coastal Monitoring Programme. This provides a consistent regional approach to coastal process monitoring which provides information for the development of SMPs, strategies and schemes and the operational maintenance and management of existing flood protection infrastructure. Some of the information provided and surveys undertaken include topographic beach surveys, LiDAR, aerial photography and wave buoy data. Reports are produced on the analysis of some of this data.
Significant wave height (H_s)	Traditionally known as the ‘mean wave height’ (trough to crest) of the highest third of waves (in a spectrum). Statistically, it is possible to encounter waves much higher than the H_s value.
SMP (Shoreline Management Plan)	It provides a large-scale assessment of the risks associated with coastal processes and presents a policy framework to manage these risks to people and the developed, historic and natural environment in a sustainable manner.
Standard of Protection (SoP)	The level of return period (or joint return period event) event which the defence is expected to withstand without experiencing significant failure.
Storm surge	A rise in the sea surface on an open coast, resulting from a storm (from the combined effects of wind stress and low pressure).
Swell waves	See information on ‘wind waves’.
UKCP18 (UK Climate Projections 2018)	This is the UKs leading sources of climate change information, providing projections of variables such as sea level rise.
Wave climate	Average condition of the waves at a given place over a period of years, as shown by height, period, direction etc.
Wave direction	Direction from which a wave approaches.
Wave height	The vertical distance between the crest and the trough.
Wave hindcast	In wave prediction, the retrospective forecasting of waves using measured wind information.

Term	Definition
Wave period	The time it takes for two successive crests (or troughs) to pass a given point.
Wave refraction	Process by which the direction of approach of a wave changes as it moves into shallow water. The process by which the direction of a wave moving in shallow water at an angle to the contours is changed so that the wave crests tend to become more aligned with those contours.
Wave reflection	The part of an incident wave that is returned (reflected) seaward when a wave impinges on a beach, seawall or other reflecting surface.
Wind waves (or surface gravity waves)	Waves in seas, lakes etc. are generated by wind blowing over the surface. They can comprise (1) wind waves -generated by the local prevailing wind, (2) swell waves which are more regular longer period waves generated by the winds of distant weather systems. ‘Sea state’ describes the combination of wind waves and swell (i.e. can be used to define whether a spectrum is unimodal or bimodal). Swell contains longer period waves which can cause greater run-up and damage at the coast.

1 Introduction

This report produced by the Eastern Solent Coastal Partnership (ESCP), now known as Coastal Partners following a rebranding in Autumn 2020, will compile the baseline coastal process understanding for the Hayling Island Coastal Management Strategy (referred to as the ‘Strategy Study’ throughout the report), being undertaken by AECOM and Coastal Partners. Existing research relating to Hayling Island will be summarised, alongside new coastal process analysis carried out as part of the Strategy Study, using South-east Regional Monitoring Programme (SRCMP) data up to 2020. The findings have underpinned the policy and management decisions in conjunction with the Flood and Coastal Erosion Risk Modelling, Defence Condition Assessment (AECOM, 2019), Coastal Landfill Report (ESCP, 2019), Economic Appraisal and Environmental Assessments (Figure 1.1).

Figure 1.1 Reporting structure for the Hayling Island Coastal Management Strategy

1.1 Overview of the Problem

The Action Plan from the North Solent Shoreline Management Plan (NSSMP) 2010 identified the need for an FCERM (Flood and Coastal Erosion Risk Management) Strategy for the Hayling Island Coastline for the next 100 years. This report will present the latest coastal process understanding (hydrodynamics and sediment dynamics) for the entirety of Hayling Island.

Situated on the central south coast of England, Hayling Island is characterised by a complex combination of coastal environments. These include a mixed sand and shingle beach on the exposed southern open coast, as well as inter-tidal mudflats and saltmarsh with intermittent small beaches inside Langstone and Chichester Harbours (Figure 1.2). The coastline around Hayling Island is diverse with differing geomorphology, multiple landowners and as a result has a range of coastal management issues.

Much of the island is rural, with some areas of urbanisation being vulnerable to flooding, most notably at Eastoke (Figure 1.3). With no maintenance, large areas of the island would be subject to significant coastal change and there are many defences that are nearing the end of their residual lives.

Figure 1.2 Location plan, showing some commonly referred to place names throughout the report

1.1.1 Flood Risk

Much of Hayling Island has been reclaimed over the years, resulting in low lying land with significant areas at risk of tidal flooding from tidal surges. Figure 1.3 presents the Strategy flood modelling which is discussed in more detail in Section 1.2.

Many of the flood events experienced in the past on Hayling Island have occurred in the south-eastern corner of the island where the coastline is most exposed to the impacts of bi-modal wave conditions. The sheltered northern parts of the island inside the harbours are prone to flooding from tidal surges rather than large wave action. Residential roads and extensive areas of grazing land have flooded on several occasions, as well as properties in Northney Road and Mill Rythe Yacht building yard (see Figure 1.3 with Figure 1.2 for location reference). Flooding has also historically occurred adjacent to the A3023 approach to Langstone Bridge. The level of risk is expected to increase in the future due to projected sea level rise.

The Economic Report for the Strategy details the number of properties at risk from flooding according to the latest predictions. Present day (2021) there are 243 residential and 92 non-residential properties across the whole of Hayling Island at risk of a 1 in 200-year flood event. This increases to 2,166 residential and 992 non-residential properties in 2121 (AECOM, 2022).

1.1.2 Erosion Risk

The majority of Hayling Island's flood and erosion risk is managed by man-made coastal defences. These are often fronted by inter-tidal mudflats, saltmarshes and beaches which work to reduce erosion risk along the coastline. Without these man-made and natural sea defences, the island would be under increased threat from erosion, most notably on the open coast compared with the harbours.

The NSSMP (2010) explored coastal erosion under two different future management scenarios; No Active Intervention (NAI) and With Present Management (WPM). The Strategy study has updated the NAI projections with new data to produce a 'Do Nothing' and 'Do Minimum' scenario. These include latest information on sea level rise, residual life, average annual erosion, rebound from removal of defences and the latest baseline of the coast (see Section 2.4 for more information). Figure 1.3 presents the 'Do Nothing' scenario. This information has informed the economic analysis to estimate the number of properties at risk. In Epoch 1 (2021-2041), a total of 34 residential and 3 non-residential properties across the whole of Hayling Island are at risk of erosion under a Do Nothing scenario. This increases to 494 residential and 77 non-residential properties in Epoch 2 (2041-2071) and 690 residential and 105 non-residential properties in Epoch 3 (2071-2121) (AECOM, 2022). Note that these numbers exclude the additional 811 properties that would be written off from the loss of Southwood Road (AECOM, 2022).

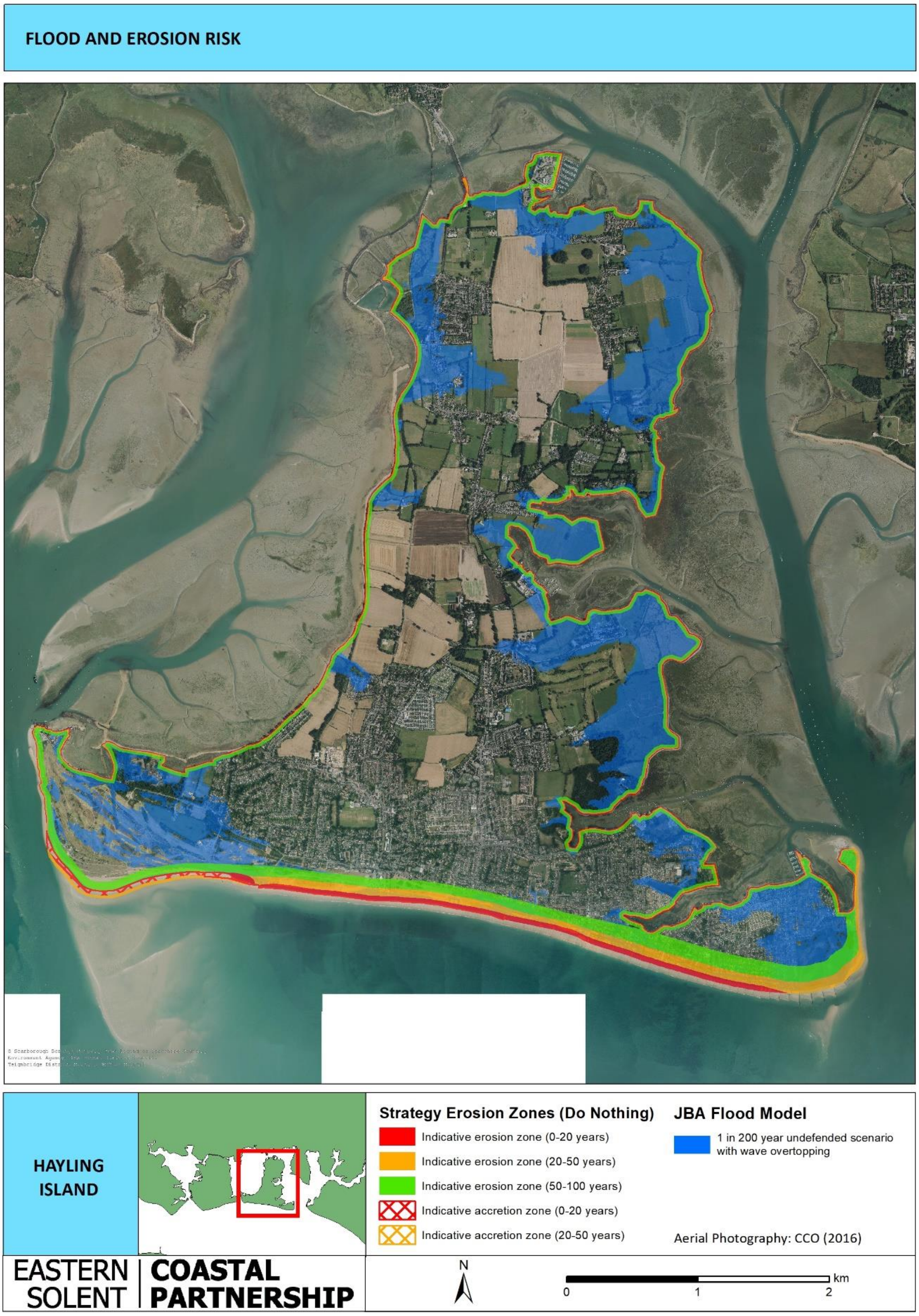

Figure 1.3 Flood and erosion risk to Hayling Island showing the present day 1 in 200 year undefended scenario with wave overtopping and the Do Nothing strategy erosion zones

1.1.3 Defences

Just over 40% of the islands flood defences are privately maintained with an assortment of defence structure types. The remainder are maintained by the EA, Havant Borough Council (HBC) and Hampshire County Council (HCC). Furthermore, in some cases, the EA maintain defences on private land, adding to the complexity of managing these frontages. Many of these assets are coming to the end of their residual life, requiring significant investment to withstand the impacts of climate change in the future (see The Defence Condition Assessment (DCA) Report, AECOM 2019, for more information).

1.1.4 Environment

Both Langstone Harbour to the west, and Chichester Harbour to the east of Hayling Island are nationally and internationally designated (Figure 1.4). Designations include:

- The Solent Maritime Special Area of Conservation (SAC);
- The Chichester and Langstone Harbours Special Protection Area (SPA);
- Chichester and Langstone Harbours Ramsar site;
- Site of Special Scientific Interest (SSSI);
- Chichester Harbour Area of Outstanding Natural Beauty (AONB).

Hayling Island (and the Solent & Dorset Coast SPA along the south coast of the Island) also supports a number of Local Nature Reserves (LNR) including: West Hayling LNR; Hayling Billy LNR; Gutner Point LNR; The Kench LNR; and Sandy Point LNR. These sites are designated SPA, SSSI and Ramsar sites and Gutner Point is also part of the SAC. An additional site, Sinah Common, is situated in a SSSI. All these habitats need to be taken into consideration and fully integrated into the development of a FCERM Strategy.

It is recognised that the Hold The Line (HTL) NSSMP (2010) policies will result in intertidal habitat loss due to coastal squeeze, which is being compensated by the Regional Habitat Compensation Programme (RHCP). The Strategic Environment Assessment (SEA) and Habitats Regulations Assessment (HRA) for the Strategy Study will address any change since the NSSMP (2010) in terms of habitat mitigation or compensation requirements.

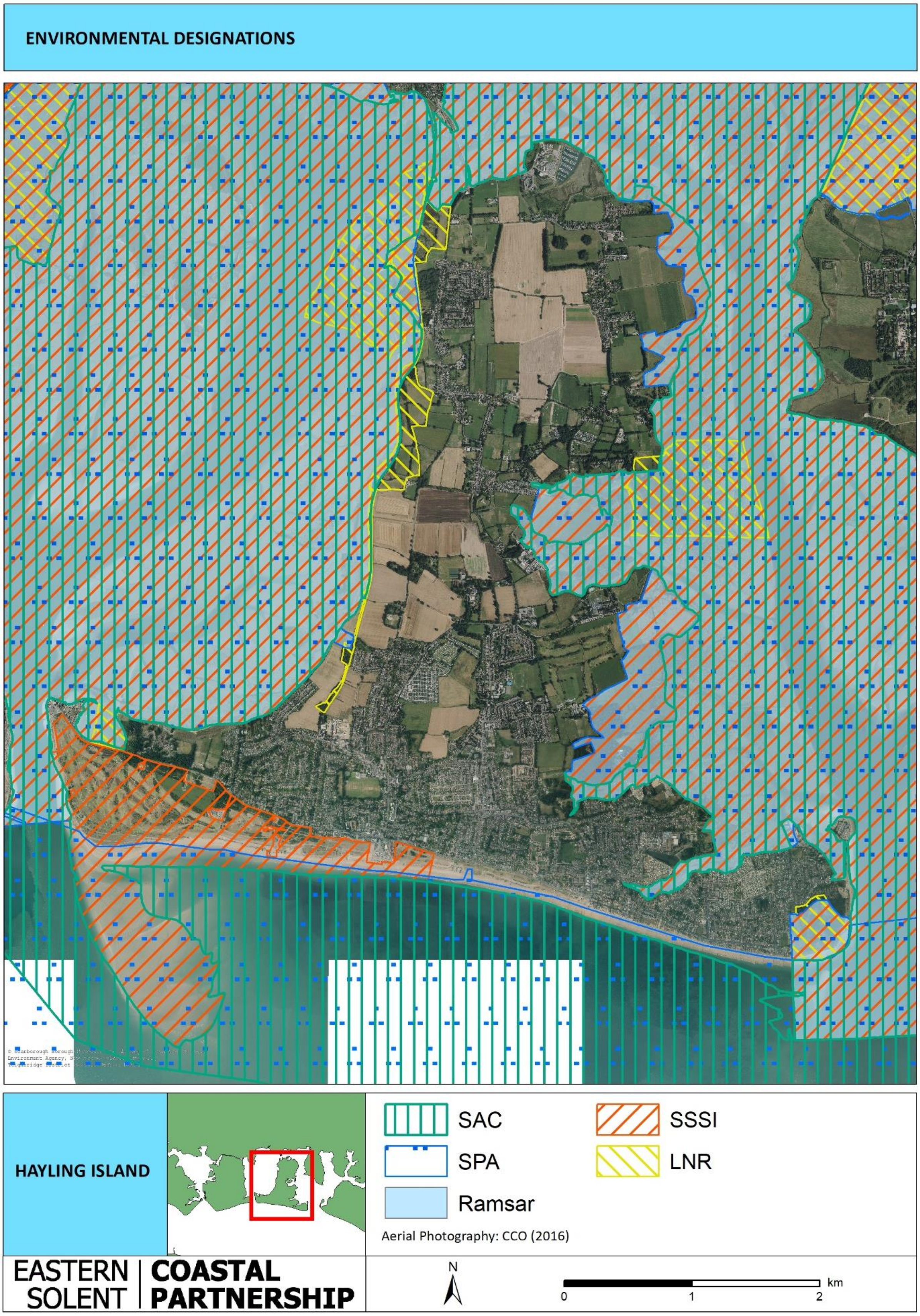

Figure 1.4 Environmental designations within the strategy area

1.2 Aims and Objectives

This report provides a baseline for coastal processes around Hayling Island up to year 2020, compiling all information to date and making recommendations for further studies. Detailed analysis undertaken as part of this report highlights any coastal processes that could influence policy decisions and future coastal management.

A breakdown of the report is as follows:

- **Section 1** - **Introduction and background**
- **Section 2 - Flood and Erosion risk:** Summarises the flooding events and erosion hotspots around Hayling Island. This section also identifies current and future flood and erosion risk areas, accounting for climate change;
- **Section 3 - Hydrodynamics:** Analysis of baseline nearshore wave climate, extreme wave conditions, tidal water levels, extreme water levels and includes considerations for climate change;
- **Section 4 - Geology and Sediment Dynamics:** This section collates existing information to identify the geological setting, bathymetric and topographic changes, sediment type, size, distribution, and transport rates and where applicable, account for climate change. This section is broken down into the Open Coast and Harbour environments;
- **Section 5 - Option Development Unit (ODU) Summary**: ODUs can be defined as manageable areas with consistent themes that help to facilitate and rationalise the appraisal and selection of coastal management options and are defined in the ODU Summary Report. This section provides a summary of the coastal processes and main geomorphological features in each ODU;
- **Section 6 - Conclusions and Recommendations**

2 Flood and Erosion Risk

The following section presents the most recent information for flood and coastal erosion risk from the Environment Agency (EA) and the North Solent Shoreline Management Plan (2010) (NSSMP, 2010) respectively, which has been updated through the Strategy Study. New erosion zones have been projected as part of the Strategy Study, incorporating updates in water levels, sea level rise and further measurements and observations (Section 2.4). Anecdotal evidence for flooding around Hayling Island is also documented.

2.1 History of Flooding and Erosion

As highlighted in Section 1.1, much of Hayling Island is at risk from both coastal flooding and erosion. This is particularly the case on the Eastoke Peninsula which is an urbanised area of low-lying land located behind a shingle barrier beach.

Table 2.1 classifies the severity of historic flooding events around Hayling Island between the early 1960s and 2019 based on a database of events produced by Ruocco *et al*. 2011. These events are illustrated in Figure 2.1. Multiple sources of information were used to update the database for flooding and erosion hotspots around the Hayling coastline including, photographs, newspaper articles and evidence from the Eastern Solent Coastal Partnership (ESCP) such as post Flood Incident Response (FIR) forms produced after a flooding event.

The increase in the frequency of documented flood events since 2005 (particularly at Eastoke), is likely driven by the more detailed ESCP data sources used since the Ruocco *et al* (2011) study. Any increase in flooding as a result of a stormier wave climate, has been investigated further through the next SCOPAC Storm Analysis study (2020) see Section 3.5.

Table 2.1 Level of severity of flooding events taken from Ruocco *et al*. (2011)

Level of Severity	Description
5	Flooding over large areas. Significant pumping required by emergency services. Generally, more than half a day disruption to homeowners and road users. More than 15 properties affected.
4	More than 5 properties affected by flooding.
3	More than 3 roads affected and/or at least one property affected.
2	Some road flooding – usually localised or shallow.
1	Flooding in open areas/promenade areas – no real structural damage or disruption.

Figure 2.1 Flood frequency and severity at different locations around Hayling Island (updated and adapted from Ruocco *et al.*, 2011)

2.2 EA Flood Zones

The EA regularly update and review the model outputs that inform the likely extents of Flood Zones 2 and 3. The most recent update has been the inclusion of data from comprehensive flood modelling carried out by JBA (2017) which feeds into the East Solent Model (2017). Most significantly, this update considered data from wave overtopping to inform the flood modelling forecasting system, compared to previous methods where the extents of Flood Zones 2 and 3 were based on still water levels only.

The EA flood zones include:

- ***Flood Zone 2*** - Land having between a 1 in 100 and a 1 in 1000 annual probability of river flooding or between a 1 in 200 and 1 in 1000 annual probability of sea flooding.
- ***Flood Zone 3*** – Land having a 1 in 100 or greater annual probability of river flooding or 1 in 200 year or greater annual probability of sea flooding.

Flood zones within the eastern Solent region are determined from the 1 in 1000-year (Flood Zone 2) and 1 in 200-year (Flood Zone 3) return period model outputs from the East Solent model (2017). These flood zones represent a present day, undefended scenario and include wave overtopping.

2.3 Hayling Strategy Flood Modelling

For the Hayling Strategy, the EA East Solent Model (originally carried out by JBA (2017) and based on climate change projections from the UK Climate Change Projections 2009 (UKCP09) dataset) was re-run by AECOM using the latest UKCP18 (2018) dataset at different return periods. These return periods included scenarios for 50%, 20%, 5%, 2%, 1.33%, 0.5% and 0.2% Annual Exceedance Probability (AEP) to tie in with the Strategic requirements for economics. The 1 in 200 year return period (0.5%) flood modelling is shown in Figure 1.3.

2.4 Hayling Island Coastal Management Strategy Erosion Zones

Erosion zone mapping was originally produced for the NSSMP (2010). As part of this study the erosion zones have been updated. The following section summarises the updated erosion zone mapping along the open coastline and inside the harbours, with the latest UKCP18 sea level rise data; another 10 years of monitoring data; structure residual life (AECOM Defence Condition Assessment (2019) report); refined 'rebound rates' following defence failure and a greater understanding of how the coastline behaves. Information from Section 4 fed into these updates. These erosion zones have been used to assess potential future damages when undertaking the updated economic assessment.

Two different scenarios were projected for the Strategy according to the Flood and Coastal Erosion Risk Management Appraisal Guidance (FCERM-AG) process:

- Do Nothing (see Figure 2.2 for the open coast and Figure 2.3 for the harbours)
- Do Minimum (see Figure 2.4 for the open coast and Figure 2.5 for the harbours)

For each scenario, erosion bands were projected over 0-20 years (Epoch 1), 20-50 years (Epoch 2) and 50-100 years (Epoch 3). Latest defence residual life information from AECOM was incorporated, which assumes under the Do Nothing scenario that Inn-on-the-Beach remains in place for 10 years, while the Do Minimum scenario assumes that Inn-on-the-Beach remains in place for 12 years. Both scenarios also incorporate longshore drift rates calculated from the Sediment Budget Analysis (SBA) to help determine how long the beaches may be present without any beach management. This is particularly noticeable around Gunner Point where the coastline is shown to accrete seawards during the first epoch and half of the second epoch, before erosion commences during the later stages of the second epoch and the third epoch.

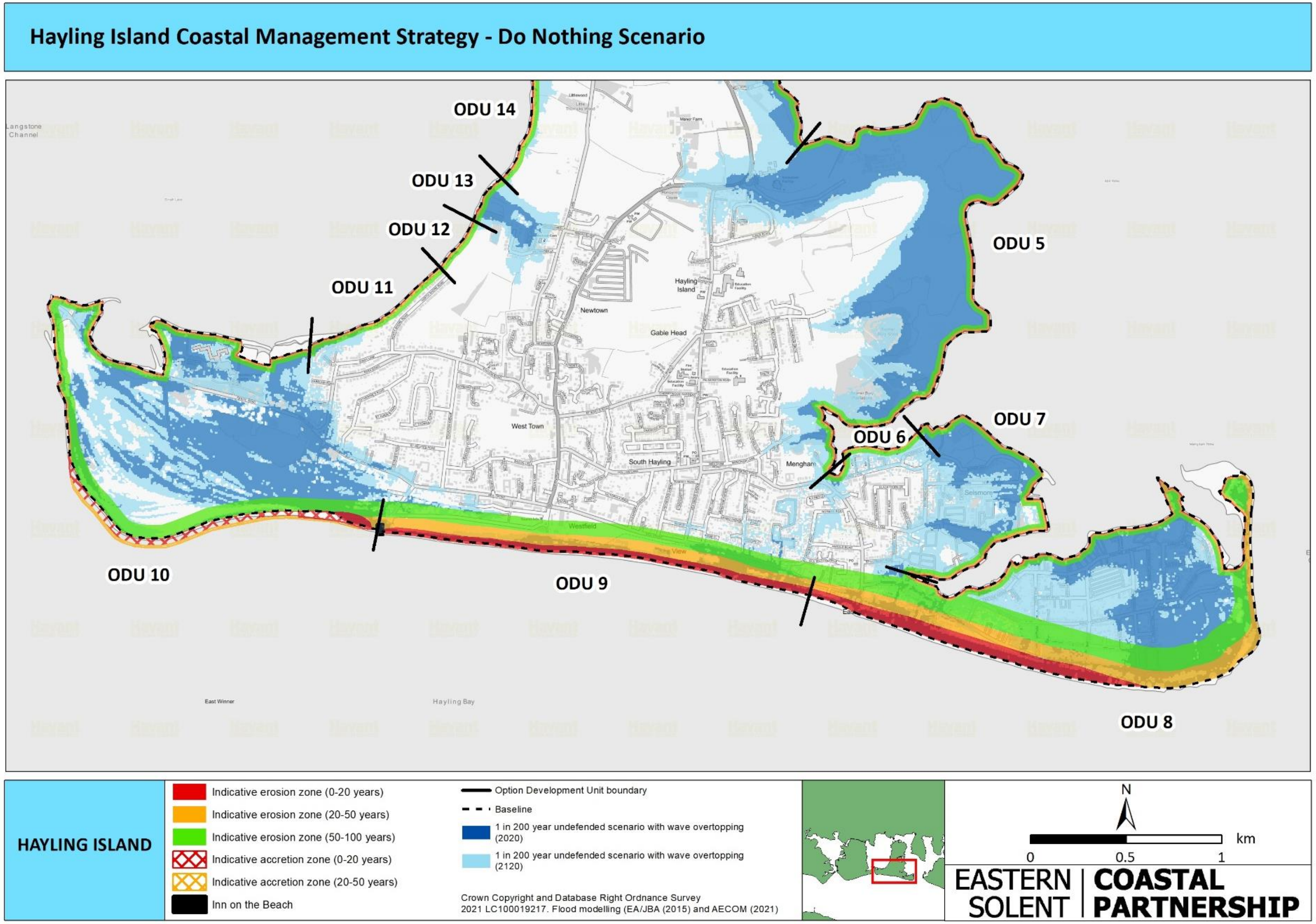

Figure 2.2 Do Nothing scenario – open coast

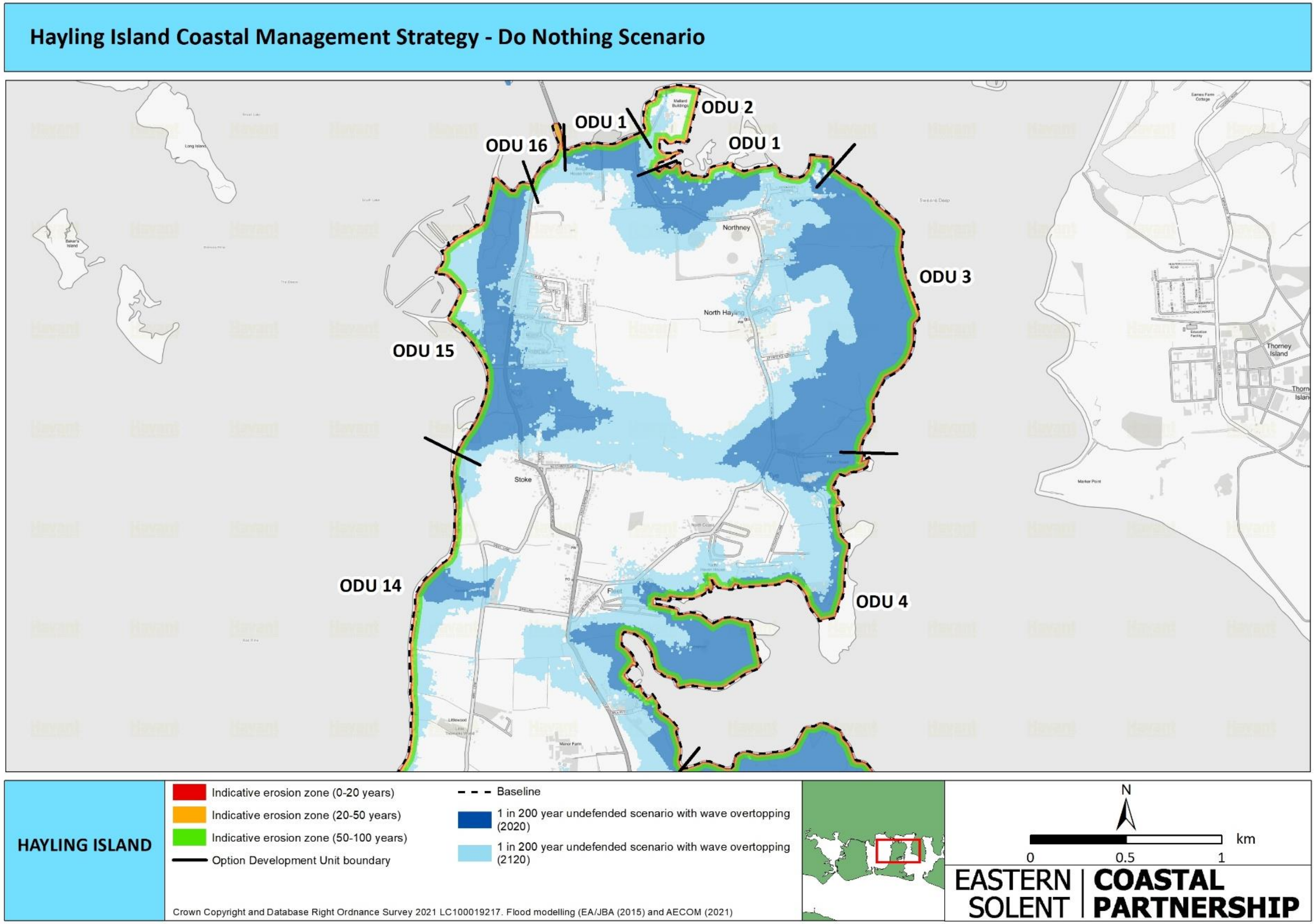

Figure 2.3 Do Nothing scenario - harbours

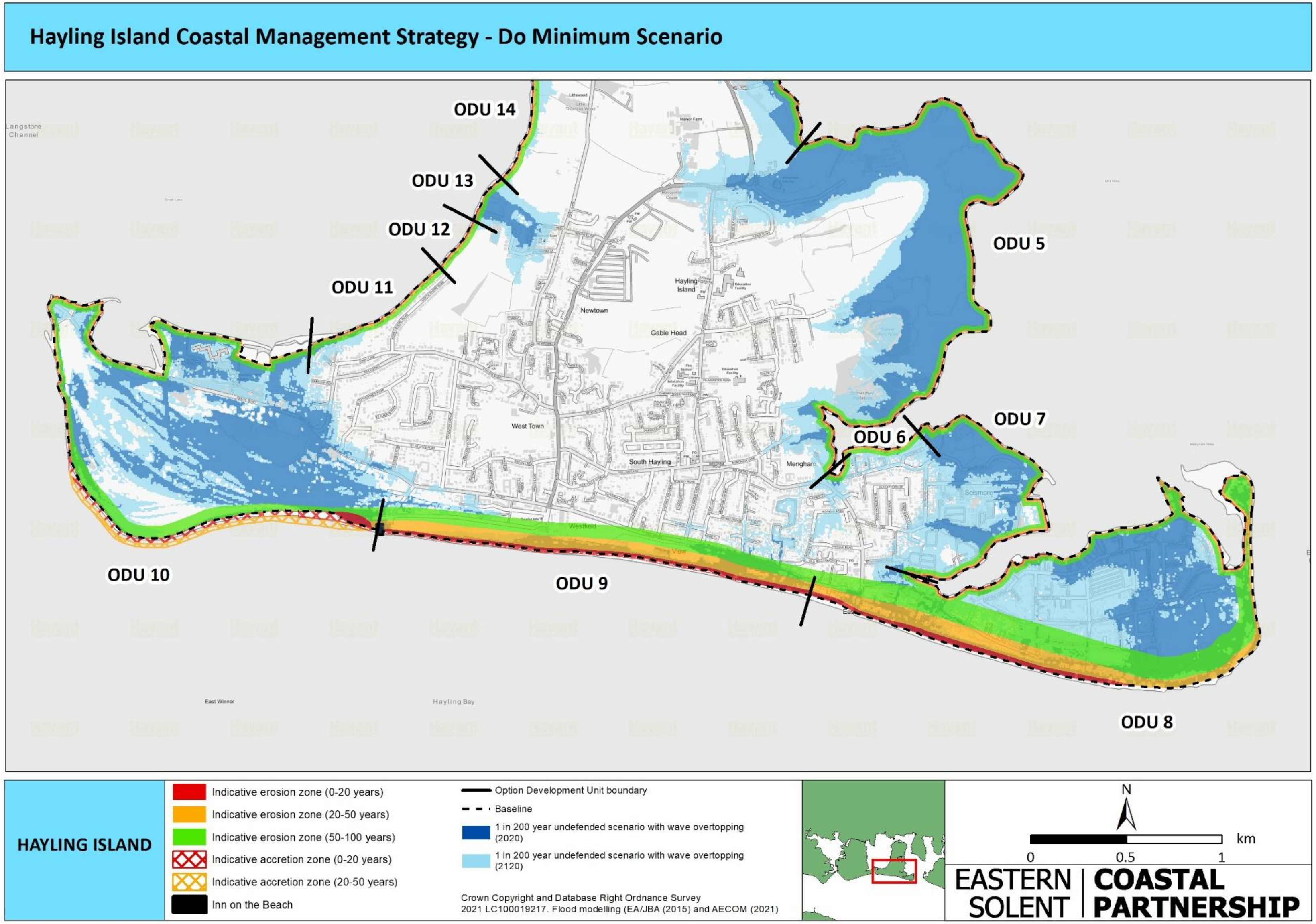

Figure 2.4 Do Minimum scenario - open coast

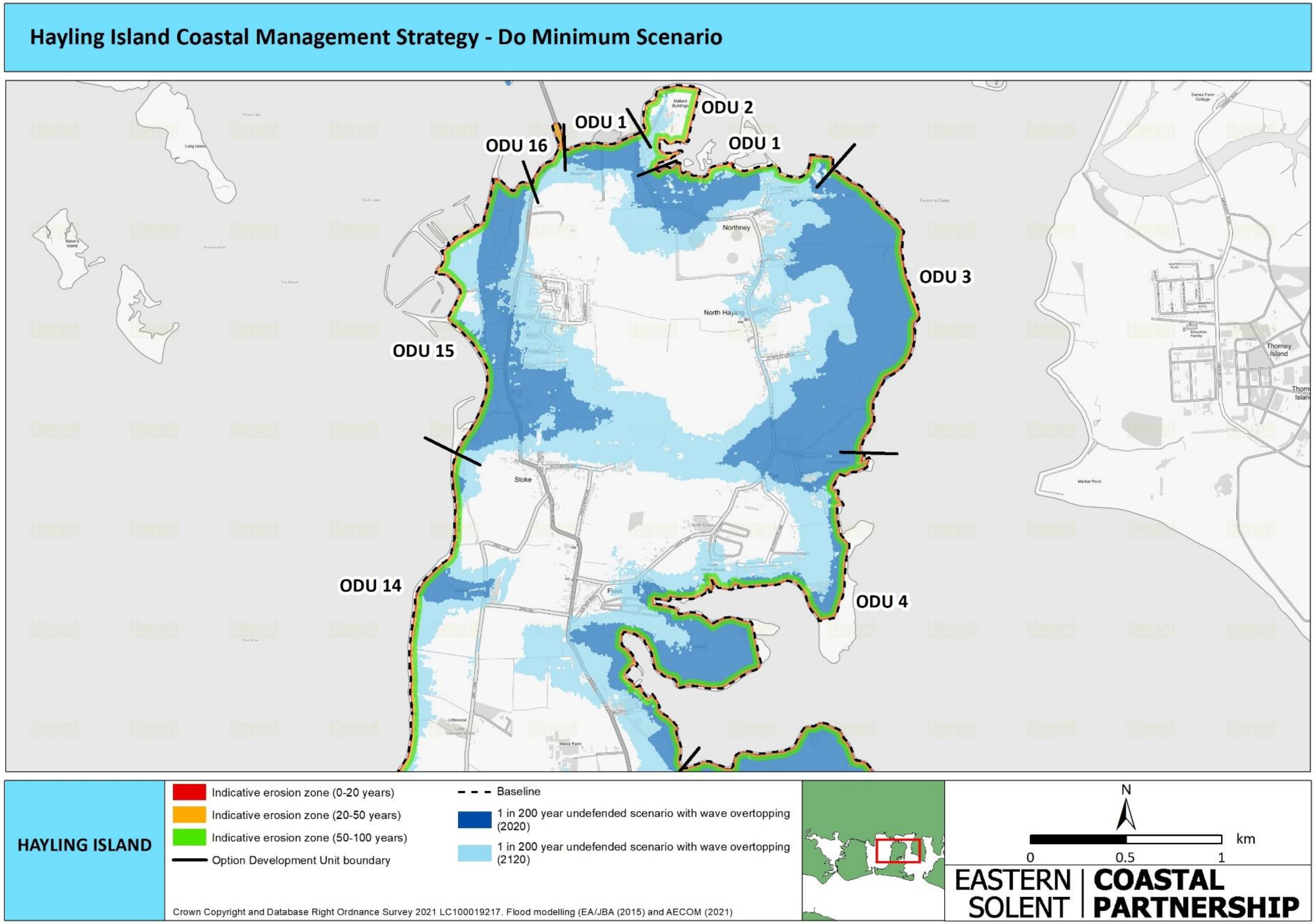

Figure 2.5 Do Minimum scenario - harbours

2.5 Coastal Change Management Areas

Coastal Change Management Area's (CCMAs) aim to reduce risk from coastal change by preventing inappropriate development in vulnerable areas therefore avoiding adverse physical changes to the coast. The National Planning Policy Framework (NPPF, 2019) states that CCMAs should be implemented by Local Authorities to ensure effective alignment of the terrestrial and marine planning regimes. Hayling Island currently has two CCMAs, one at Hayling Beachfront and one along West Hayling (Figure 2.6).

2.5.1 Hayling Beachfront

The policy here is to Hold The Line (HTL), whilst allowing the natural shoreline around Gunner Point (which covers West Beach) to evolve naturally with minimal interference. The Open Beach section is undefended.

2.5.2 West Hayling

The West Hayling CCMA covers the stretch of coastline running parallel to the Hayling Billy Line, which was assigned a policy of No Active Intervention (NAI) with localised HTL at Newtown in the NSSMP (2010). There are several undefended areas and areas with failing and failed defences (AECOM, 2018). It is an area that is currently susceptible to erosion where the defences have failed.

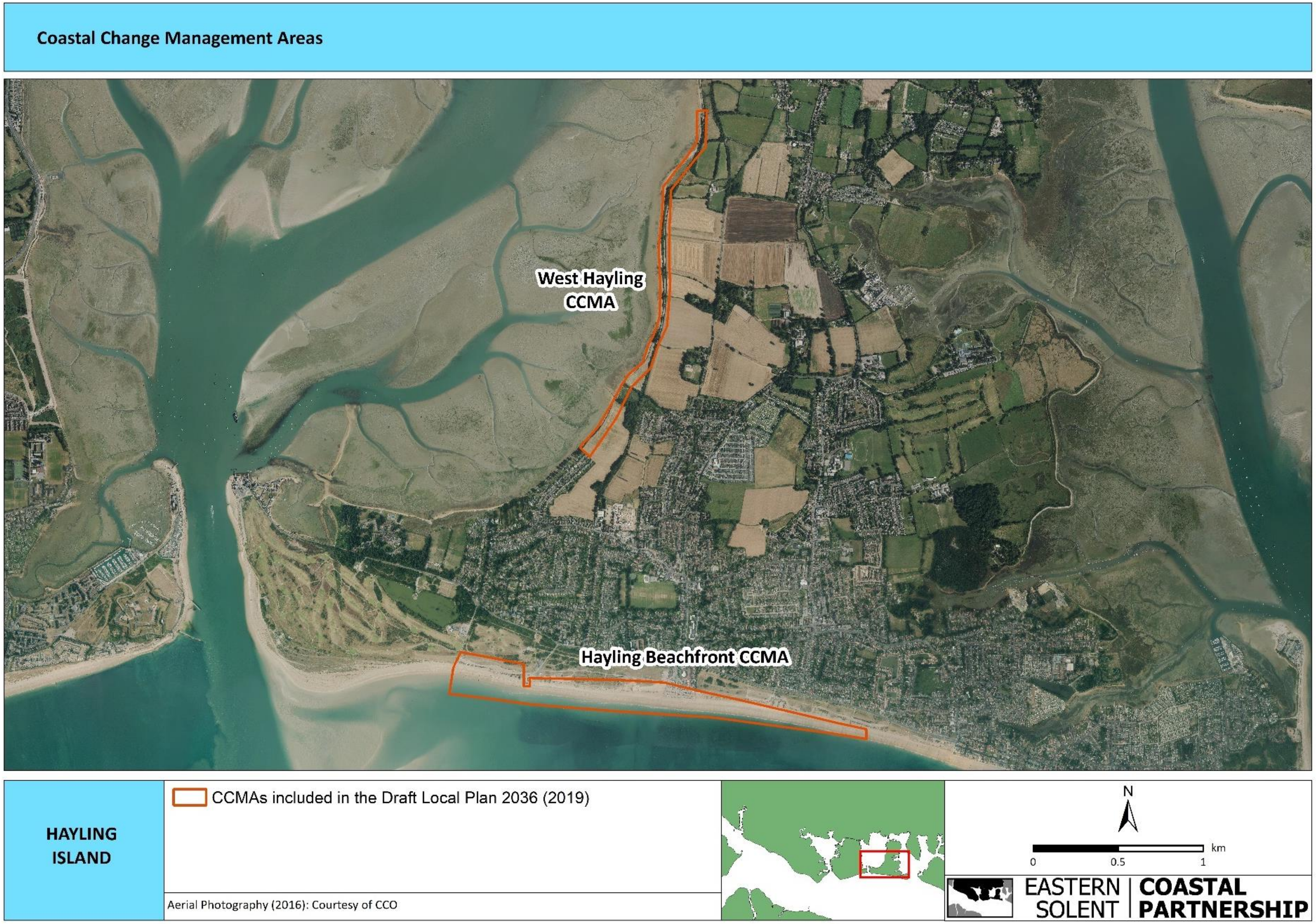

Figure 2.6 Locations of CCMAs in the Local Plan

3 Hydrodynamics

The following section presents the baseline conditions for hydrodynamics around Hayling Island including information on waves, water levels, tides and Joint Probability Analysis (JPA).

Given the sheltering effect of Portsea Island, Hayling Island and Chichester and the narrow harbour entrances, wave heights are fetch limited in the harbours and are therefore relatively low. The main threat of flooding within the harbours is from still water level overtopping rather than wave overtopping. In comparison, the open coast is more exposed to storm and swell waves and bi-modal seas (a combination of the two), resulting in high risk of wave and water level overtopping and erosion.

3.1 Waves

Live wave data is readily available for the open coast of Hayling Island as part of the South-east Regional Coastal Monitoring Programme (SRCMP), which furthers the understanding of beach response under different wave climates and directly informs beach management activities. This information is limited in comparison for Chichester and Langstone Harbour. Generally, the wave climate inside the two harbours is much less severe, with the primary flood risk being from extreme water levels rather than extreme wave action.

3.1.1 Hayling wave buoy analysis

In 2003, as part of the SRCMP, a Waverider buoy was placed off the south-eastern corner of Hayling Island in approximately 10m of water (Figure 3.1). This buoy collects wave height, period and direction every 30 minutes. At the end of each year, the Channel Coastal Observatory (CCO) produce a wave report summarising the statistics over the past year and the whole deployment period. At the time of writing, the 2019 Annual Wave Report was the latest report available. The following section describes the statistics from this wave buoy. The latest extreme wave heights up to December 2019 are shown in Table 3.1 and the annual maximum wave heights up to 2019 are in Table 3.2 (this is the latest information available at the time of writing the report).

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<tr><td>OS</td><td>473565 E 92973 N</td></tr>
<tr><td>WGS84</td><td>Latitude: 50° 43.90' N
Longitude: 00° 57.54' W</td></tr>
<tr><td colspan="2">Instrument type</td></tr>
<tr><td colspan="2">Datawell
Directional Waverider Mk III</td></tr>
<tr><td>Water depth</td><td>~10m CD</td><td>Buoy in situ off Hayling Island. Photo courtesy of Fugro GB Marine Limited</td><td>Location of buoy (Google mapping, image ©2016 TerraMetrics)</td></tr>
</table>

Figure 3.1 Details of the Hayling Island Wave Buoy (CCO, 2019)

Table 3.1 Significant wave height return periods as calculated by CCO (2019)

Observation period	July 2003 to December 2019	
Return period (years)	**Significant wave height (m)**	**Comments**
0.25	2.73	No depth limitation
1	3.33	
2	3.57	
5	3.86	
10	4.05	
20	4.22	
50	4.41	Depth-limited at MLWS
100	4.54	

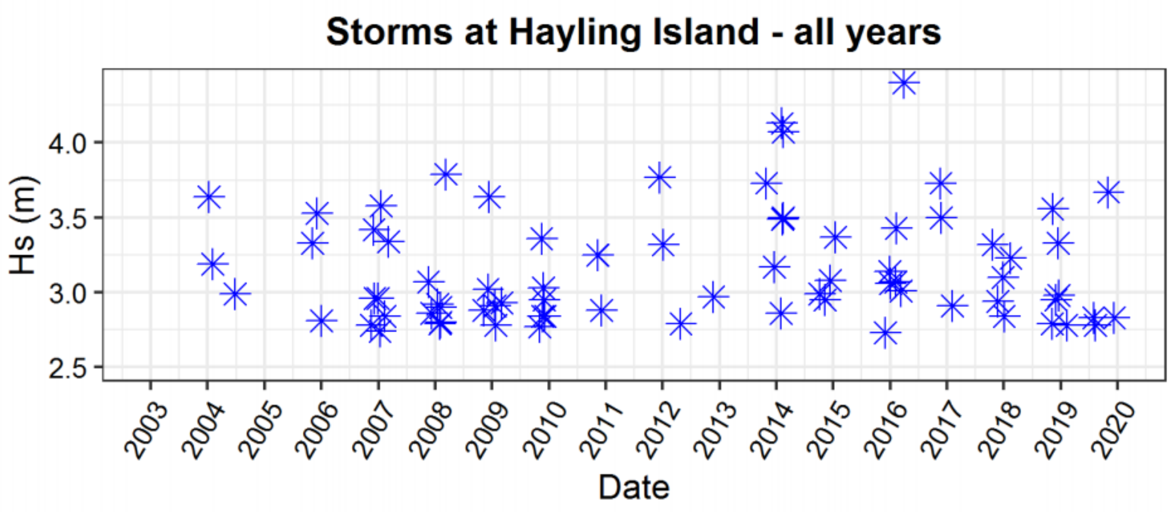

Figure 3.2 Significant wave heights measured at Hayling Island wave buoy during storms (CCO, 2019)

Table 3.2 Annual statistics – annual maximum significant wave height measured at the buoy (CCO, 2019)

Annual Maximum H_s	
Date	A_{max} (m)
29-Nov-2003 09:30:00	2.68
08-Jan-2004 10:00:00	3.64
02-Dec-2005 16:30:00	3.53
03-Dec-2006 07:30:00	3.42
18-Jan-2007 12:30:00	3.58
10-Mar-2008 07:30:00	3.79
14-Nov-2009 13:00:00	3.36
08-Nov-2010 07:30:00	3.25
13-Dec-2011 00:30:00	3.77
03-Jan-2012 08:00:00	3.32
28-Oct-2013 06:00:00	3.73
05-Feb-2014 14:00:00	4.13
15-Jan-2015 03:00:00	3.37
28-Mar-2016 02:30:00	4.4
21-Oct-2017 13:00:00	3.32
09-Nov-2018 22:00:00	3.56
02-Nov-2019 14:30:00	3.67

Analysis of the Hayling Island wave buoy data shows the significance of the 2013/14 and 2015/16 winters with a high frequency of storms with large wave heights (Figure 3.2). The highest wave height of 4.4m was recorded on the 28th March 2016. Further evidence from the SCOPAC Storm Analysis Project (2020) demonstrates that it's not only wave height that is an indicator of flood and erosion risk at Hayling. Magnitude and frequency of swell wave events and bi-modal wave events also play an important role.

3.1.2 Extreme waves

The East Solent SMP (1997), Eastoke Strategy (2006), NSSMP (2010), and North Portsea Island Modelling Studies (2014) have all published datasets for extreme waves. The most recent extremes have been derived as part of the EA East Solent Modelling undertaken by JBA, which used data from the State of the Nation National Flood Risk Assessment (NAFRA, 2014) to calculate the wave overtopping volumes at locations around the island.

3.1.3 Climate Change Allowances

The Environment Agency (EA) Flood and coastal risk projects, schemes and strategies: climate change allowances (2020) gives percentage change allowances for extreme wave heights for two different epochs. Wave heights may change due to changes in water depths that result from Sea Level Rise (SLR) and the frequency, duration and severity of storms and winds is also expected to change (EA, 2018). Table 3.3 shows the allowances that should be used for waves over the next 100 years due to climate change. The 2018 guidance does state that there are large uncertainties in these values. Changes in wave period and direction are small and harder to interpret.

Table 3.3 Recommended national precautionary sensitivity ranges for offshore wind speed and wave height.

Applies around all the English coast	2000 to 2055	2056 to 2125
Offshore wind speed	+5%	+10%
Offshore wind speed sensitivity test	+10%	+10%
Extreme wave height	+5%	+10%
Extreme wave height sensitivity test	+10%	+10%

3.2 Water Levels

The tidal regime along the Solent is complex with an extended high water and spatial variability. This section will summarise the existing published extreme water levels and tidal currents as well as SLR due to climate change over the next 100-year period.

3.2.1 Tides

The water levels for both Portsmouth and Chichester are shown in Table 3.4 below (Admiralty Tide Tables, 2020):

Table 3.4 Current tide levels

	Portsmouth		Chichester	
	mCD	mOD	mCD	mOD
Highest Astronomical Tide (HAT)	5.15	2.42	5.26	2.52
Mean High Water Springs (MHWS)	4.73	2.00	4.79	2.05
Mean High Water (MHW)	4.30	1.57	4.35	1.61
Mean High Water Neaps (MHWN)	3.86	1.13	3.90	1.16
Mean Water Level (MWL)	2.9	0.17	2.90	0.16
Mean Low Water Neaps (MLWN)	1.91	-0.82	1.82	-0.92
Mean Low Water (MLW)	1.48	-1.26	1.38	-1.37
Mean Low Water Springs (MLWS)	1.04	-1.69	0.93	-1.81
Lowest Astronomical Tide (LAT)	0.15	-2.58	0.21	-2.53

3.2.2 Extreme Water Levels: EA CFB dataset 2018

The EA Coastal Flood Boundary (CFB) Dataset update was published in 2018 (EA, 2018). This dataset is an update from the 2011 dataset and now includes extreme water levels for the harbours, as well as for the open coast. Table 3.5 contains this data and Figure 3.3 shows the reference points, which are spaced around the coastline at 2 km intervals. The base year for this data is 2017 and return periods range from 1 in 1 to 1 in 10,000 years (the dataset provides estimated values along with the 2.5 and 97.5 percentiles).

The previously published datasets (NSSMP, 2010 and Eastoke Strategy, 2005) give values ~20 cm lower than those published in the 2018 CFB dataset.

Table 3.5 EA Coastal Flood Boundaries Dataset (2018)

Location	Extreme Sea Levels (mOD)				
	Return Period				
	1 in 1 (100% AEP)	1 in 10 (10% AEP)	1 in 50 (2% AEP)	1 in 100 (1% AEP)	1 in 200 (0.5% AEP)
4604	2.7	2.93	3.09	3.16	3.23
4606	2.67	2.91	3.07	3.14	3.21
4608	2.65	2.89	3.05	3.12	3.19
4610	2.63	2.87	3.03	3.1	3.17
4604_1	2.7	2.94	3.1	3.17	3.24
4610_1	2.65	2.88	3.04	3.11	3.18

Figure 3.3 Locations of the data extracted from the EA CFBD 2018

3.2.3 Sea Level Rise

The latest figures for SLR data have been published as the UK Climate Projections 2018 (UKCP18) dataset which present a range of different SLR estimates based on different emission scenarios. The UKCP18 information comes under 4 Representative Concentration Pathways (RCP), which capture the assumptions in each scenario and the differences in the predicted increase in temperature. These are RCP2.6, RCP4.5, RCP6.0 and RCP8.5.

The EA guidance, released in July 2020, is to use the RCP8.5 70th %ile for design purposes and use RCP8.5 90th %ile as a sensitivity test to consider more serious events and adaptability. The RCP8.5 pathway represents "a world in which global greenhouse gas emissions continue to rise. It is a potential future where the nations of the world choose not to switch to a low-carbon future" and we could experience an increase in global mean surface temperature of 4.3°C (Met Office, 2018).

The SLR values for the RCP8.5 70th and 95th percentiles are presented in Table 3.6. The changes in tidal water levels are also available in Appendix B1.

Table 3.6 Expected values for sea level rise over the next 100 years according to UKCP18 RCP8.5

SLR Values		
Year	**70th %ile**	**95th %ile**
2020	0	0
2040	0.13	0.16
2070	0.41	0.53
2120	1.03	1.4

3.2.4 Tidal Currents

The tidal currents around the Solent are complex. The area experiences a double high tide where the tide rises following low water but the tidal stream slackens two hours before high water leading to a stand (known as the Young Flood Stand) before rising to high water which can take a further three hours (Pugh, 1989). The effect is most pronounced around Southampton but is evident throughout the Solent. The ebb tide is very short and therefore associated with strong currents. The vertical tidal range across the East Solent is approximately 4m on average (NSSMP, 2010).

Current speeds in the entrances to Langstone and Chichester Harbours are the strongest with weaker current speeds elsewhere in the harbours where the bathymetry is much shallower. Information from the Admiralty Tide Charts for Langstone and from the Eastoke Point Coastal Defence Study carried out by HR Wallingford in 1994 for Eastoke are available in Appendix B2.

3.3 Joint Probability Analysis

Joint probability extreme datasets take into consideration the probability of certain wave heights and water levels occurring at the same time. JPA informs engineering design for locations such as the south coast of Hayling Island, which are prone to extreme waves and tides. The Eastoke Sectoral Strategy (2006), Eastoke Point Construction Scheme (2013), State of The Nation study (Gouldby *et al.*, 2017) have each produced a JPA dataset.

3.4 EA JBA flood model used in the Strategy

The Environment Agency's State of the Nation (SoN) flood risk analysis project saw the application of a new coastal methodology for deriving extreme wave overtopping rates around the coastline. As described in the HR Wallingford SoN report; Guide to coastal datasets for local flood risk analysis (2018), the SoN analysis is a risk-based analysis which employs risk-based methods. This differs to the traditional joint exceedance contour approach that has been widely applied in the past, and which is limited in the number of variables considered.

The risk-based approach adopted in the SoN project comprises a series of components; offshore multivariate extreme value modelling, offshore to nearshore wave transformation modelling, and surfzone and wave overtopping modelling. These components are summarised below:

- Offshore multivariate extreme value modelling – an extreme value model was used to extrapolate wave, wind and sea level data. The model was fitted and used to stochastically generate a large sample (approximately 10,000yrs) of peak wave, wind and sea level events for a series of joint probability points / locations around the English coastline.
- Offshore to nearshore wave transformation modelling – the offshore sea condition data was transferred to a series of nearshore points / locations using a SWAN 2D wave transformation model and a series of statistical emulators. The nearshore points are at a spatial resolution of approximately 1km along the coastline.
- Surfzone and overtopping model – the nearshore wave data was translated to wave overtopping rates using SWAN 1D surfzone modelling and the BAYONET overtopping model.

The East Solent Modelling undertaken by JBA for the Environment Agency (as described in section 2.3) used data from the SoN National Flood Risk Assessment (NAFRA, 2014) to calculate the wave overtopping volumes at locations around the island.

The EA East Solent flood model was updated and used in the Strategy as the best available information at a strategic scale. It has been used determine a broad analysis of risk, conservative estimates of damages and to set the direction for the recommended strategic management options. However, given the impact of long period swell waves and bi-modal waves on the south coast of Hayling Island, further work is recommended to refine the overtopping and flood modelling during the next stage of the FCERM process.

3.5 SCOPAC Storm Analysis (2020)

Research undertaken by the University of Southampton, Bournemouth, Christchurch and Poole (BCP) council and the Eastern Solent Coastal Partnership (ESCP), on behalf of SCOPAC, has been putting the recent stormy winters into context with longer datasets. Records show that since the stormy 2013/14 winter, Hayling has experienced the highest recorded significant wave height (4.4m on the 28th March 2016) and the month with the highest occurrence of bi-modal seas (38% in December 2015) since recording began in 2003. Furthermore, sea levels continue to rise at an average of 3.8 mm per year and the peak of the 18.6 year lunar tidal cycle was in 2015, resulting in more frequent Highest Astronomical Tides. Sea level rise will continue, although longer datasets are required to confirm whether wave power and bi-modality in particular, will increase into the future and whether the frequency and magnitude of longer period swell events are on the rise (SCOPAC Storm Analysis, 2020).

4 Geology and Sediment Dynamics

The geometry of Hayling Island is largely a result of its location between two lower relief river valleys which previously drained the surrounding coastal plain. Holocene sea level rise resulted in the flooding of these valleys to form Chichester and Langstone harbours which form its modern east and west coastlines, respectively (Mills *et al.*, 2007). Bedrock on Hayling Island comprises of various marine deposits of differing ages: shallow marine deposits from the Paleogene, Wittering Formation of Bracklesham Beds and the Whitecliffe Sand Member. Surficial (drift) geology over much of the island is dominated by River Terrace Deposits (undifferentiated) - Sand, Silt and Clay (British Geological Society, 2019). More information on the regional geological setting can be found in Appendix C2.

The following section provides a background to the geology and sediment dynamics of Hayling Island. This includes the regional geological setting, sediment type, sediment transport, topographic and bathymetric changes. Due to the contrasting nature of the open coast and harbour environments, these sections will be presented separately with associated relevant information. The information has been collected through desk-based studies, surveys and analysis of various datasets (see Appendix C1 for more detail).

4.1 Open Coast Sediment Dynamics

This section presents the Open Coast sediment dynamics. There is a wealth of data and information along this stretch of coast, much of which has come from Eastern Solent Coastal Partnership (ESCP) analysis of South-east Regional Coastal Monitoring Programme (SRCMP) datasets (www.channelcoast.org) and tracer studies to assess the coastal processes.

4.1.1 SCOPAC Sediment Transport Study

The SCOPAC Sediment Transport Study (STS) presents comprehensive findings on sediment transport rates, direction and sources along the coastline between Start Point in Devon and Beachy Head in East Sussex (SCOPAC STS, 2012). The coastline is broken down into units, with Portsmouth, Langstone and Chichester Harbours comprising two units (one to illustrate the sediment movement on the open coast and one in the harbours). These represent the sediment type, direction, volume, transport mechanism and reliability of that information. The results of the Open Coast unit are presented in Figure 4.1.

Historically, there was a substantial onshore feed of material to Eastoke as depicted by F1 on Figure 4.1. Through time, this feed reduced, which caused a prolonged lowering of beach levels, in turn resulting in a higher flood risk to properties. By 1985 a large capital recharge scheme was required at Eastoke, importing ~500,000 m^3 of material to increase beach levels.

It is understood that from the drift divide at Eastoke, material moves in an easterly direction (approximately one third of material) and a westward direction (approximately two thirds of material). The open coast sediment budget has been updated as part of the Strategy Study using topographic data (see Section 4.1.6). This provides an up to date understanding of the longshore drift rates.

Figure 4.2 provides an overview of the latest understanding of coastal processes along the open coast and helps to explain the location of hotspots of erosion and accretion. The drift divide at Creek Road means that this area rapidly depletes of material and hence needs regular topping up through beach management. To the east of the drift divide, mixed sand and shingle accretes at The Ness. Some material is flushed out to the ebb delta (West Pole Sands), whilst sand travels north to Sandy Point spit. It’s important to note that this area is very much linked in with the wider Chichester Harbour flood and ebb delta system.

To the west of the drift divide, there is another pocket of erosion at Eastoke Corner where there is a slight step-change in the coastline. Material accretes west of this on the open beach as Inn-on-the-Beach (IOTB) behaves as a semi-permeable structure. This structure also causes immediate downdrift erosion at West Beach. Gunner Point continues to accrete as it has for at least a century.

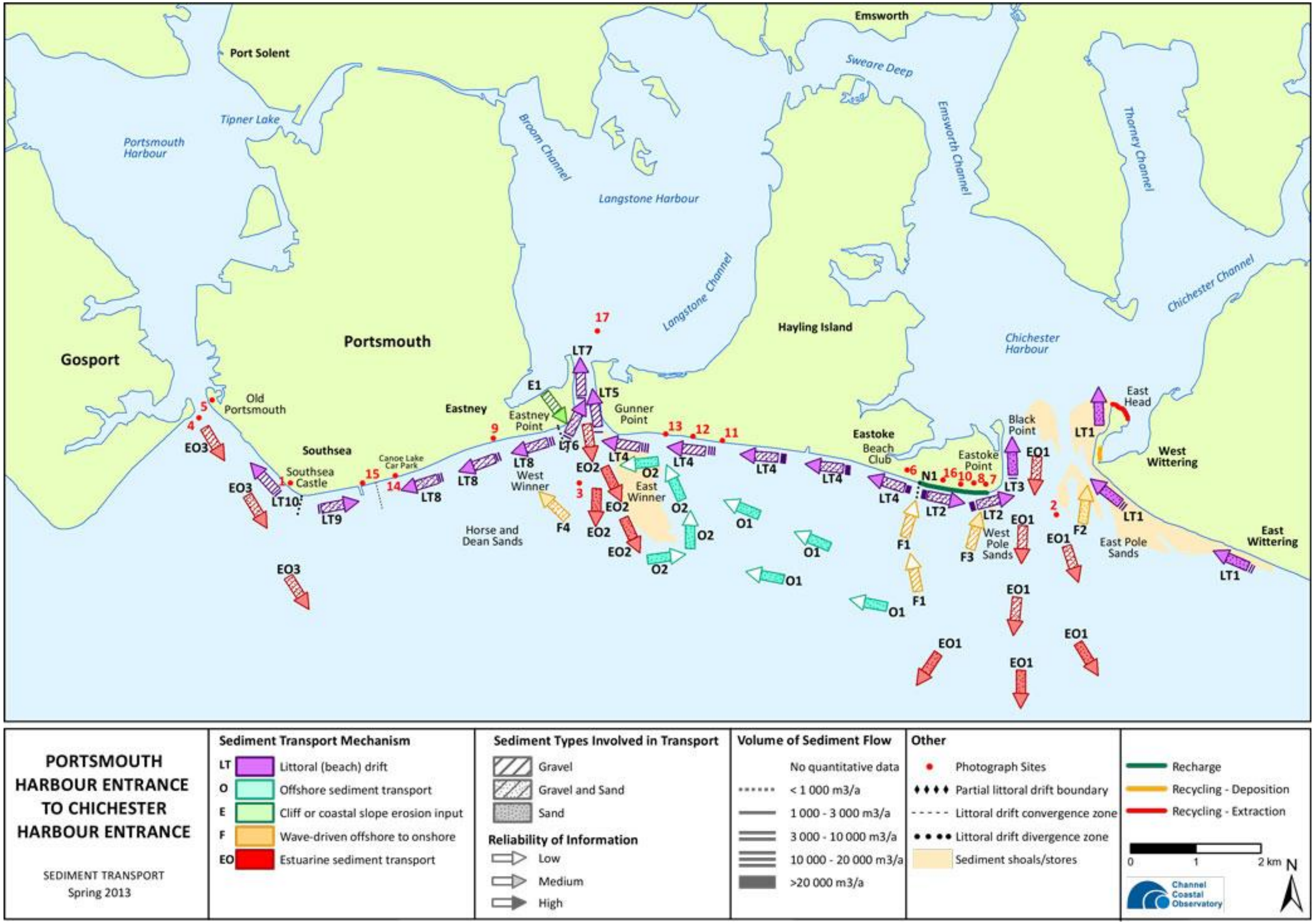

Figure 4.1: Sediment transport between Portsmouth Harbour entrance and Chichester Harbour entrance (SCOPAC STS, 2012)

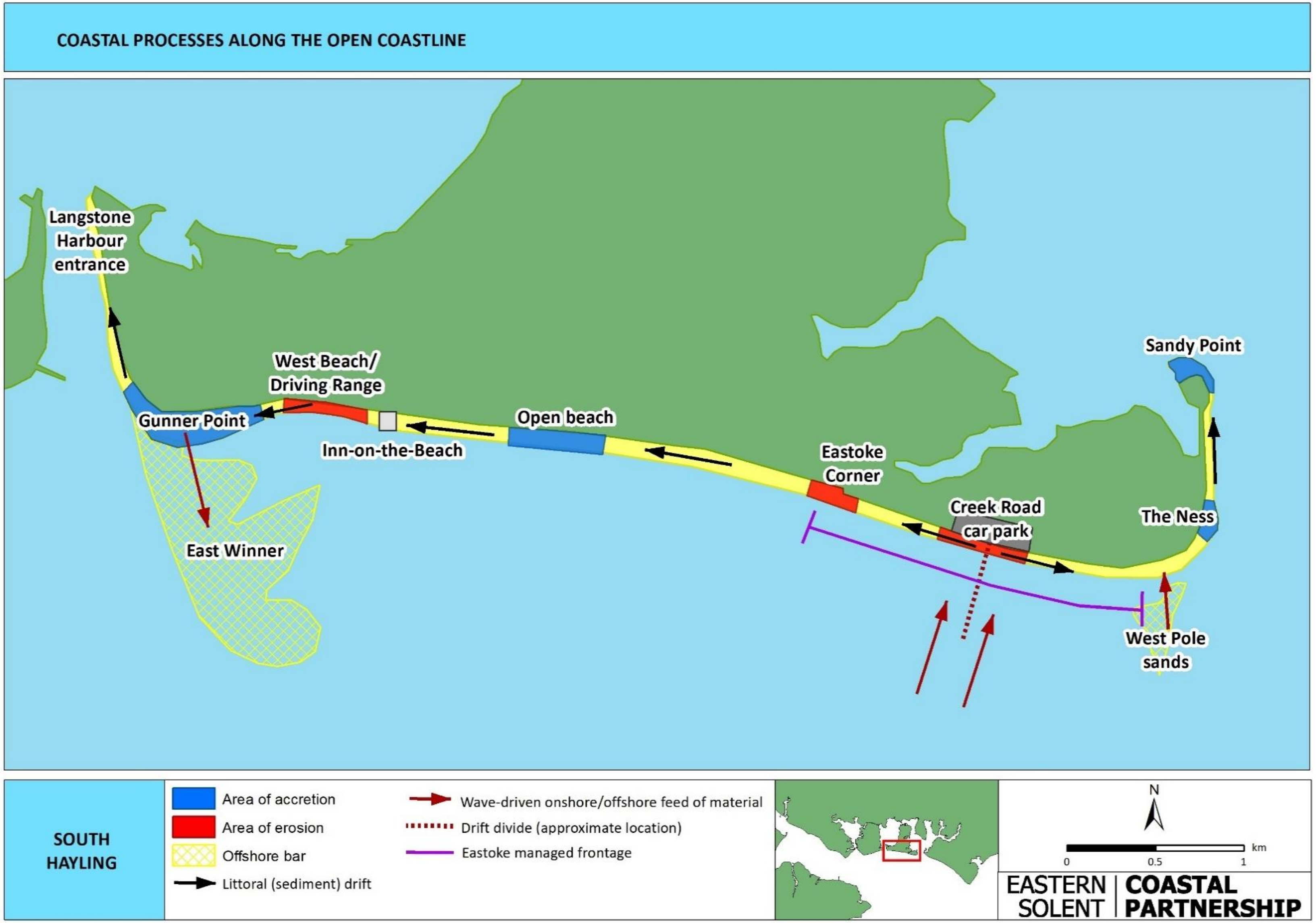

Figure 4.2 An overview of the coastal processes along the Hayling south coast.

4.1.2 Sediment Type

4.1.2.1 Coastal geomorphology

A summary of the SRCMP habitat mapping undertaken by Environment Systems (2017) is presented in Figure 4.3 using 2016 aerial photography. This data, along with anecdotal evidence shows that although the harbours are mainly mudflat and saltmarsh, there are some areas directly adjacent to the shoreline which contain some coarser sediments.

The open coast is dominated by intertidal shingle. There are areas of coastal sand dunes and unvegetated sand dunes above the high tide mark, both of which occur at the eastern and western extremities. The central open coast is backed by coastal vegetated shingle. The East Winner is dominated by intertidal sand.

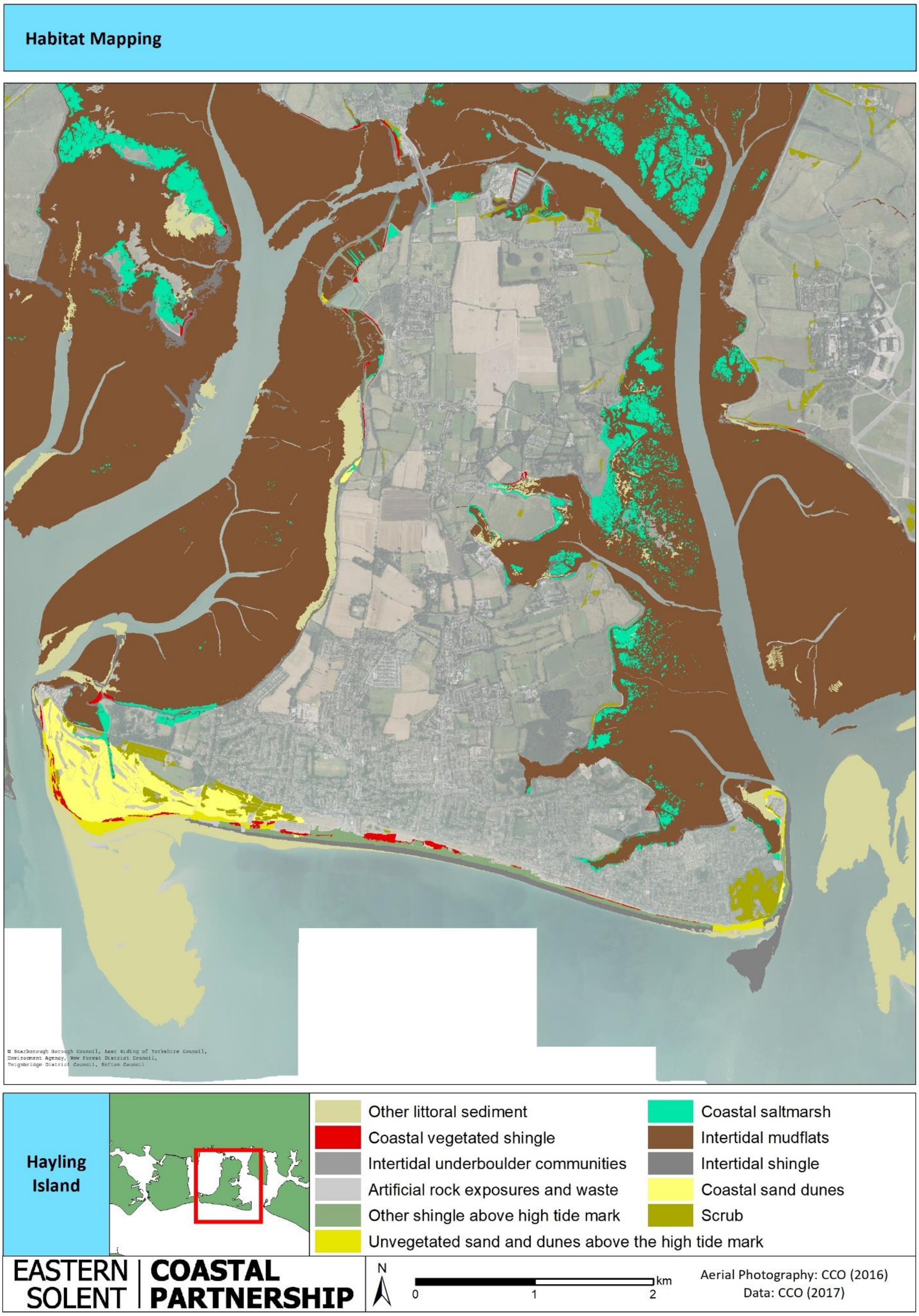

Figure 4.3 Habitat mapping from 2016 (Environment Systems, CCO 2017)

4.1.2.2 Sediment Sampling

The latest round of sediment sampling was carried out under the previous Hayling Beach Management Plan (BMP) (2012-2017) in January 2017. Samples of native material were taken from four different points along eight profile lines. These points included the Mean Low Water (MLW), Mean Sea Level (MSL), Mean High Water (MHW) and the beach crest (Cr). The percentage of gravel, sand and mud was determined using the Wentworth Scale and the detailed results of this are presented in Appendix C3. In general, the crest of the beach has the higher portion of gravel compared to sand. Mud is only present in small quantities (<1%). Another sediment sampling survey is due to be carried out in 2022.

Using results from the sediment sampling detailed above, together with information on sediment type from baseline topographic surveys, it has been possible to map the sediment type around the coastline of Hayling Island which is explained further in Appendix C3.

4.1.3 Topographic Changes

Due to its exposed nature, the open coast of Haying Island is highly dynamic. These morphological changes can be measured by analysing various data sources available for this area. Changes observed since the 1940s using aerial photography are highlighted below and more recent changes since 2003 can be described in more detail with the collection of SRCMP topographic data.

4.1.3.1 Changes in Shoreline – Aerial Photography

Using historical aerial photography, the shoreline position was digitised between 1946 and 2016 along the open coastline to highlight the change in contour position. The main differences are apparent around Gunner Point and West beach. The shoreline position around Gunner Point and along the Open Beach was much further landward in 1946 compared to 2016, whilst at West Beach, directly west of IOTB, the shoreline position was much further seaward in 1946 (Figure **4.4**).

The more recent shoreline positions (2008 and 2016) highlight many interesting morphological changes around Hayling Island including the seaward growth at Gunner Point; the progradation of the spits within Langstone Harbour entrance and Sandy Point; and has identified pulses of material moving northwards in Langstone harbour entrance.

Drift direction is predominantly westward from the approximate location of Creek Road and as a result material has built up along the Open Beach due to an inhibited flow at IOTB bringing the coastline forwards at this location (Figure **4.4**). West Beach has retreated due to downdrift erosion and Gunner Point continues to accrete. With substantial management (shingle recycling and beach control structures) the coastline has retained a much more stable position in recent years.

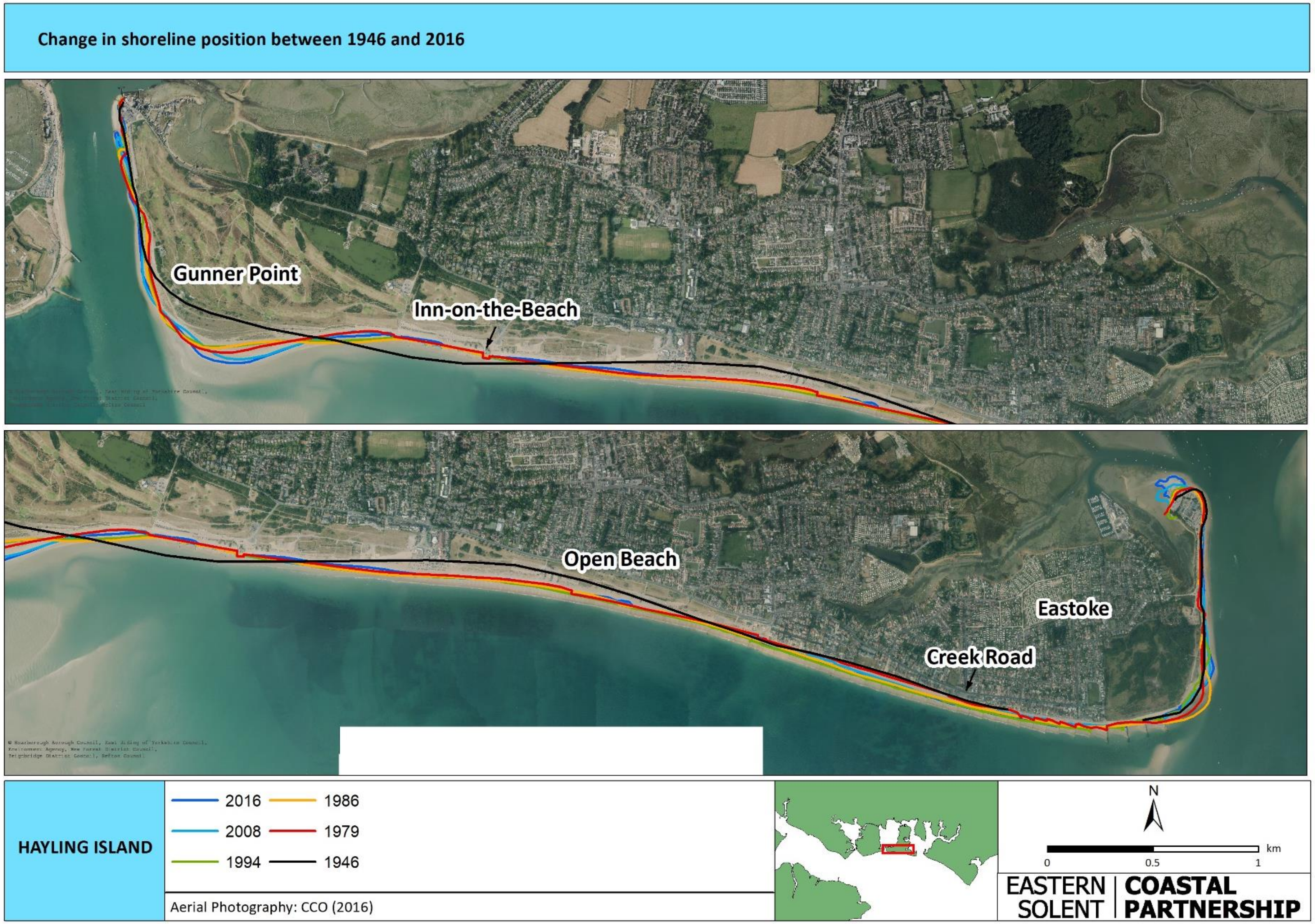

Figure 4.4 Changes in the shoreline position between 1946 and 2016, mapping using historical aerial photography

4.1.3.2 Changes in Mean High Water

The Mean High Water (MHW) contours (4.3mCD) have been extracted from the 2005, 2013 and 2018 SRCMP digital terrain models (DTM) to assess how MHW is changing. The change in contour position also provides an indication of eroding or accreting areas and is useful to cross-check with the elevation difference plots (Section 4.1.3.4). Figure 4.5 shows the changes in MHW between 2005 and 2019. Along the open coast, the MHW contours were extracted from topographic datasets.

Gunner Point has experienced significant accretion since the late 1800s which continues to be the case, evident by the seaward growth of the MHW contour (Figure 4.5). However, at West Beach, significant cutback was observed between 2016 and 2019 following the removal of timber groynes in March 2018. The groynes had been outflanked as the beach retreated and they became a health and safety hazard. Prior to the groyne removal, a section of timber revetment was removed between 2012 and 2013 as it had reached the end of its residual life and suffered storm damage. Approximately two thirds of the remaining timber revetment was removed in July 2020 when it too became a health and safety hazard. Only the section directly adjacent to IOTB remains. More detail on the monitoring at West Beach can be seen in Appendix A1.

Changes in the MHW contour highlight the extensive accretion of material at Sandy Point in the east of the Island. The material here is sand rather than shingle. A similar build up of sand is occurring on the eastern side of Chichester Harbour at Cakeham, indicating a link with the flood and ebb delta system (ESCP, 2015). There has also been significant progradation of the two spits located on the west of the Island in the Langstone Harbour entrance channel (Figure 4.5).

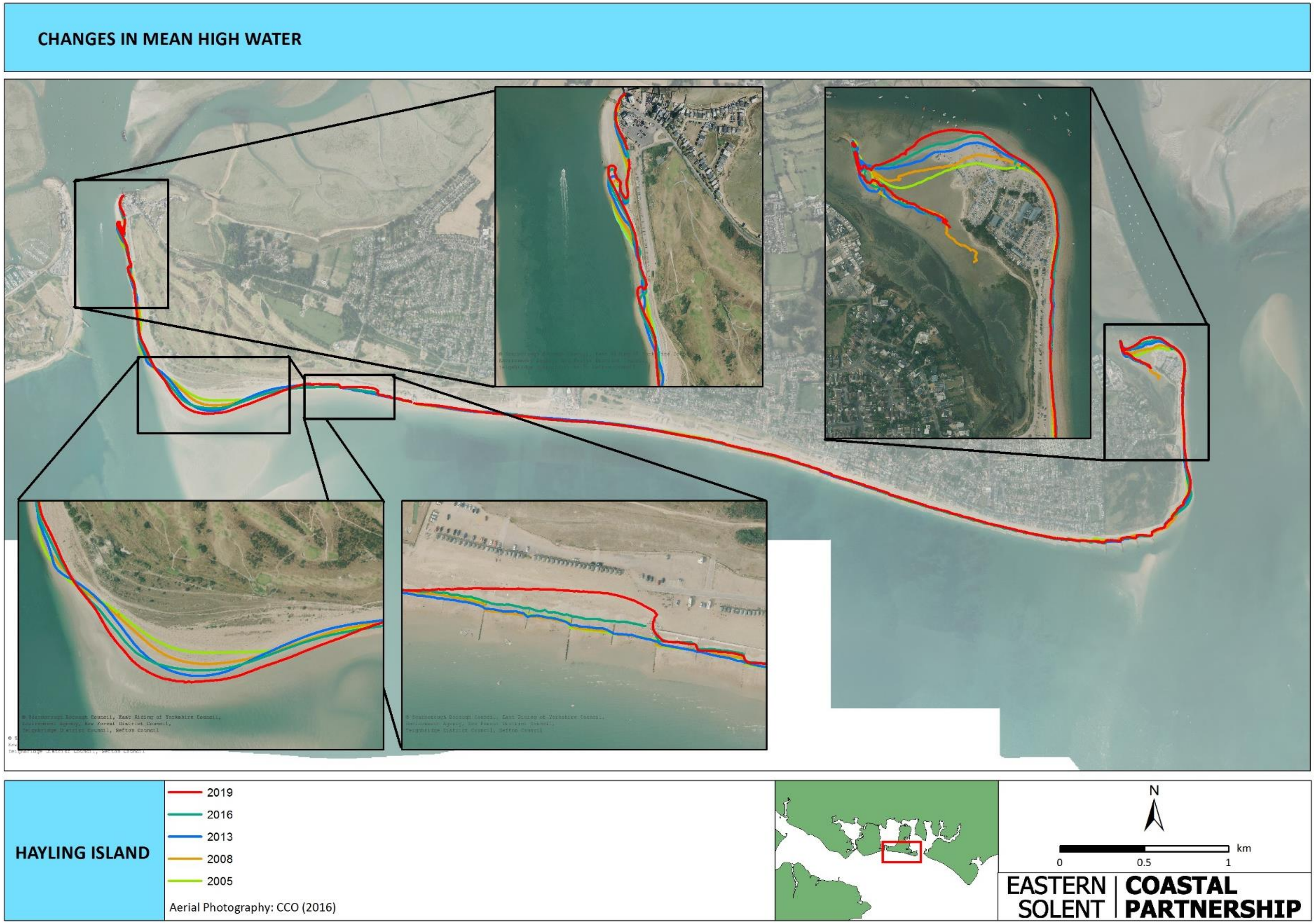

Figure 4.5 Mean high water contours over South Hayling

4.1.3.3 Profile Data

Some example topographic profiles were taken from South Hayling SRCMP data (Figure 4.6) to investigate in detail how the cross sections have changed along the open coast between 2005 and 2019.

The two profiles located at Eastoke (5a00286 and 5a00304) show a relatively stable beach profile, which is consistent with beach management working to maintain a constant design beach height and width. Whilst this management approach works well to stabilise the profile, ensuring that the standard of protection is maintained, it does mean that natural changes become much more difficult to deduce.

Profile 5a00363 at West Beach shows how the beach has rolled back by approximately 10-15 m since the removal of control structures starting in 2012. Previously, a timber revetment and a series of groynes reduced sediment drift rates through this frontage which held the beach crest in place. Since the structures' removal in 2012, the shoreline is taking a more natural alignment, in keeping with the North Solent Shoreline Management Plan (NSSMP) (2010) policy. As mentioned in Section 4.1.3.2, the section of revetment to the east was removed in July 2020 and is currently being monitored. Only a short portion adjacent to IOTB remains.

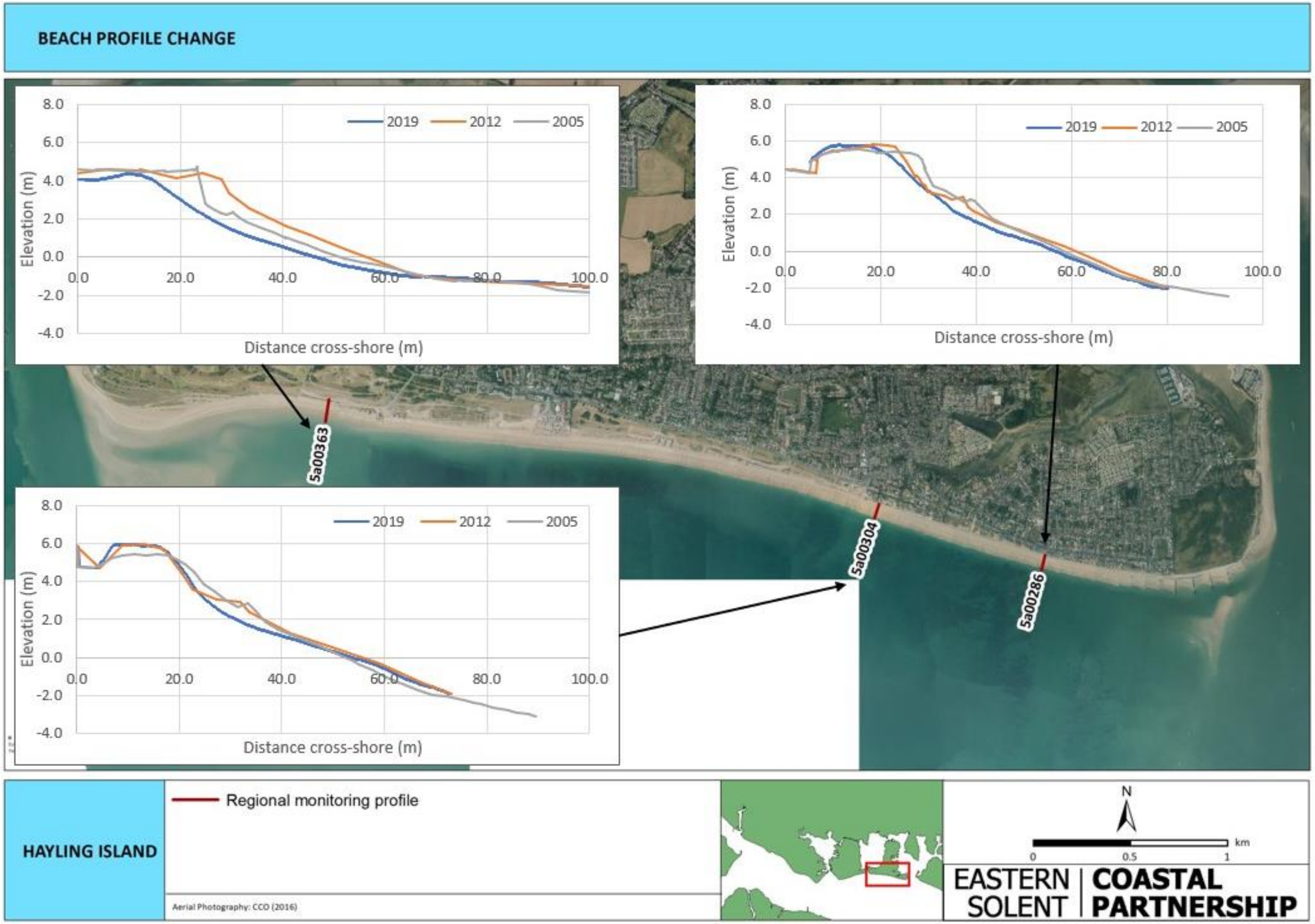

Figure 4.6 Profile changes along the south of Hayling (elevations are in mOD)

4.1.3.4 Difference Plots

Difference plots are created by subtracting one DTM from another. They are a useful tool for illustrating areas of erosion (sediment loss depicted in red) and accretion (sediment gain depicted in blue), therefore providing an indication of beach elevation change and sediment movement along a frontage (see Figure 4.7).

Figure 4.7 shows how the south coast of Hayling is very dynamic with some areas of both significant erosion and accretion. The use of Light Detection and Ranging (LiDAR) rather than topographic data for production of this different plot allows changes over the East Winner (off the Langstone Harbour Entrance) and West Pole Sands (off the Chichester Harbour entrance) to be observed as this data extends out beyond the MLWS contour.

The East Winner continues to accrete sand, with the Langstone Harbour channel cutting through the west side of the bank. Conversely, West Pole Sands shows erosion since 2005. Eastoke shows little change in beach heights, due to beach management interventions, although this is still a very active stretch of coastline. Gunner Point continues to accrete, along with the sediment pulses moving north at both harbour entrances. Sandy Point also continues to accrete sand at the tip of the spit. The sediment dynamics of the South Hayling coast are explored in further detail in Section 4.1.6.

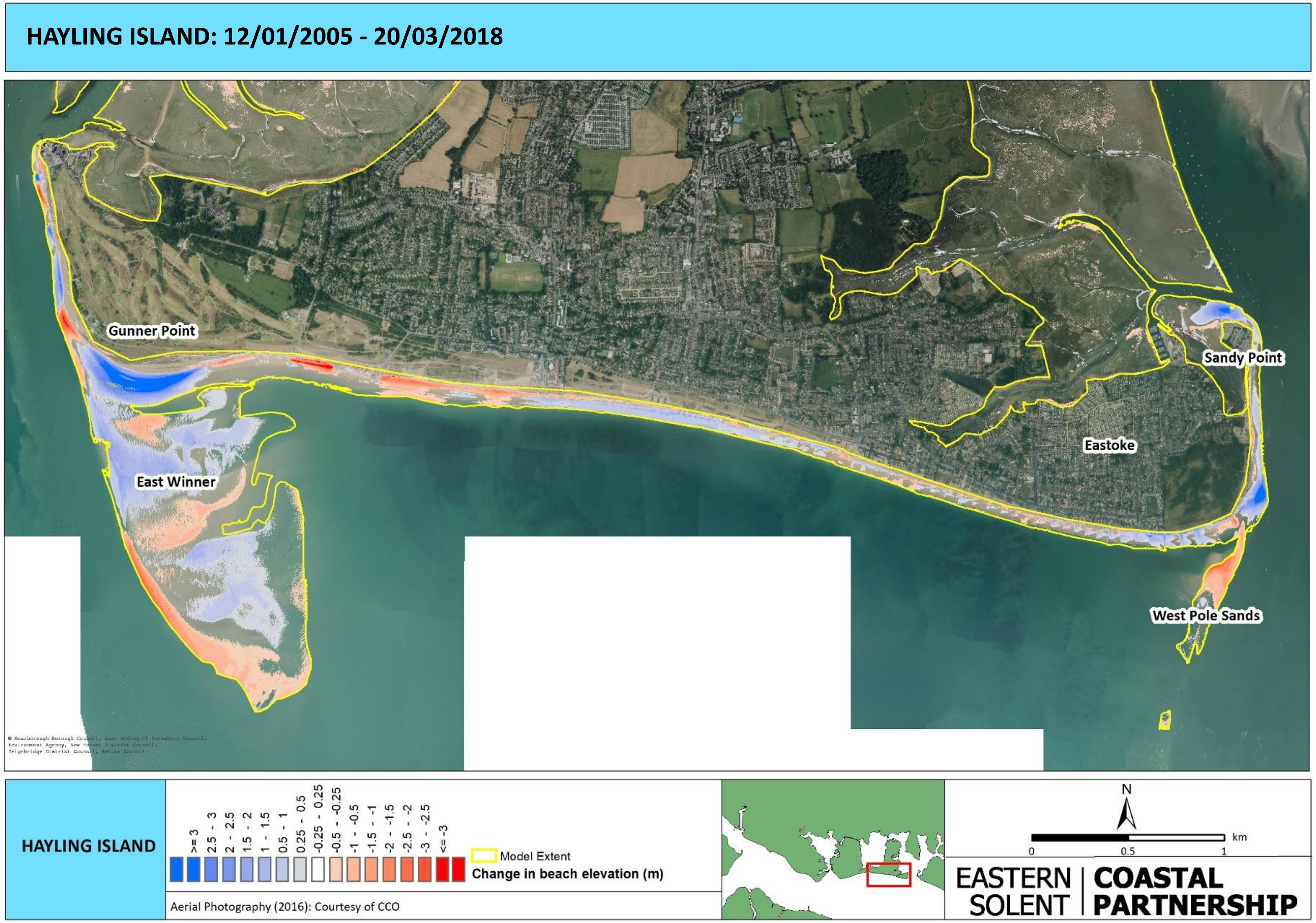

Figure 4.7 Difference plot over South Hayling Island between 2005 and 2018 (LiDAR data)

4.1.4 Tracer Studies

Two tracer pebble studies have been undertaken along the South Hayling open coastline using Radio Frequency Identification (RFID) Tags embedded into native pebbles to track sediment movement along the frontage. The first study was conducted in March 2011 and the second in April 2019. The two reports (ESCP, 2013 and ESCP 2018) detail the methods and set up of these two projects.

Results from the 2011 study showed the presence of a drift divide located approximately at Creek Road car park in Eastoke. Tracer pebbles deployed east of the drift divide were generally found to move around into Chichester Harbour entrance, while tracer pebbles deployed west of the drift divide showed considerably larger transport rates westwards (Figure 4.8). At Gunner Point, tracer pebbles showed strong westerly transport towards Langstone Harbour entrance. These findings informed the update to the SCOPAC STS (2012).

Similarly, the net transport direction at Eastoke in the 2018 study was shown to be westerly from the deployment site at Creek Road Car Park and easterly from deployment sites east of Creek Road, suggesting that there remains a drift divide located around Creek Road car park (Figure 4.8).

No evidence of short-term drift reversals at Gunner Point were found in this later study. The tracks of individual pebbles suggest a steady east to west direction of transport around Gunner Point and then north along the entrance of Langstone Harbour. Despite the tendency for material to build up along the up-drift face of a structure, results also indicate that material was able to bypass IOTB from east to west (Figure 4.9).

In general, the highest rates of transport of 1,554 m/yr were seen from pebbles that were deployed immediately east of IOTB and bypassed IOTB as they travelled westwards around Gunner Point, while considerably lower rates of transport were found in deployments at Eastoke (Table 4.1). The observed drift rates across all deployment sites appeared to be highly influenced by the local wind and wave conditions at the sites. Interestingly, the previous study in 2011 also found that the highest drift rates along the frontage occurred at Gunner Point, however this time with pebbles deployed immediately west of IOTB, with a maximum rate of approximately 1,584 m/yr (Table 4.1).

Table 4.1 Rate of transport (m/yr) calculated for deployment sites 1 to 9 (Table A7 in 2018 tracer study report)

Deployment Location	Deployment Site	Maximum Rate 2018 (m/yr)	Maximum Rate 2011 (m/yr)
Gunner Point	**1**	895	N/A
	2	1167	1584
	3	1266	821
	4	1322	N/A
	5	1554	N/A
Eastoke	**7**	448	484
	8	502	
	9	445	N/A

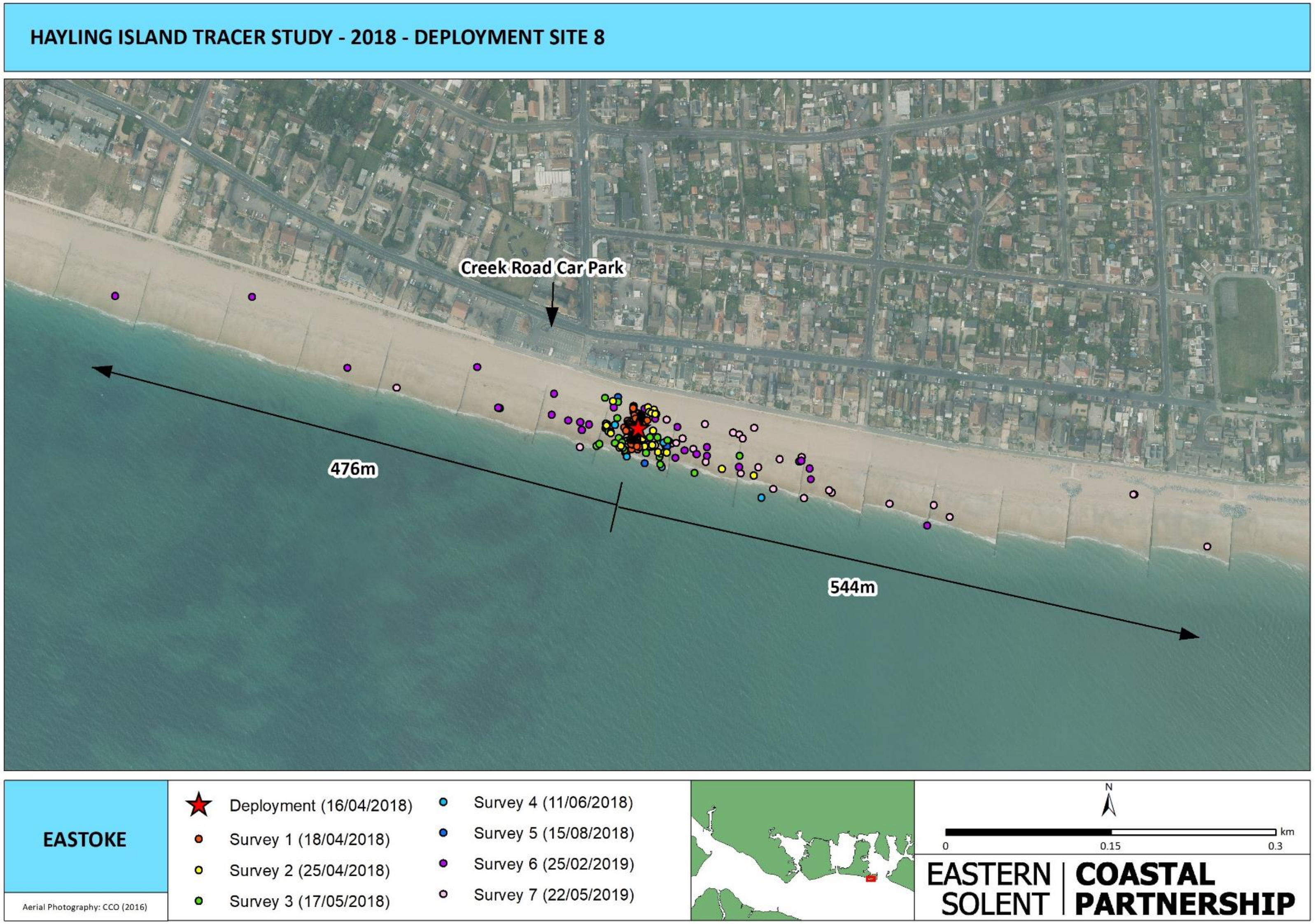

Figure 4.8 All retrieved tracer pebbles between April 2018 and May 2019 from Eastoke, Site 8

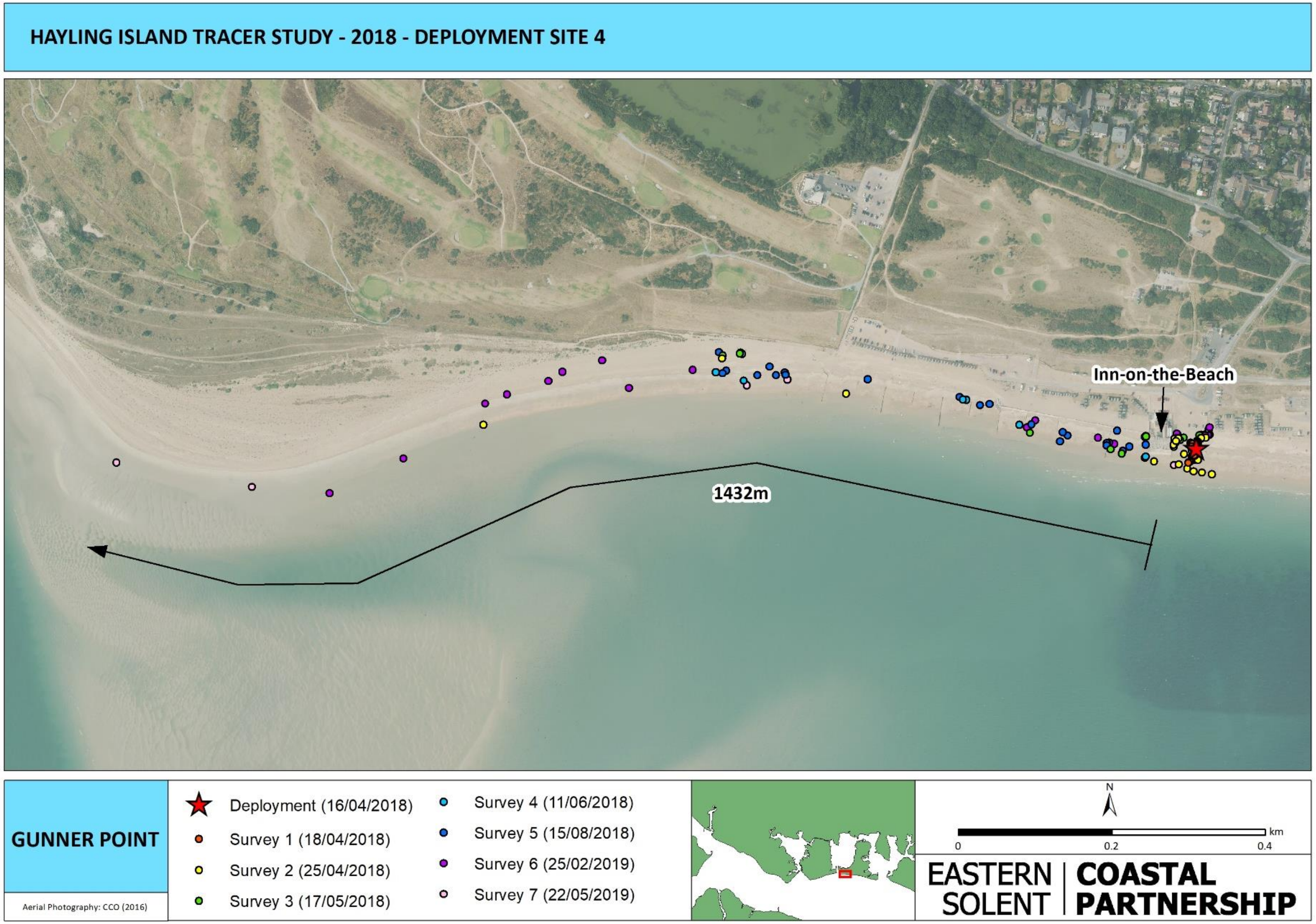

Figure 4.9 All retrieved tracer pebbles between April 2018 and May 2019 from deployment site 4 to the east of IOTB

4.1.5 Bathymetric Changes

This section presents the bathymetric changes that have occurred along the open coast using SRCMP data, with a focus on areas of greatest change at the harbour entrances and ebb tidal deltas.

4.1.5.1 Contours

Research into the evolution of the Langstone and Chichester ebb-tidal deltas identified the possibility of West Pole Sands, which is located at the entrance to Chichester Harbour, decreasing in size in the future (Moon, 2008). This was identified as being a similar morphological change to the possible reduction of West Winner at the entrance to Langstone Harbour. Figure 4.10 shows the decline of the West Winner at Langstone Harbour entrance between 1841 and 2008 (Moon, 2008).

Depth contours have been extracted from the most recent hydrographic data of Langstone Harbour entrance and Chichester Harbour entrance and is presented in Figure 4.11 and Figure 4.12 respectively. These figures provide an update to those produced by Moon (2010) in Figure 4.10. For consistency and direct comparison, the updated contours are measured in fathoms (1 fathom = 1.83 m).

At Langstone Harbour entrance there is evidence of shallowing as the 0 fathom contour has extended south eastwards between 2007/08 and 2018 and the eastwards growth of the 1 fathom contour over the same period. From 2007/08, the Langstone Harbour entrance channel is deeper and more prominent – the Portsmouth and Hayling sides are now less connected than they were in the past which could be a contributing factor to the accretion of the East Winner.

4.1.5.2 Profile Data

Changes in the bathymetry of Hayling Island between 2005 and 2019 are shown in Figure 4.13. This illustrates the relative stability of the Hayling nearshore zone, along the Open Coast.

4.1.5.3 Difference Plots

The difference plot in Figure 4.14 shows elevation change between 2008 and 2018, using the earliest to most recent bathymetry data available. As with the LiDAR difference plot (Figure 4.7), Figure 4.14 shows minimal change to the open coast with more significant elevation changes on the harbour ebb deltas.

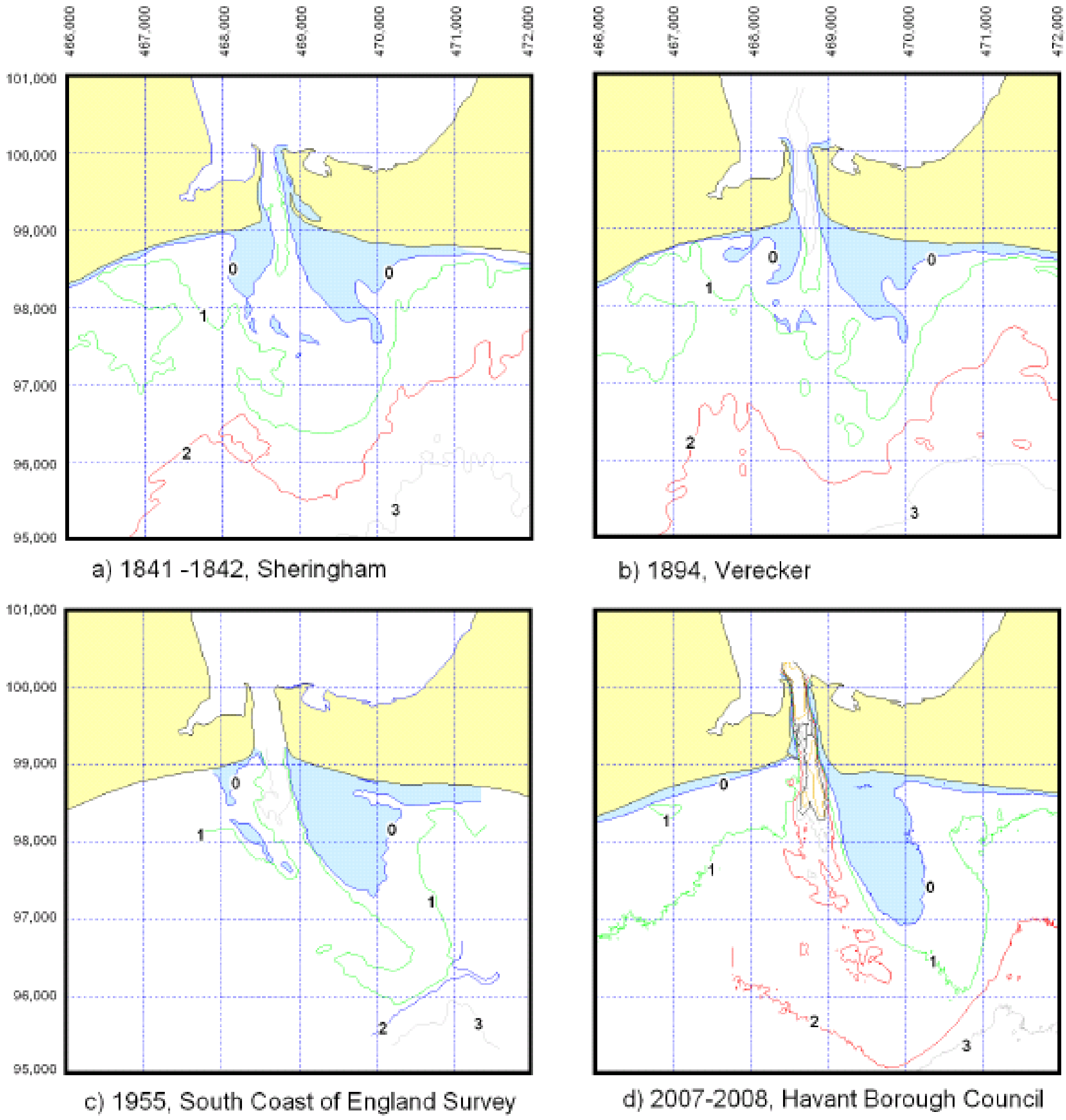

Figure 4.10: Evolution of Langstone ebb-tidal delta morphology, 1841 - 2008. Contours shown in fathoms relative to chart datum (1 fathom = 1.8288m) (Moon, 2008).

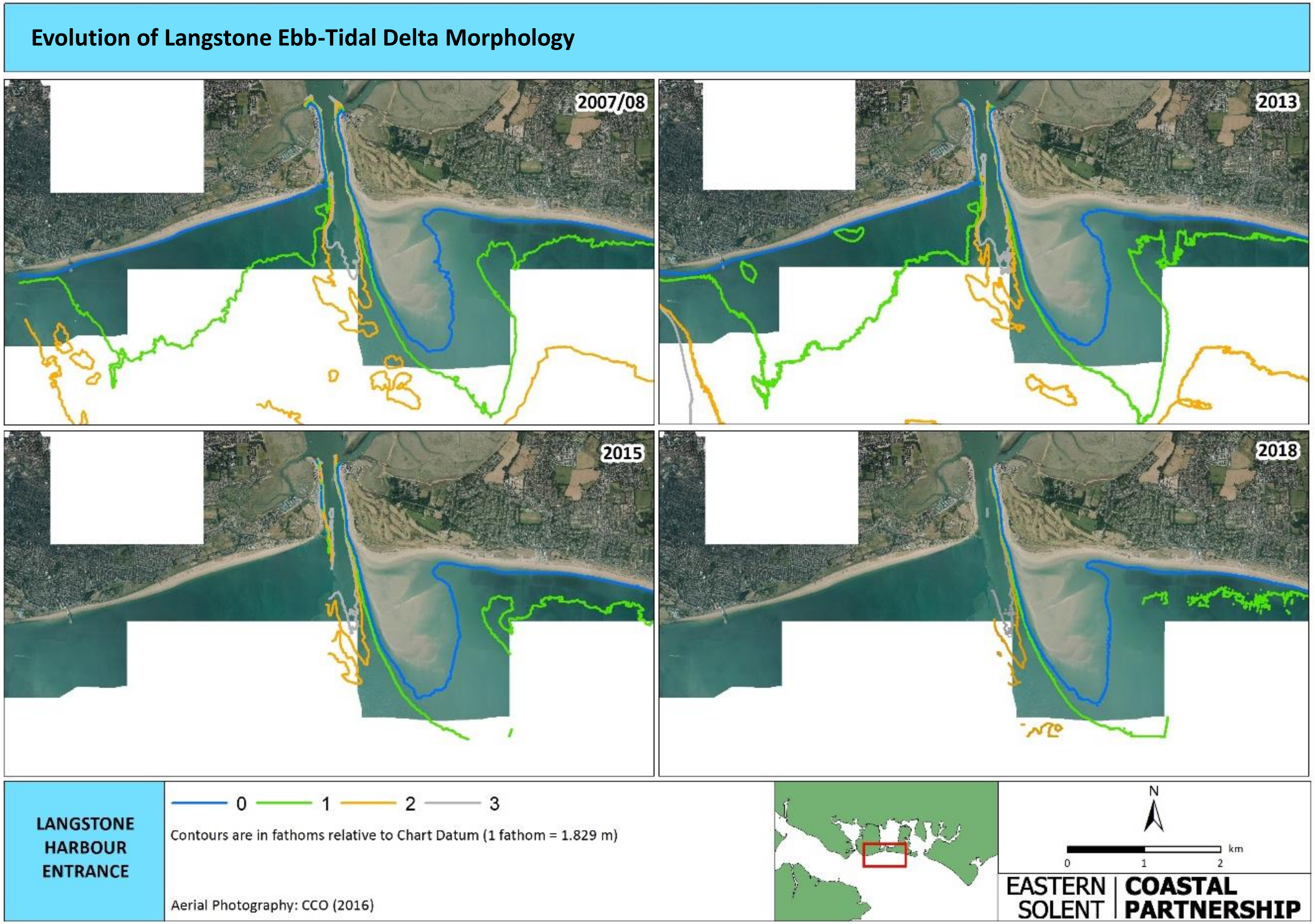

Figure 4.11 Bathymetry contours at the entrance of Langstone Harbour (note: no data available for Portsmouth in 2015 and 2018)

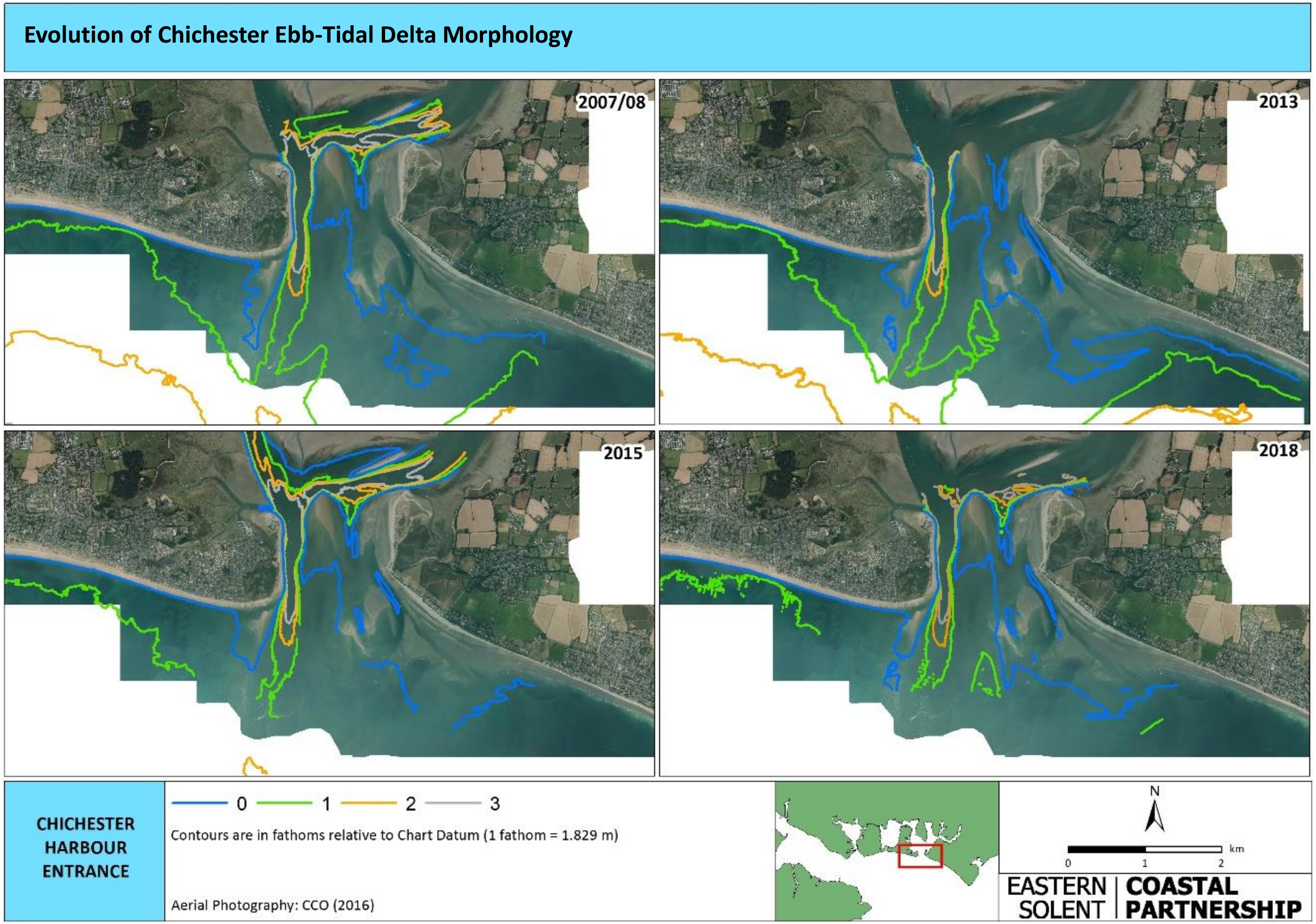

Figure 4.12 Bathymetry contours at the entrance of Chichester Harbour

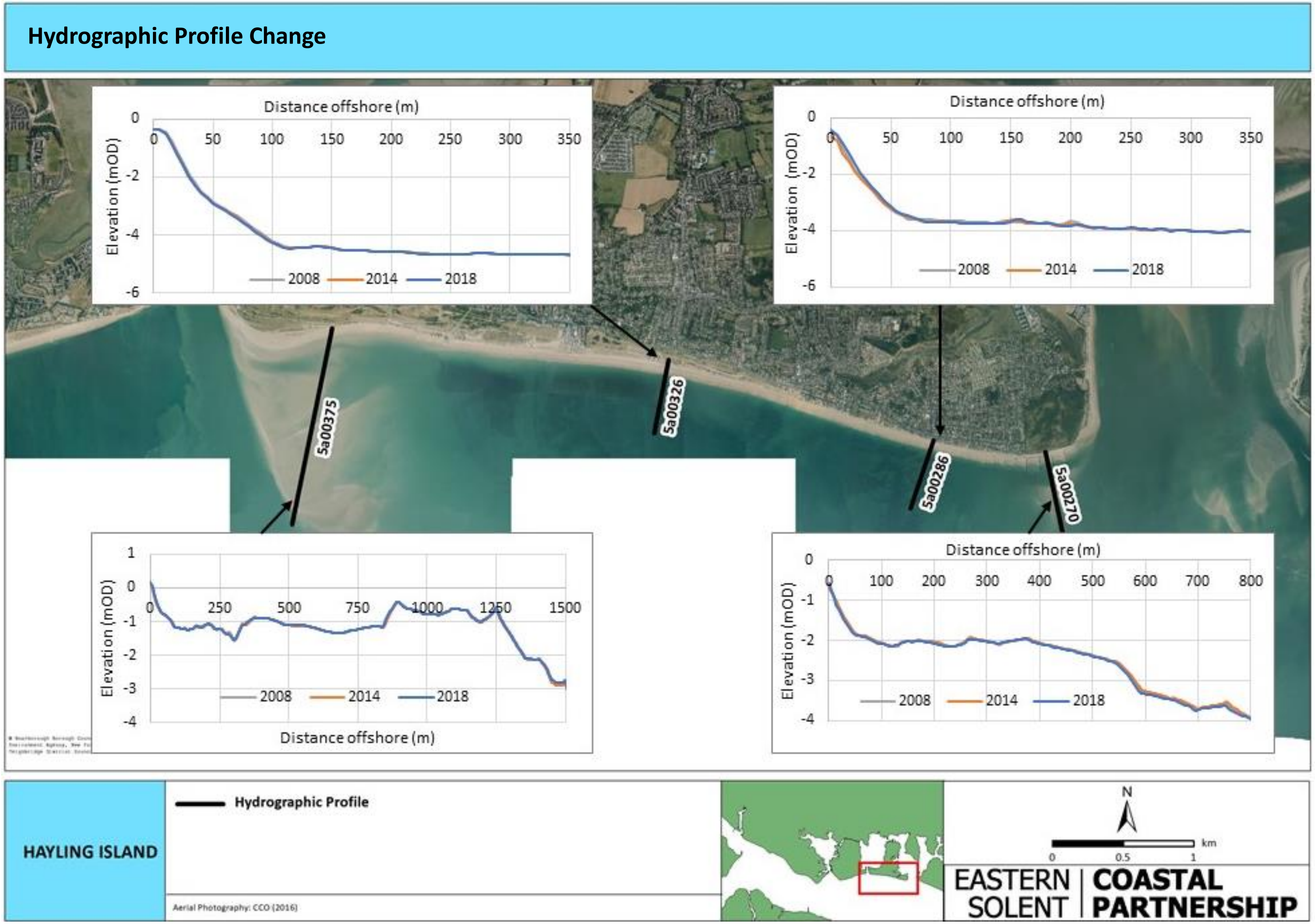

Figure 4.13 Profile changes in the bathymetry of South Hayling

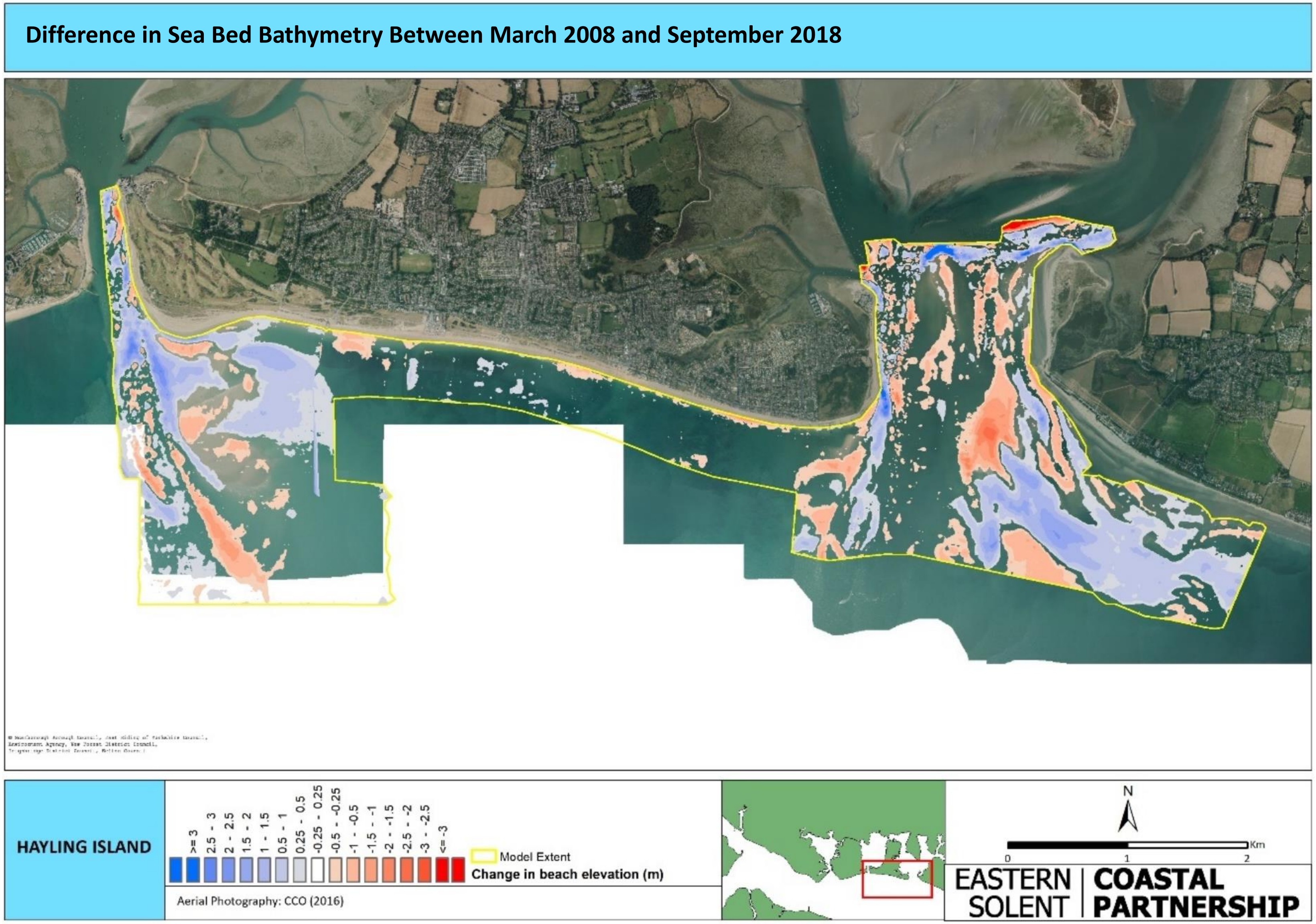

Figure 4.14 Changes in bathymetry off Hayling Island between 2008 and 2018

4.1.6 Sediment Budget Analysis

Using the information presented above, an up to date sediment budget was produced for the open coast of Hayling Island based on the Rosati and Kraus (1999) equation. This provides an estimate of the 'natural' sediment drift rates between sub cells, accounting for beach management. There are, however, some limitations and assumptions made within the Sediment Budget Analysis (SBA). Importantly, the SBA assumes that this is a closed system (where no material enters or leaves the defined system) where in reality, sediment exchanges will be made with the adjacent coastline.

The 2005 LiDAR[1] and 2019 topographic dataset were used to calculate changing beach volumes, whilst the 2008 and 2018 bathymetry were compared for volume changes to the ebb deltas at the East Winner and West Pole Sands. Sediment pathways on the beach were based on the tracer studies and difference plots and the onshore and offshore losses were refined from the SCOPAC STS (2012).

The results of the sediment budget are presented in **Error! Reference source not found.** and coincide well with the SCOPAC STS (2012), the biggest difference being in refining the longshore drift rates and onshore/offshore feed. The sediment budget shows two thirds of the material moving west (~53,000 m^3) from the drift divide at Eastoke and slowing as it reaches Gunner Point (~35,000 m^3) and one third moving east (~13,000 m^3) from the drift divide at Eastoke. Material moves quickest along the open coast and more slowly in the harbour entrances. Gunner Point and the East Winner at the entrance to Langstone Harbour are increasing by 16,831 m^3/yr and 13,834 m^3/yr, respectively. The alternating cells of erosion and accretion within Langstone Harbour entrance show the pulses of material moving up into the harbour.

This sediment budget assumes the onshore feed at Eastoke is made up of the volume change at West Pole Sands between 2005 – 2019, the recycling and recharge activities, as well as some additional onshore feed to balance the sediment budget.

[1] The earlier 2003 topographic survey for South Hayling did not extend down to Mean Low Water Springs (MLWS) along its length or capture areas of significant accretion (e.g. Gunner Point) required to allow comparisons with later data.

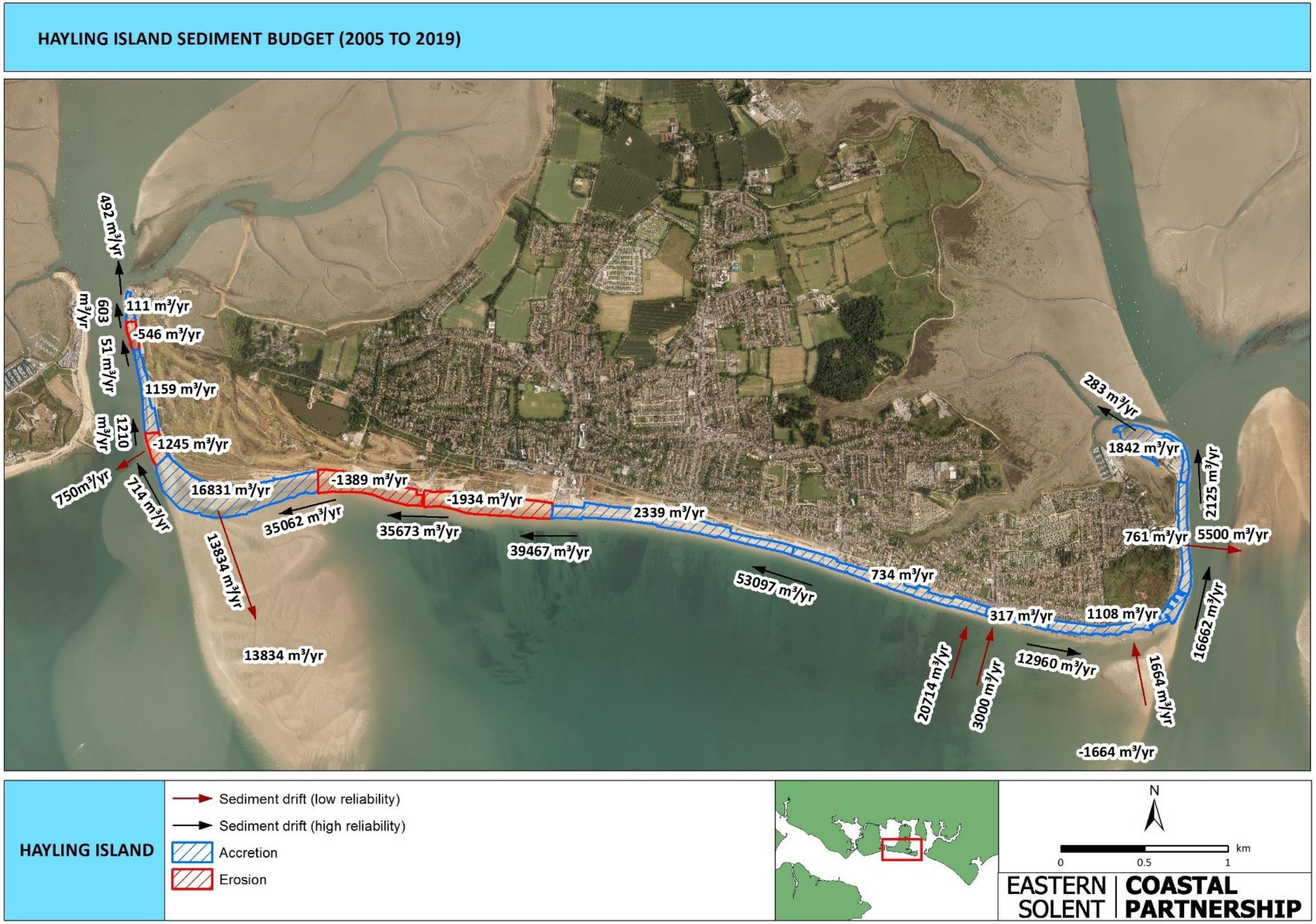

Figure 4.15 Sediment budget for the South Hayling Island Open Coastline

4.2 Harbour Sediment Dynamics

This section presents the sediment dynamics in Chichester and Langstone Harbours. There is less data collected as part of the SRCMP for the harbours compared with the open coast, therefore the analysis is less detailed than Section 4.1.

4.2.1 SCOPAC Sediment Transport Study

Chichester and Langstone Harbours located to the east and west of Hayling Island respectively are characterised by fine bed sediments and a much less energetic hydrodynamic climate. Most of the larger swell and storm waves are filtered out by the narrow harbour entrances and the relatively small fetch in the harbours is not large enough to allow large wind generated waves.

Figure 4.16 provides an overview of all the sediment inputs and outputs within Portsmouth, Langstone and Chichester Harbours, taken from the SCOPAC STS (2012). Much of the sediment movement around the harbour coastline is dominated by fine sediment, with the exception being cliff and coastal slope erosion from the Hayling Billy.

Appendix C3.2 shows detail on sediment type, which has been recorded during profile surveys undertaken for the Regional Monitoring Programme.

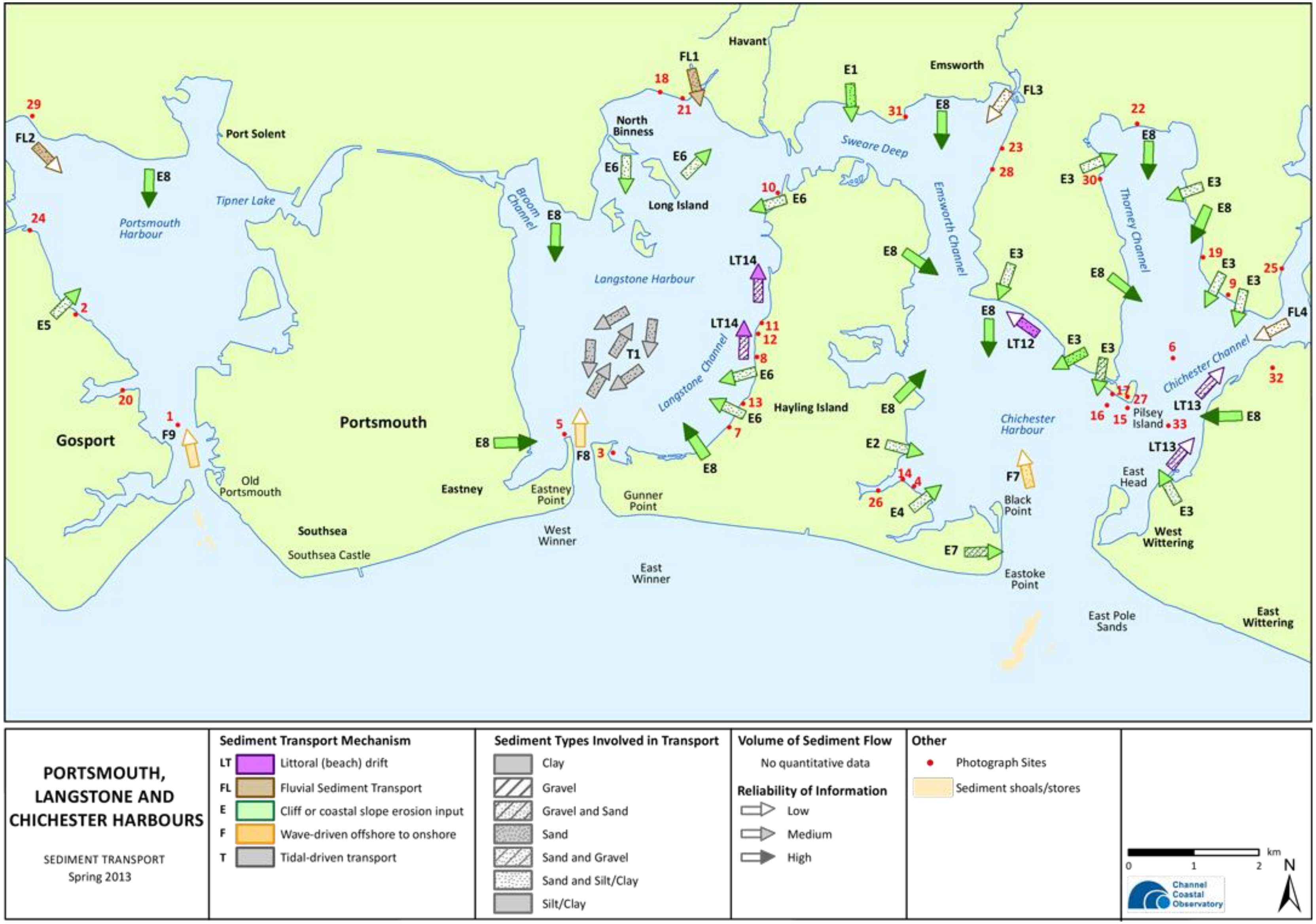

Figure 4.16 Overview of all inputs and outputs within Portsmouth, Langstone and Chichester Harbours (SCOPAC STS, 2012)

4.2.2 Topographic Changes

4.2.2.1 Changes in Mean High Water

MHW contours have been extracted from LiDAR datasets using the same process outlined in Section 4.1.3.2. Variations in the MHW contour are generally much smaller in the harbours, as the hydrodynamic forcing is much less (Figure 4.17). However, the contours shown in Figure 4.17 still show the growth of the spit to the south of the former oyster beds in Stoke by approximately 57 m between 2005 and 2018.

4.2.2.2 Profile Data

Along the west coast of Hayling Island, seven beach profiles were analysed. Two of these beach profiles are shown in Figure 4.18. Profile 5a00411C shown in Figure 4.18 indicates little change in elevation or lateral position of features which is consistent with the nature of the sheltered harbours. Profile 5a00411L shows a slightly larger change over the 13-year period between 2006 and 2019, although this only equates to approximately 0.2 m/yr of erosion which is similar to the erosion rate given in the NSSMP (2010).

4.2.2.3 Difference Plots

Difference plots are created by subtracting one DTM from another. In this case, the 2005 and 2018 LiDAR datasets have been compared to identify erosion of inter-tidal areas (sediment loss depicted in red) and accretion of inter-tidal areas (sediment gain depicted in blue) (see Figure 4.19).

On the eastern side of Langstone Harbour there appears to be mudflat lowering of approximately 0.5 m over the 13-year period, as shown by the areas in red (Figure 4.19). These areas that face west are exposed to the prevailing conditions in this area, so experience greater wave action from longer fetch lengths. An inspection of the western-facing shores of Thorney Island (which are not displayed in the image) show the same pattern of greater erosion. The accuracy of the 2005 dataset is +/- 15 cm and the accuracy of the 2018 dataset is +/- 5 cm (Appendix C).

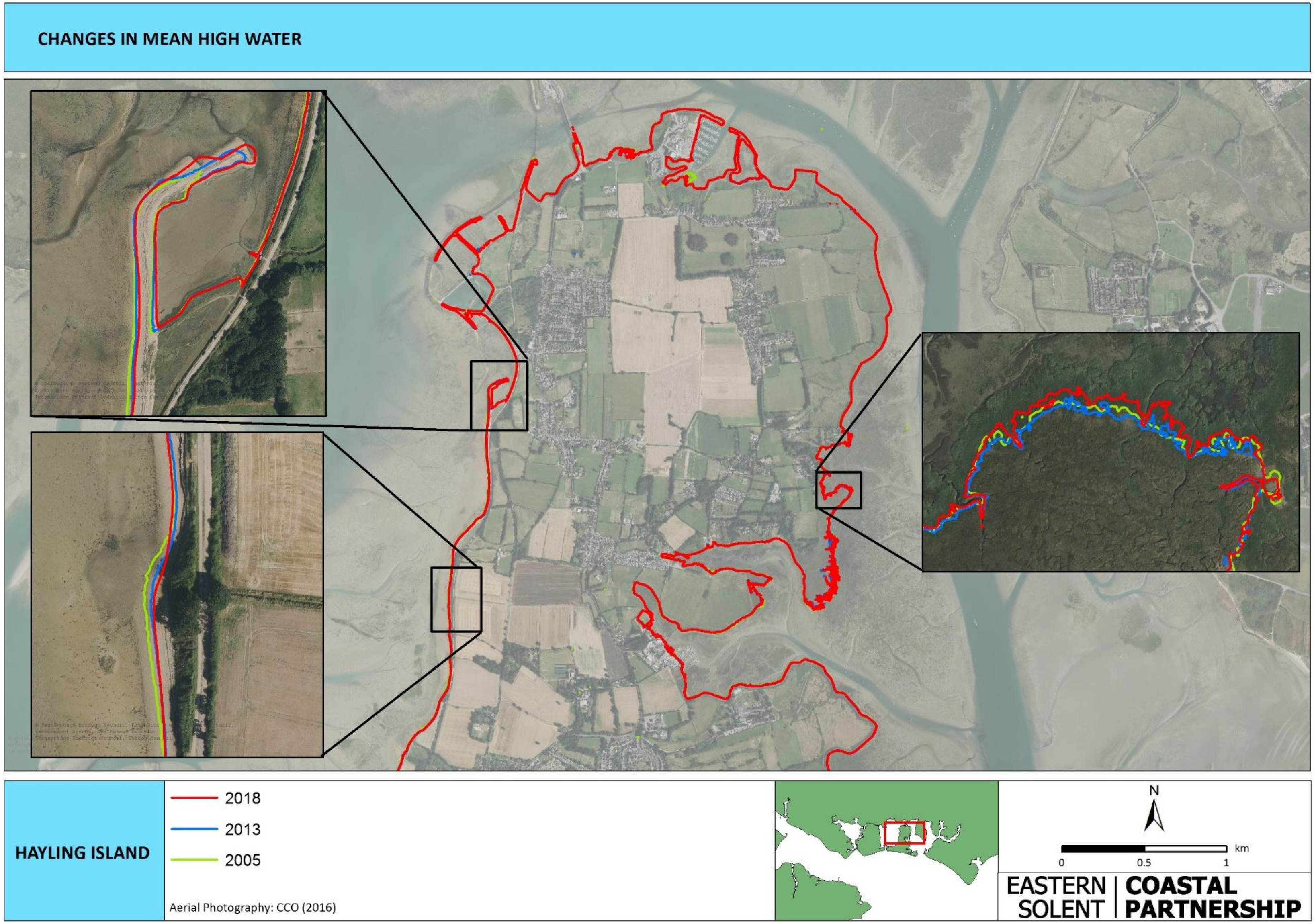

Figure 4.17 Mean high water contours over North Hayling

Figure 4.18 Example of two of the beach profiles analysed along the west coastline of Hayling Island

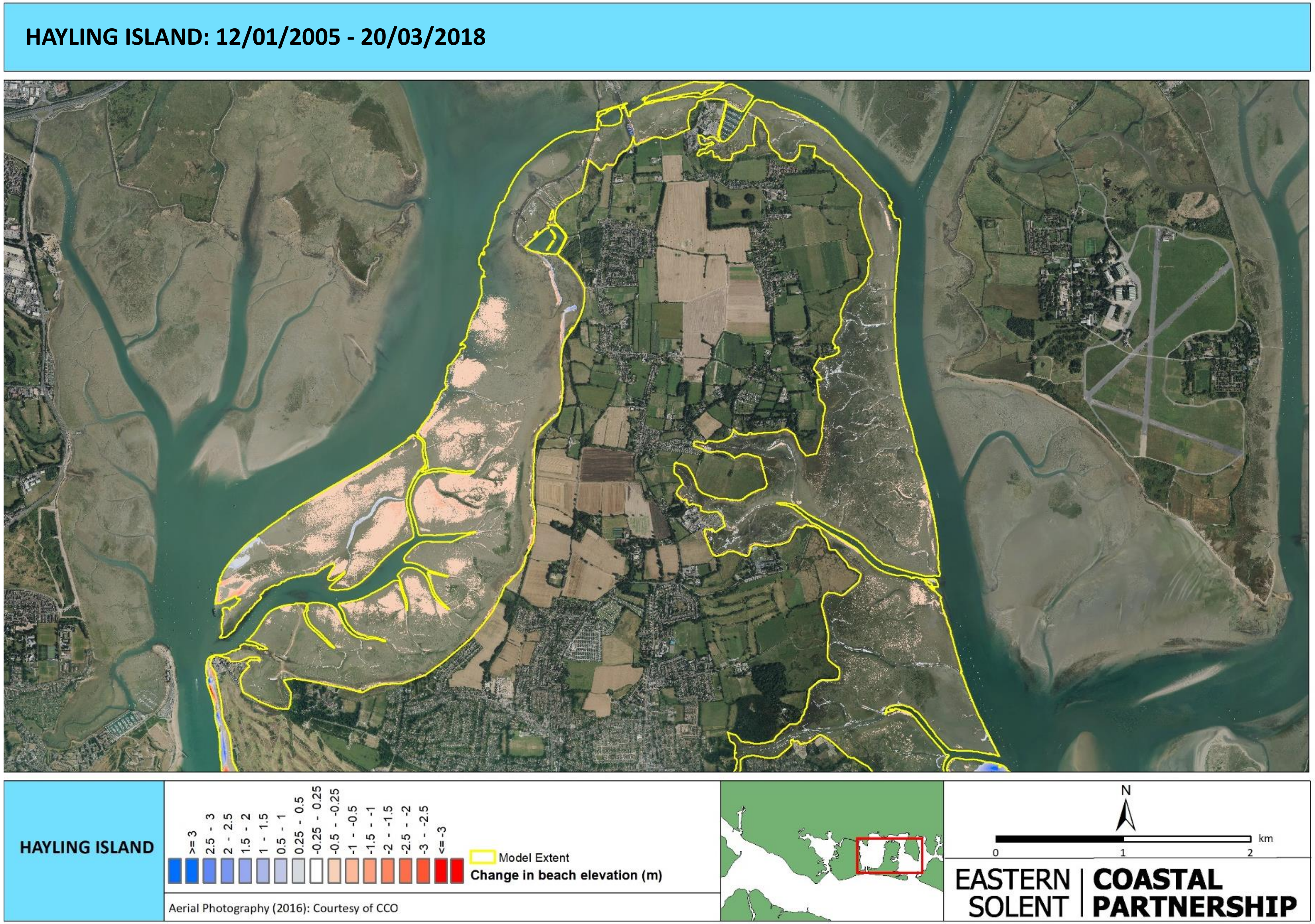

Figure 4.19 Change in inter-tidal elevation inside the harbours around Haying Island

4.2.3 Coastal Habitats

The following section updates the saltmarsh mapping undertaken from historical aerial photography as part of the Solent Dynamic Coast Project (SDCP, 2008).

4.2.3.1 Saltmarsh loss

Saltmarsh extent was digitised from aerial photography for the following years as part of the Solent Dynamic Coast Project (SDCP) (2008); 1940's, 1960's 1980's 1990's and 2000s. These outputs have been updated using the SRCMP 2013 and 2016 habitat mapping.

The results of the saltmarsh mapping are shown in Figure 4.20 and Figure 4.21 for Langstone Harbour and Chichester Harbour respectively. The saltmarsh areas digitized for 1946 and 2016 are included in the map as an example. A sharp decrease in saltmarsh is evident, although this appears to be stabilizing since the 1990s as described below in further detail.

Langstone Harbour Special Protection Area (SPA)

Between 1946 and 2016 saltmarsh declined by 86 %, decreasing from 424 ha to 60 ha (Figure 4.20). Approximately 81% of decline occurred in the 38-year period between 1946 and 1984 decreasing from 424 ha to 77 ha, yielding an average annual loss rate of 9.12 ha per year. Around 5 % of the decline occurred over the following 32-year period, decreasing from 77.4 ha to 59.8 ha (Figure 4.20). The fastest period of loss between 1984 and 2016 occurred after 2005 in which 13 ha were lost over an 11-year period. This yields an average loss rate of 1.2 ha per year (Figure 4.20).

Chichester Harbour SPA

Between 1946 and 2016 saltmarsh extent decreased by 58 %, from 696 ha in 1946 to 295.5 ha in 2016 (Figure 4.21). Approximately 52 % of this decline occurred between 1946 and 1991, losing 362 ha over a 45-year period and yielding an average annual decrease rate of a rate of 7.43 ha per annum. The remaining 5.6 % was lost over the following 25 years, decreasing by a further 39 ha. This yields an average loss rate of 2.45 ha per annum. A small 2.2% recovery can be observed between 2013 and 2016 (Figure 4.21). This is too small a change over too short a time frame to know that it truly may be recovering.

4.2.3.2 Climate Change Allowances

The SDCP project also considered future changes under climate change allowances to assess how the saltmarsh and mudflat habitats may evolve in the future. A sea level rise (SLR) of 6mm/yr (DEFRA guidance, 2006) was added to the tidal levels and used to flood the LiDAR DTM. Three scenarios were run, each accounting for a different amount of vertical sediment accretion: 0 mm/yr, 3 mm/yr and 6 mm/yr.

These findings formed the basis of the North Solent Shoreline Management Plan (NSSMP, 2010) Habitats Regulation Assessment and subsequent habitat creation requirements to be delivered by the EA's Southern (now Solent and South Downs) Regional Habitat Compensation Programme (RHCP).

The Strategy study has used this information and recommended that the SDCP is revised to include latest SLR estimates (UKCP18) for future Habitats Regulations Assessments. Further detail can be found in the draft Hayling Island Coastal Management Strategy Habitat Regulations Assessment.

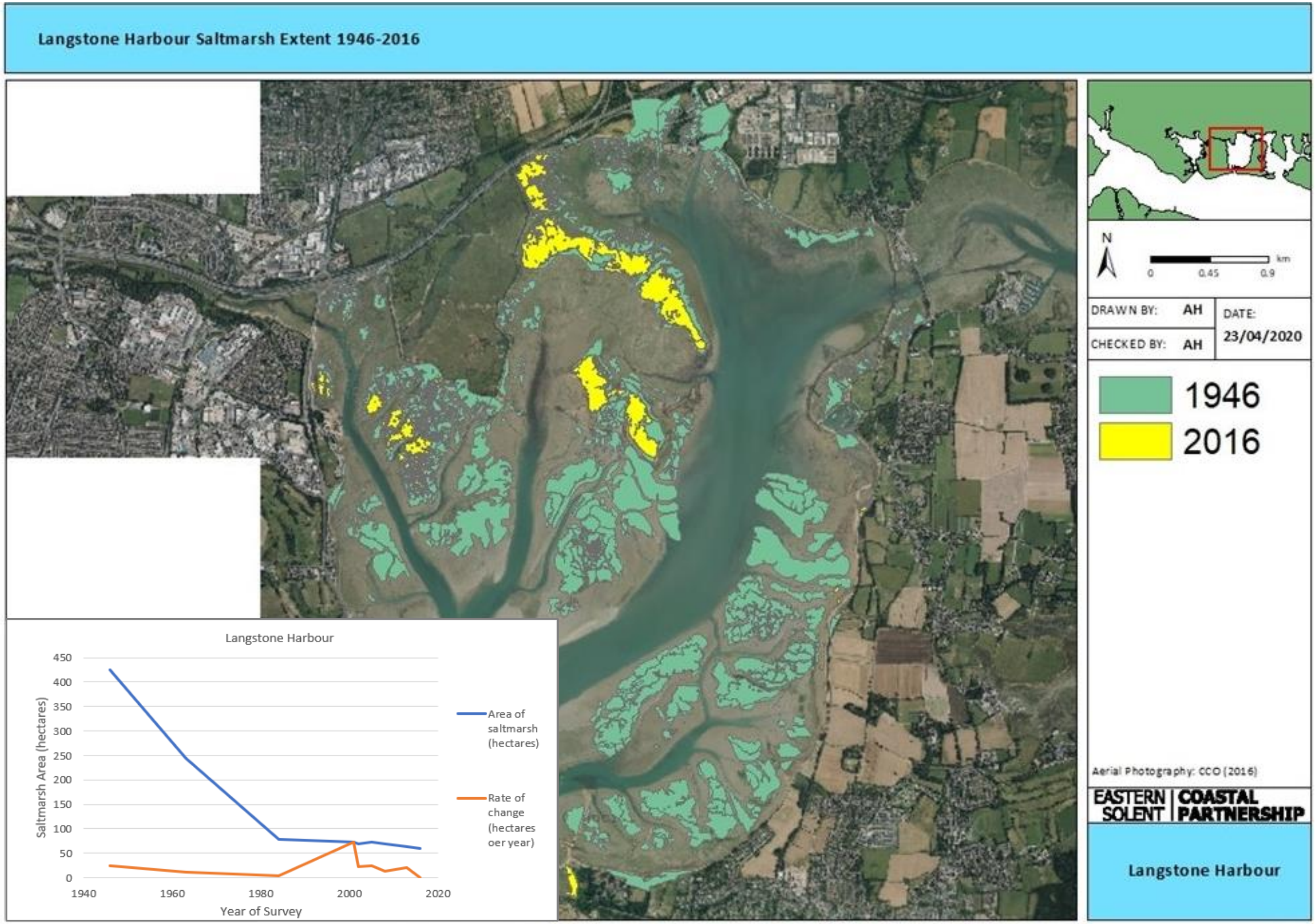

Figure 4.20 Saltmarsh loss in Langstone Harbour between 1946 and 2016

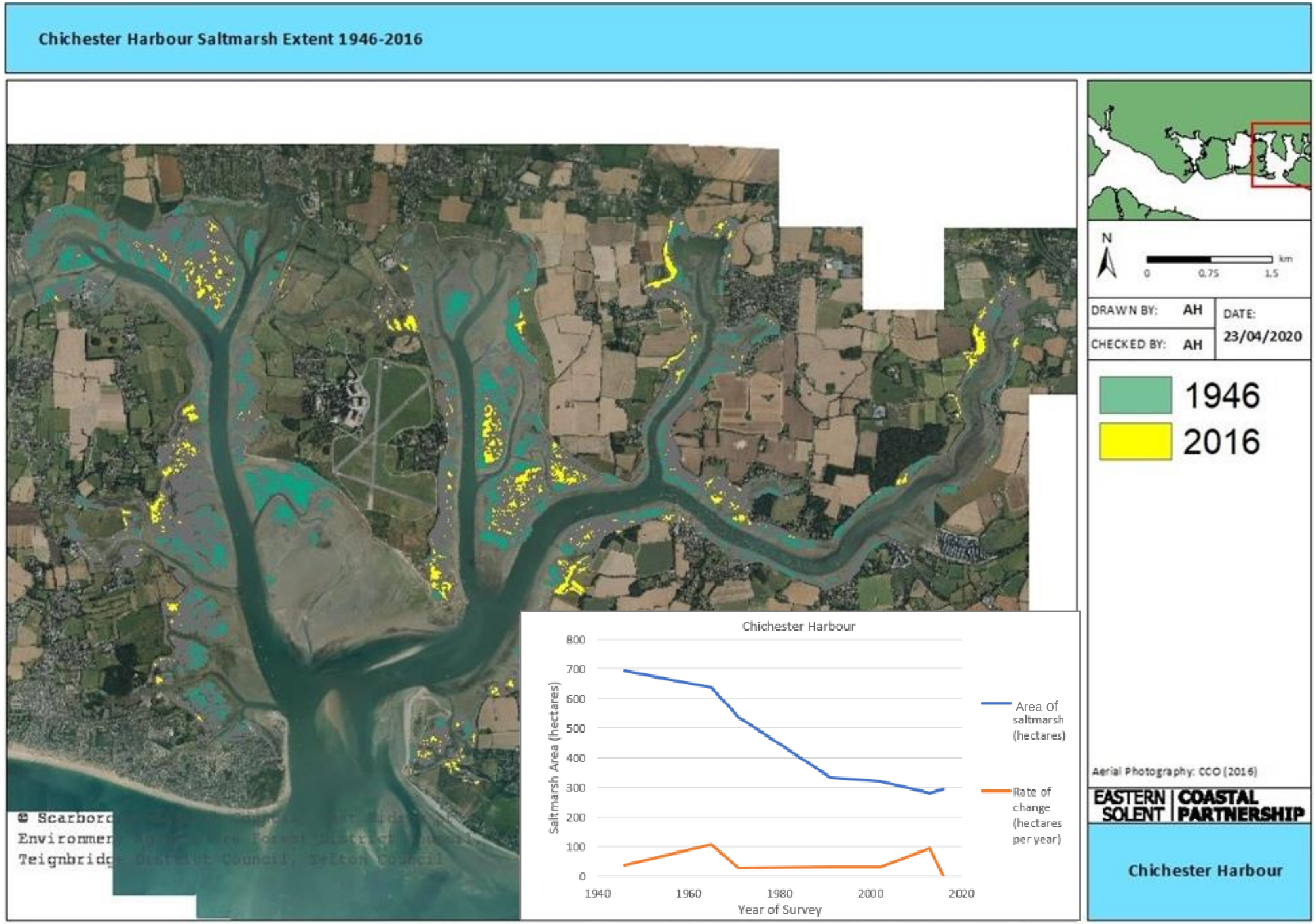

Figure 4.21 Saltmarsh loss in Chichester Harbour between 1946 and 2016

5 Option Development Unit Summary

The information and analysis carried out on the coastal process data in the preceding sections has been pulled together to summarise the characteristics of each ODU. This is available in Table 5.1.

ODUs can be defined as manageable areas with consistent themes that help to facilitate and rationalise the appraisal and selection of coastal management options and are defined in the ODU Summary Report (2019b). This section provides a summary of the coastal processes and main geomorphological features in each ODU. The development of these units is described in the Identification of ODU – Summary Reports (AECOM, 2019b) which also includes information on the defence type, condition and residual life.

Figures 5.1 to 5.12 show the overall flood and erosion risk using the EA East Solent Model and the updated erosion zone projections. Figure 5.1 to Figure 5.6 show the Do Nothing erosion projections for ODUs, while Figure 5.7 toFigure 5.12 show the Do Minimum erosion projections for ODUs.

Table 5.1 Summary of the coastal processes and features of each Option Development Unit

ODU	LOCATION	COASTAL PROCESSES	GEOMORPHOLOGY, SEDIMENT TYPE, TRENDS AND MANAGEMENT	HABITATS	ISSUES/COMMENTS
1	Langstone Bridge to Northney Farm	Harbour/estuary. Sheltered.	Muddy and fine sediments. Defence types include embankments, revetments, sea walls and gabions.	Mudflats dominate the foreshore. Some saltmarsh is present. Hinterland is predominantly agricultural land.	Incidences of flooding occurring along Northney Road, to the west of Northney Marina, during storm events.
2	Northney Marina	Harbour/estuary. Sheltered.	Muddy and fine sediments. Defence types include embankments and verges.	Mudflats dominate the foreshore. Marina development forms the hinterland.	No recorded incidences of coastal flooding.
3	Northney Farm to Chichester Road	Harbour/estuary. Sheltered.	Muddy and fine sediments. Defence type is an embankment.	Extensive mudflats dominate the foreshore. Some saltmarsh present. Hinterland is predominantly agricultural land.	No recorded incidences of coastal flooding.
4	Chichester Road to Mill Rythe Junior School	Harbour/estuary. Sheltered.	Muddy and fine sediments. Defence types include embankments and a short section of sheet piling.	Extensive mudflats dominate the foreshore. Some saltmarsh present. Hinterland is predominantly agricultural land with some residential gardens.	Some incidences of minor road flooding occurring on Gutner Lane.
5	Mill Rythe Junior School to Salterns Lane	Harbour/estuary. Sheltered.	Muddy and fine sediments. Defence types include embankments, revetment and rock.	Extensive mudflats dominate the foreshore. Some saltmarsh present. Hinterland is predominantly agricultural land.	No recorded incidences of coastal flooding.
6	Salterns Lane to Wilsons Boat Yard	Harbour/estuary. Sheltered.	Muddy and fine sediments. No defence type information available along this section of the frontage.	Extensive mudflats dominate the foreshore. Some saltmarsh present. Residential gardens form the hinterland.	No recorded incidences of coastal flooding.
7	Wilsons Boat Yard to Fishery Creek	Harbour/estuary. Sheltered.	Muddy and fine sediments. Defence types include revetments, sea wall, gabions and verges.	Extensive mudflats dominate the foreshore. Some saltmarsh present. Hinterland consists of green open space, residential properties and a caravan park.	No recorded incidences of coastal flooding.
8	Eastoke	Northern frontage is harbour/estuary and sheltered. The southern frontage is exposed open coast and subject to wave action and overtopping and the eastern frontage is semi-exposed. The eastern frontage is also subject to strong tidal currents through the harbour entrance. There is a drift divide at Creek Road car park where the predominant drift direct east to west, but some material does also move west from the drift divide around Eastoke Point. An ebb tidal delta (West Pole Sands) is present of the western side of the harbour mouth. Sandy Point is a sandy, accreting spit.	Southern frontage characterised by a mixed shingle/sand beach. Beach forms primary flood defence at this location, with promenade and concrete setback splash wall behind and groyne control structures. Storm boards can be installed ahead of storm events to control flow of water through to Southwood Road behind. A rock revetment structure is in place at Eastoke Point and wooden revetment structure at Eastoke Corner. Beach management currently takes place along this southern frontage every year. This ODU includes West Pole Sands, an ebb tidal delta, and Sandy Point spit, an area that is accreting. The Ness, located in the harbour entrance channel, has previously formed a small extraction site for Beach Management Activities (BMA). The northern frontage is characterised by muddy/fine sediment.	Shingle beach, with vegetated shingle along the rear face of the beach. Residential area and Sandy Point Nature Reserve form the hinterland.	Potential for flooding from both the northern and southern frontages. Wave overtopping in larger storm events collects along the back of the beach between the crest and seawall. There have been incidences where drainage has been overwhelmed and Southwood Road has flooded.

ODU	LOCATION	COASTAL PROCESSES	GEOMORPHOLOGY, SEDIMENT TYPE, TRENDS AND MANAGEMENT	HABITATS	ISSUES/COMMENTS
9	Eastoke Corner to Inn-on-the-Beach (IOTB)	Exposed open coastline subject to wave action and overtopping. Sediment transport direction is from east to west.	Mixed shingle/sand beach. Defence types include a timer revetment at Coastguard Revetment and a concrete recurve sea wall fronting IOTB. This ODU includes both extraction (open beach) and deposition (Eastoke Corner) areas for beach management.	Shingle beach with vegetated shingle present along the upper stretches. Extensive green open space forms the hinterland.	Some incidences of overtopping during major storm events resulting in properties having flooded in the past. More recently flooding has only occurred over localised roads and in open areas behind the beach during larger storm events.
10	IOTB to North Shore Road	Exposed southern frontage and semi-exposed eastern frontage which is subject to strong tidal currents through the harbour entrance. Gunner Point and the East Winner (an ebb tidal delta) are prominent accretionary features. Sediment transport direction is east to west around Gunner Point. Section of frontage between the Ferryboat Inn to North Shore Road is sheltered harbour/estuary.	Mixed shingle/sand beach. Defence types include a timber revetment structure and groynes immediately west of IOTB and sections of sheet piling, sea wall and embankment further north and west towards the Ferry Road Inn. Gunner Point has formed an extraction site of material for beach management at Eastoke and a small deposition has taken place nearer to the Ferry Road Inn. This ODU includes the East Winner, an extensive ebb tidal delta, and two spit features on the eastern side of Langstone harbour entrance channel. Muddy and fine sediments. Minimal sediment movement but some mudflat lowering. Defence types include sea walls and embankments. Relic double spit present east of The Kench.	Shingle beach with extensive vegetated shingle around Gunner Point and up to the Ferry Boat Inn. Extensive sandy ebb delta. Extensive green open space (including golf club) form the hinterland. Extensive mudflats dominate the foreshore. Residential gardens and some open space make up the hinterland.	Some incidences of overtopping and flooding over the open areas behind West Beach and localised roads. West Beach has significantly cutback since the removal of part of the timber revetment structure.
11	North Shore Road	Harbour/estuary. Sheltered.	Muddy and fine sediments. Minimal sediment movement but some mudflat lowering.	Extensive mudflats dominate the foreshore. Residential gardens make up the hinterland.	One recorded instance of flooding within this ODU.
12	North Shore Road to Newtown	Harbour/estuary. Sheltered. Subject to erosion along the former Hayling Billy line.	Muddy and fine sediments. Minimal sediment movement but some mudflat lowering in the harbour.	Extensive mudflats dominate the foreshore. Agricultural land forms the hinterland.	Frontage along the former Hayling Billy line susceptible to erosion.
13	Newtown	Harbour/estuary. Sheltered. Subject to erosion along the former Hayling Billy line.	Muddy and fine sediments. Defence type is an embankment.	Extensive mudflats dominate the foreshore. Agricultural land forms the hinterland.	No recorded incidences of coastal flooding. Frontage along the former Hayling Billy line susceptible to erosion.
14	Newtown to Stoke	Harbour/estuary. Sheltered. Subject to erosion along the former Hayling Billy line.	Muddy and fine sediments. Minimal sediment movement but some mudflat lowering in the harbour. Relic spit at Stoke.	Extensive mudflats dominate the foreshore. Agricultural land forms the hinterland.	No recorded incidences of coastal flooding. Frontage along the former Hayling Billy line susceptible to erosion.
15	Stoke to Langstone Bridge Carpark	Harbour/estuary. Sheltered. Subject to erosion along the former Hayling Billy line.	Muddy and fine sediments. Defence types include embankment, rock and gabions. ODU contains remnants of the former Hayling Island Oyster Beds and a spit (part of former Hayling Billy railway line).	Old oyster beds present. Mudflats dominate the foreshore and hinterland comprised of some agricultural land and green open space.	No recorded incidences of coastal flooding. Frontage along the former Hayling Billy line susceptible to erosion.

ODU	LOCATION	COASTAL PROCESSES	GEOMORPHOLOGY, SEDIMENT TYPE, TRENDS AND MANAGEMENT	HABITATS	ISSUES/COMMENTS
16	Langstone Bridge Carpark to Langstone Bridge	Harbour/estuary. Sheltered. Subject to erosion along the former Hayling Billy line.	Muddy and fine sediments. Defence types include sheet piling and revetment.	Mudflats dominate the foreshore. Hinterland is predominantly green open space.	No recorded incidences of coastal flooding.

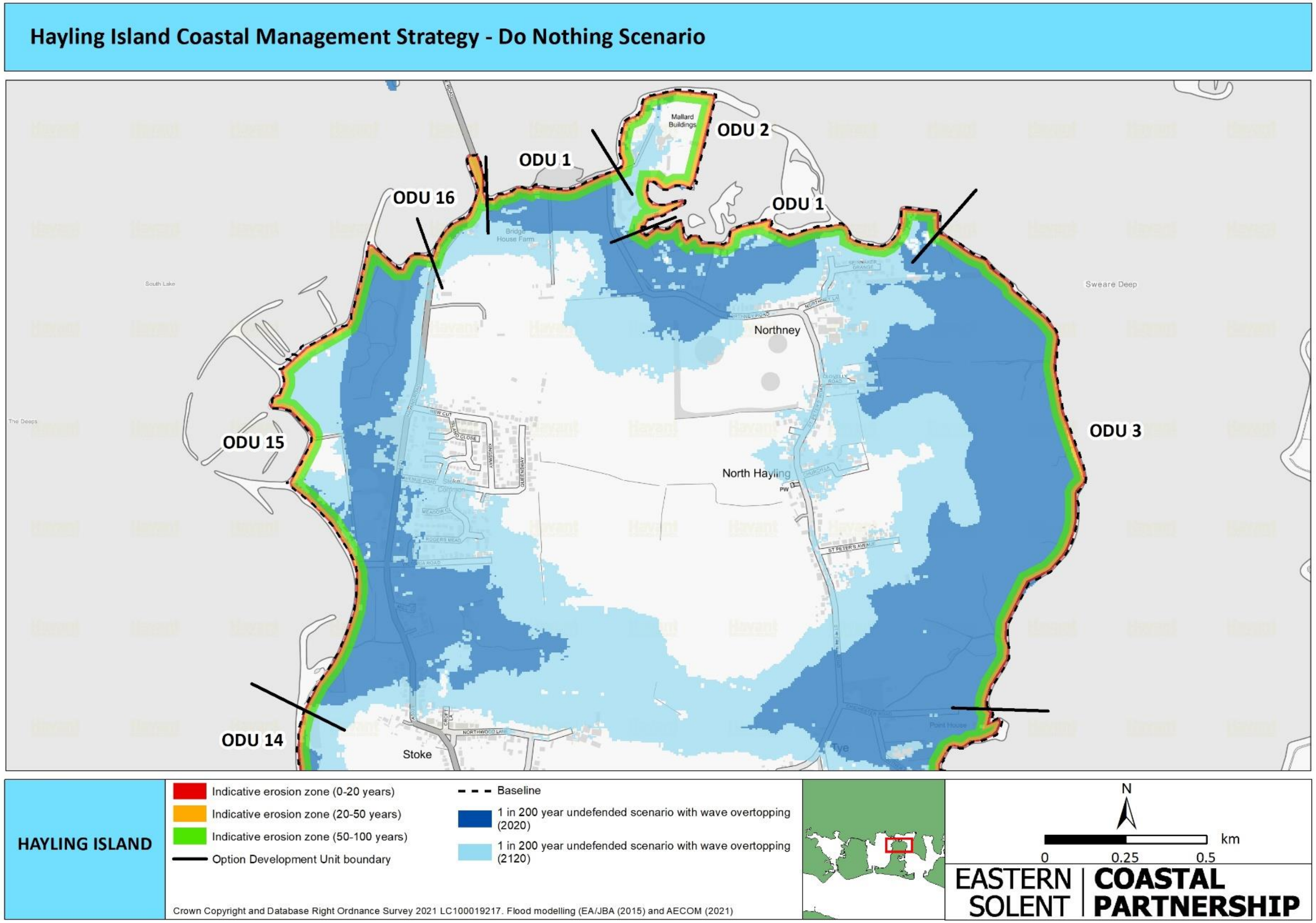

Figure 5.1 Do Nothing scenario for ODUs 1, 2, 3, 15 and 16

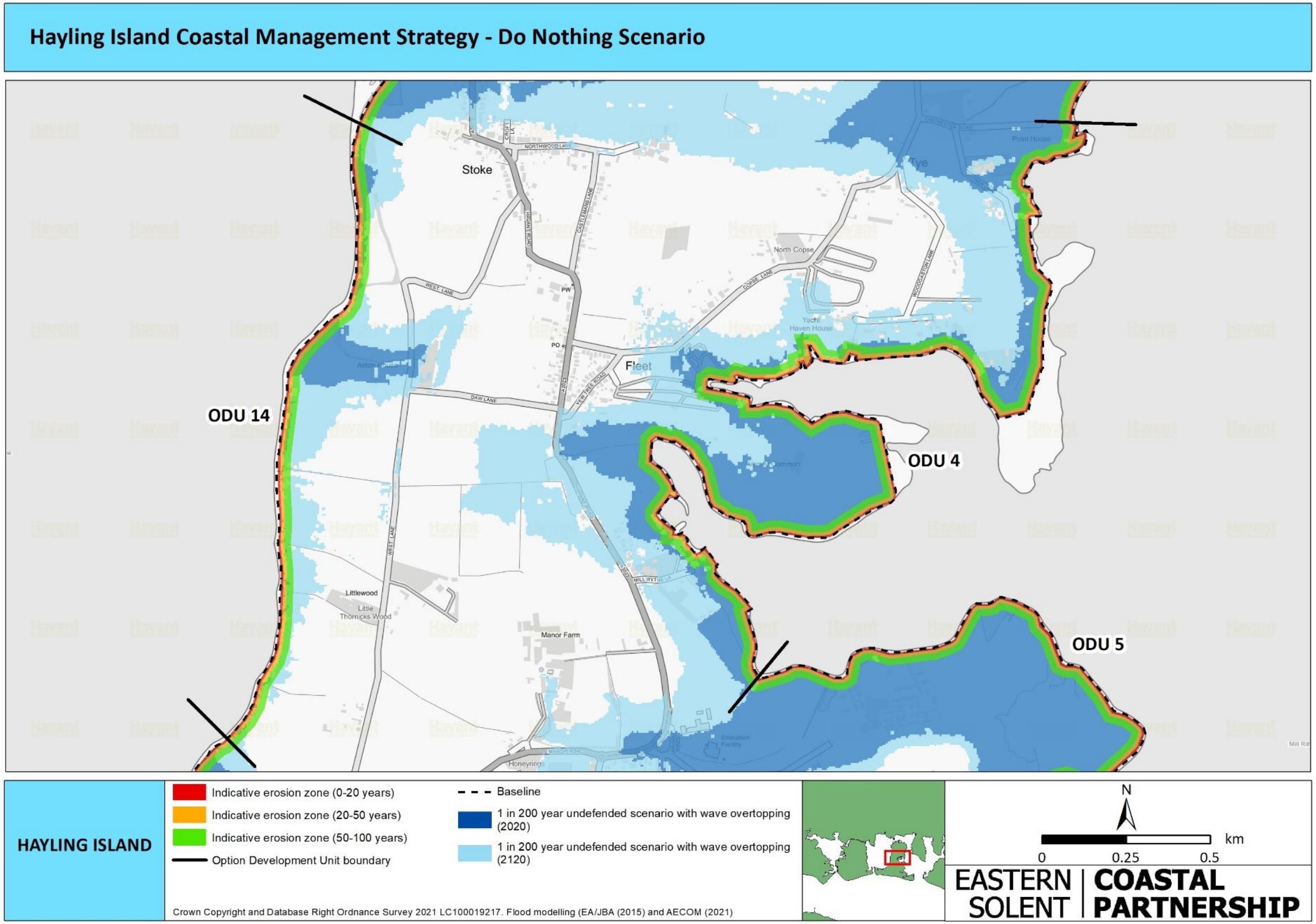

Figure 5.2 Do Nothing scenario for ODUs 4 and 14

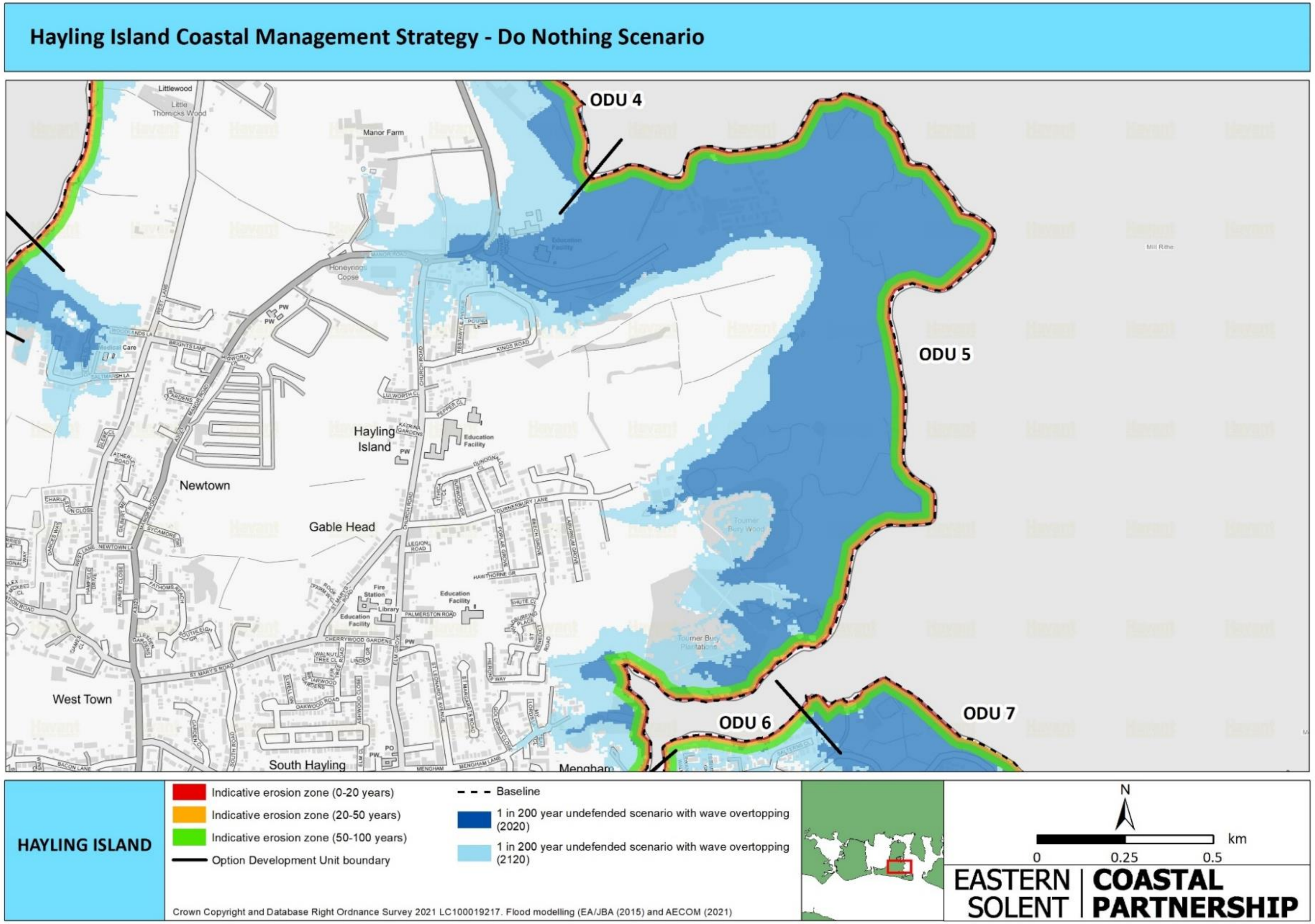

Figure 5.3 Do Nothing scenario for ODU 5

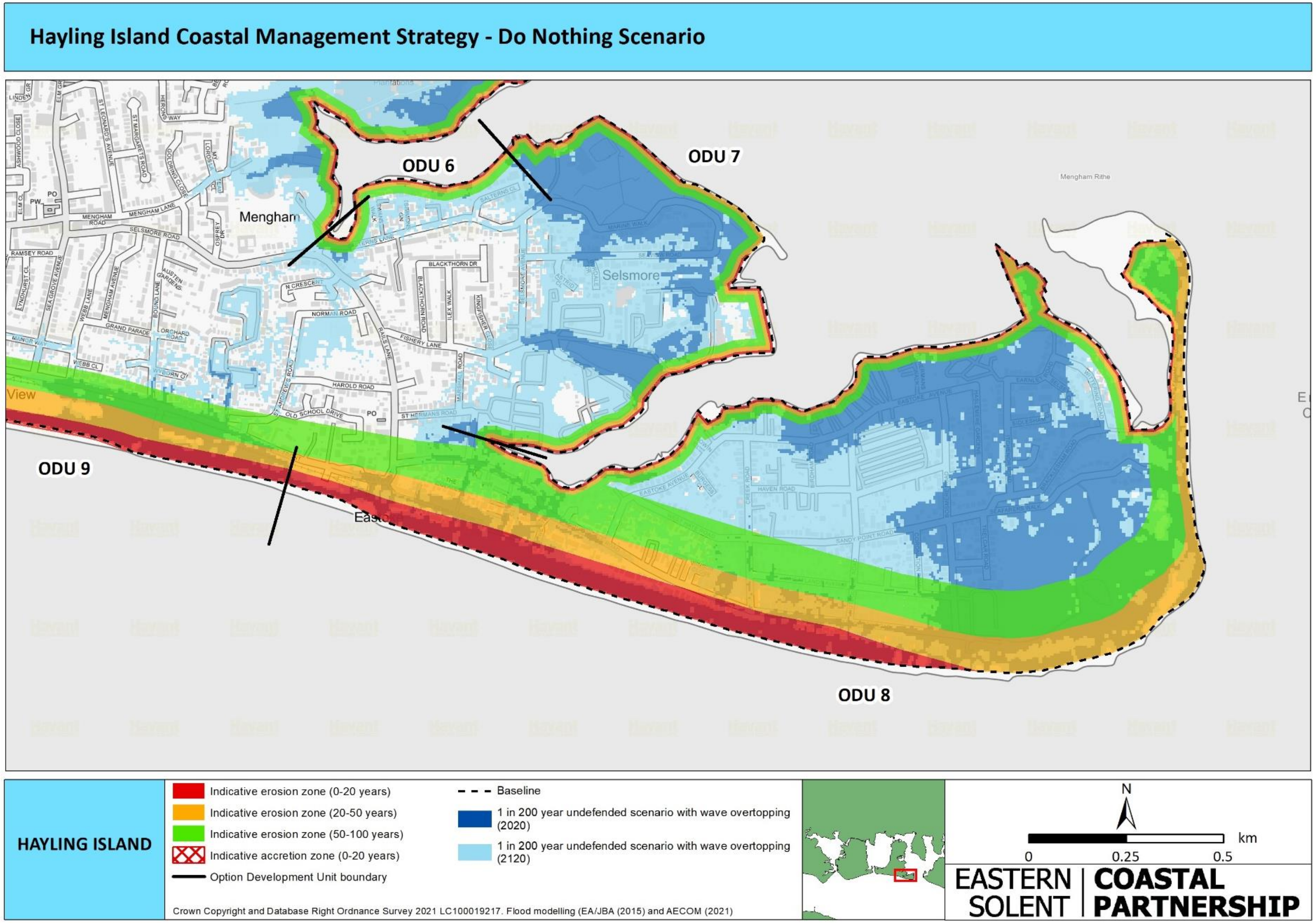

Figure 5.4 Do Nothing scenario for ODUs 6, 7 and 8

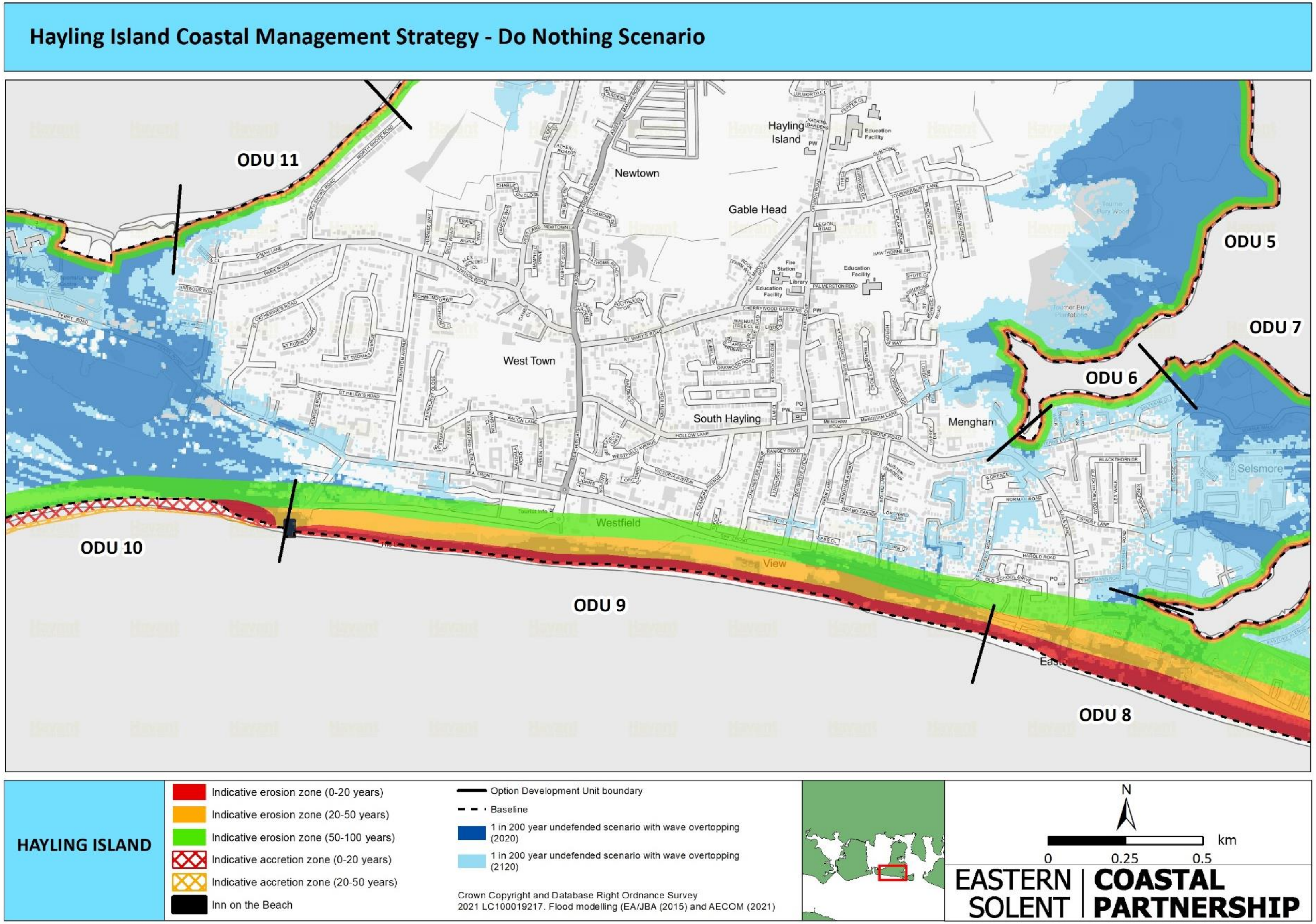

Figure 5.5 Do Nothing scenario for ODU 9

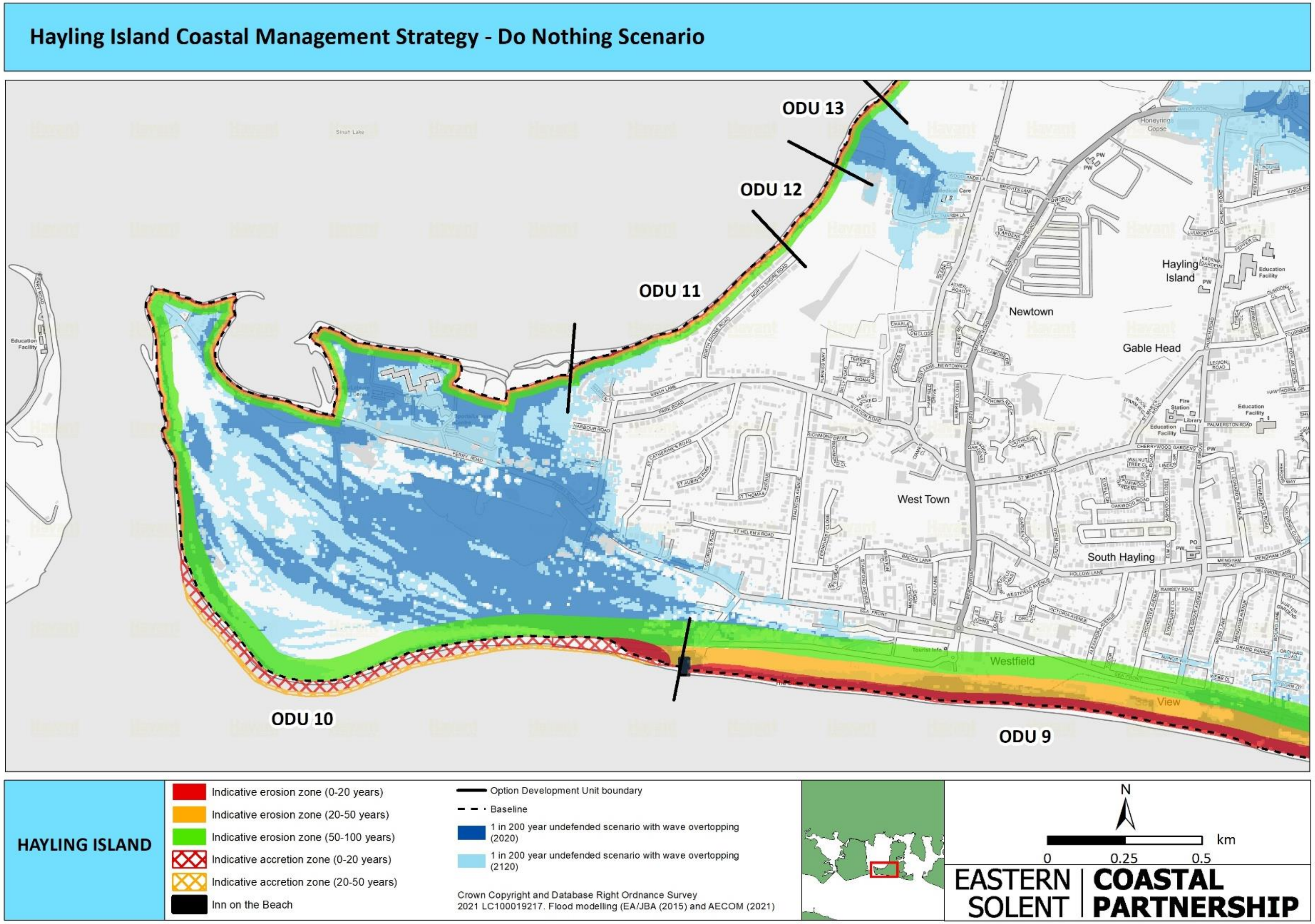

Figure 5.6 Do Nothing scenario for ODUs 10, 11, 12 and 13

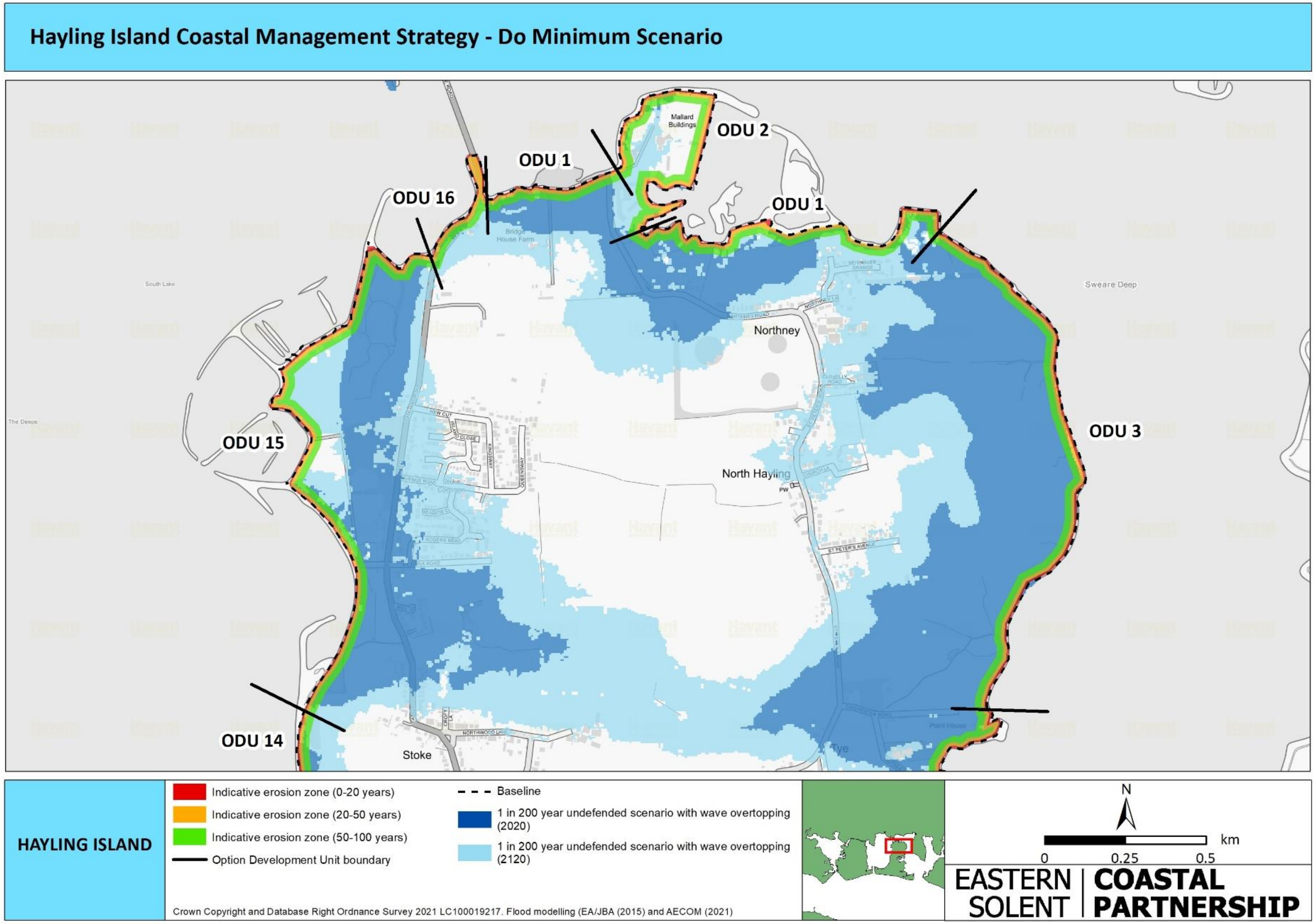

Figure 5.7 Do Minimum scenario for ODUs 1, 2, 3, 15 and 16

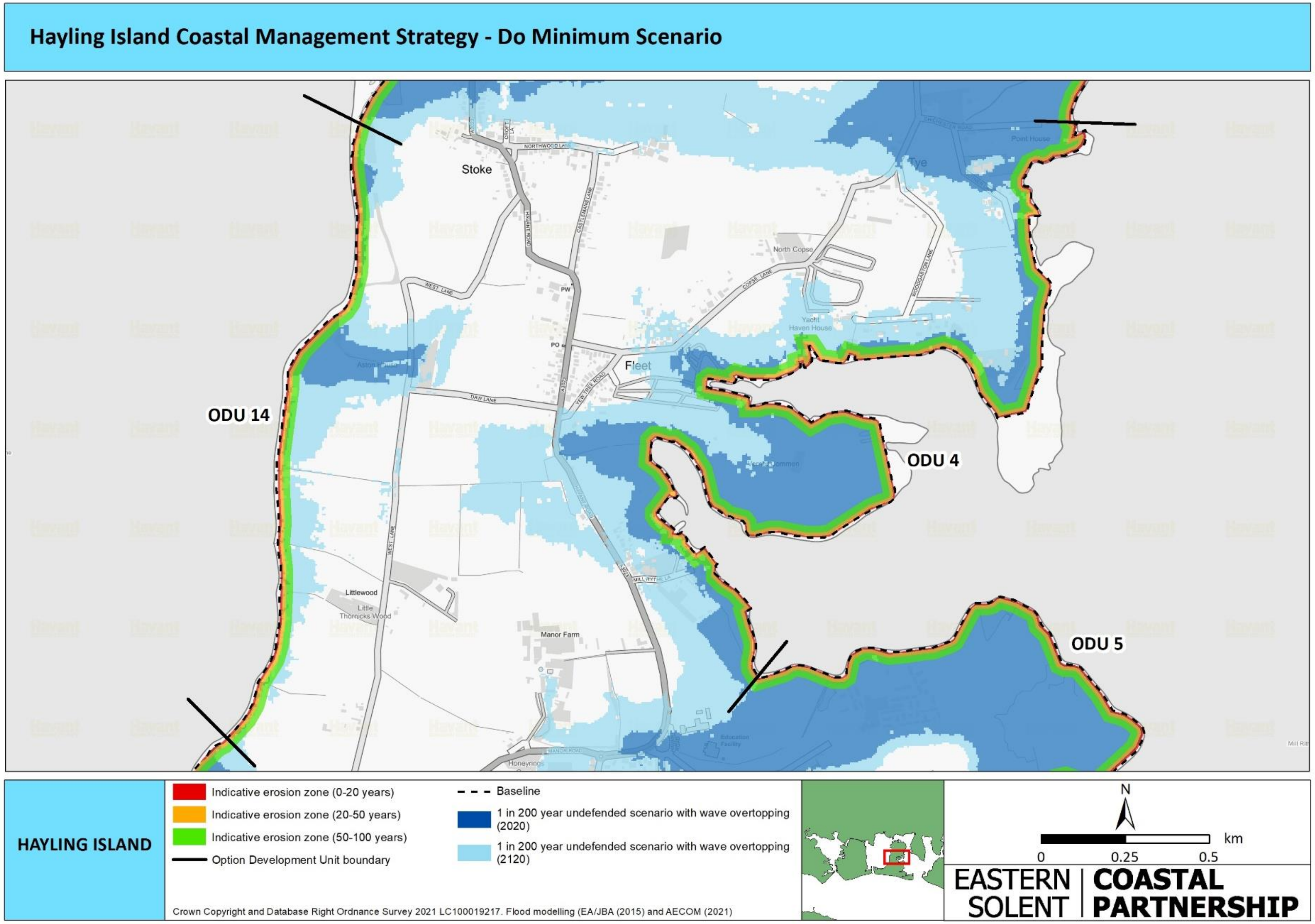

Figure 5.8 Do Minimum scenario for ODUs 4 and 14

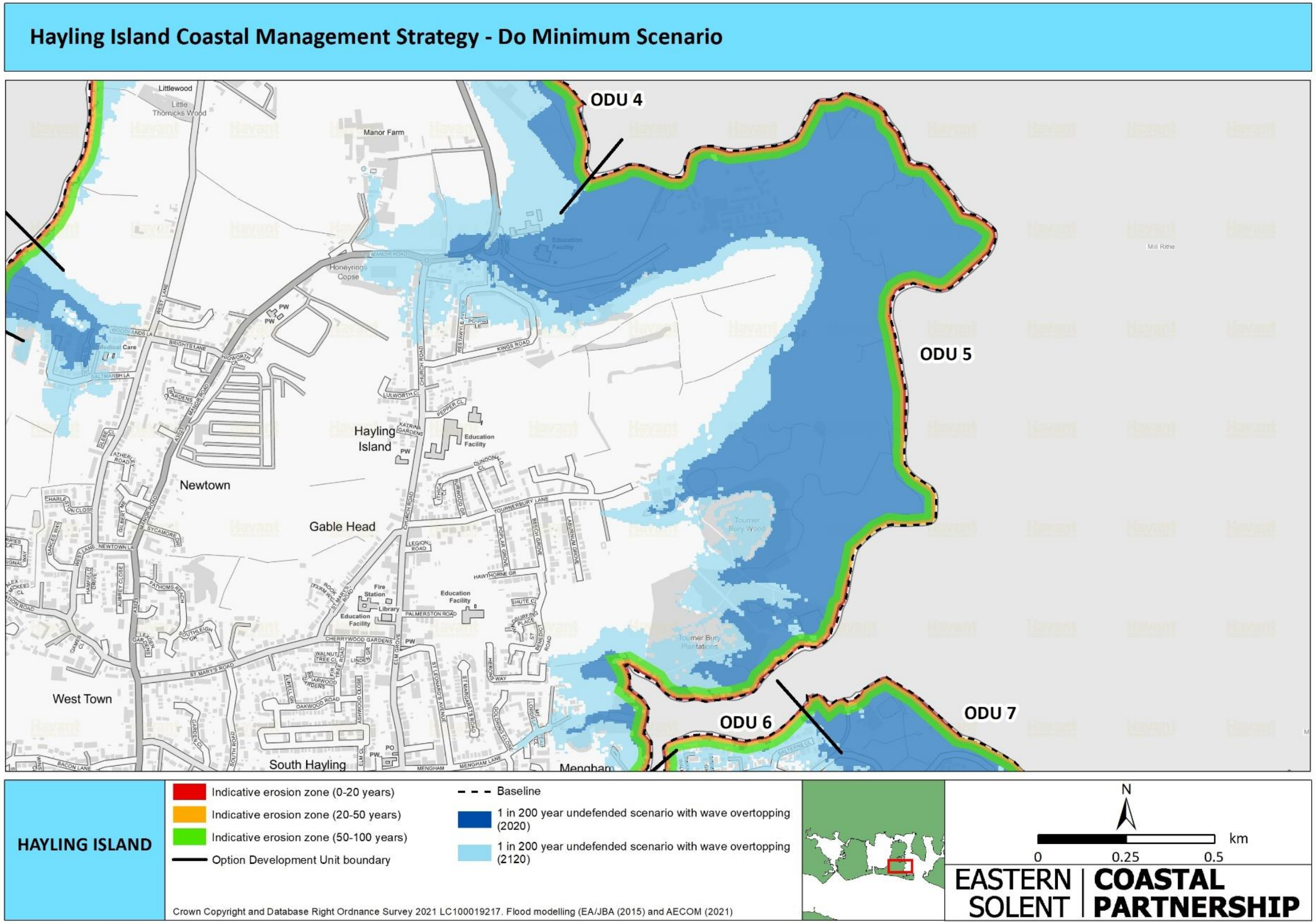

Figure 5.9 Do Minimum scenario for ODU 5

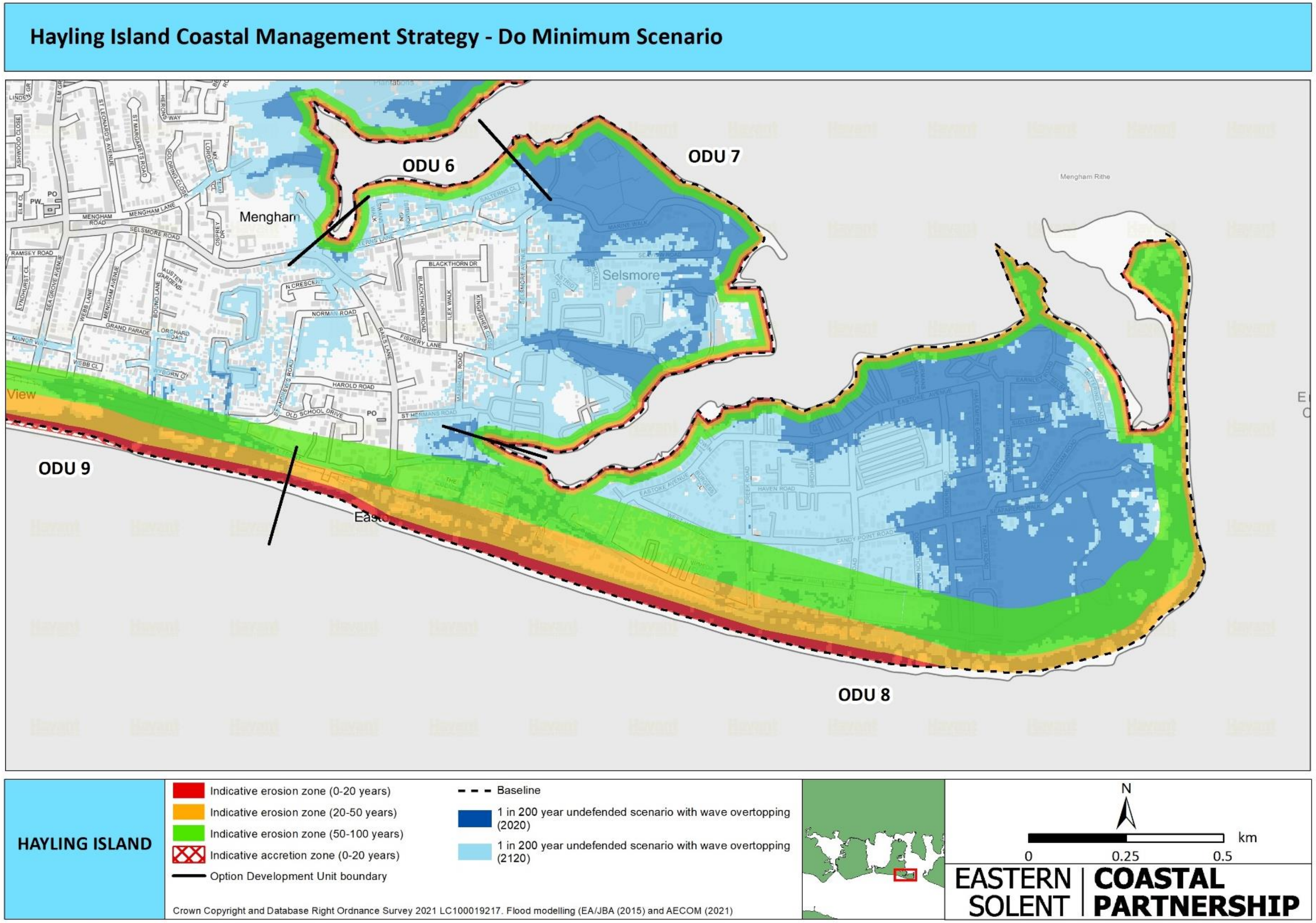

Figure 5.10 Do Minimum scenario for ODUs 6, 7 and 8

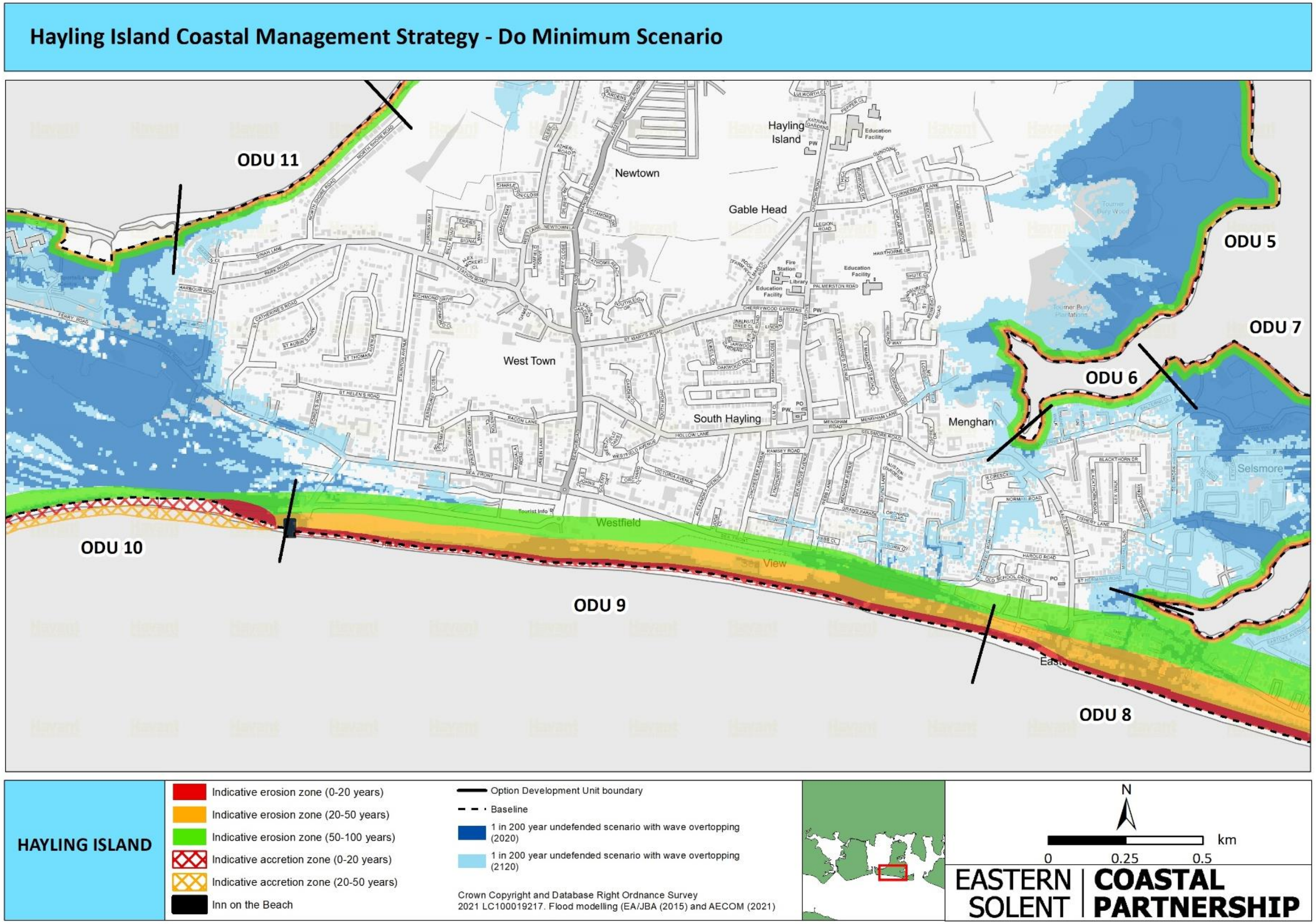

Figure 5.11 Do Minimum scenario for ODU 9

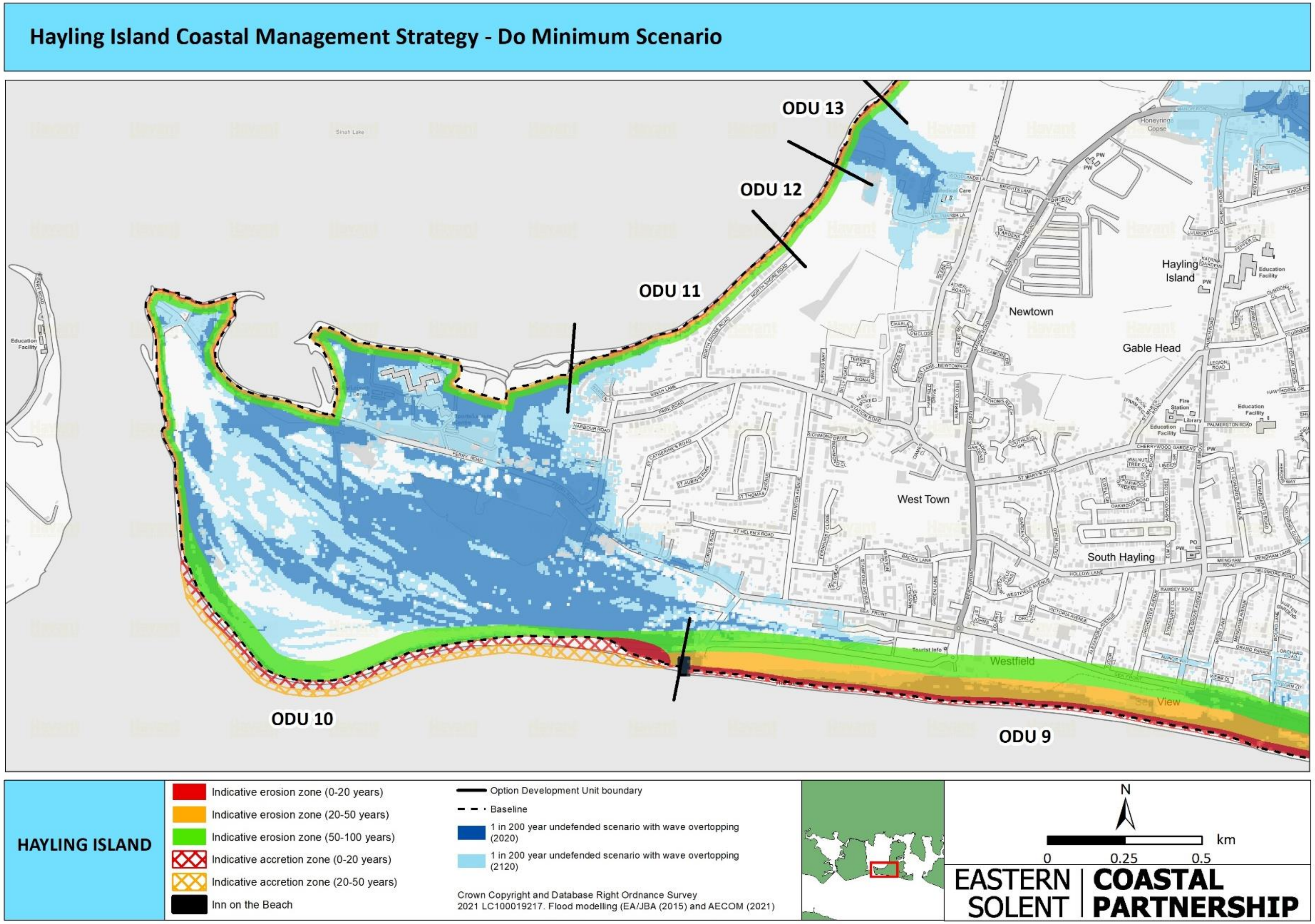

Figure 5.12 Do Minimum scenario for ODUs 10, 11, 12 and 13

6 Summary and Recommendations

Given its position on the open coast and within the harbours, distinct variations in the environment can be seen around the coastline of Hayling Island. The island hosts a number of local, national and international environmental designations, as well as an assortment of defences, some with complex owner/maintainer relationships.

The Hayling coastline that sits within Chichester and Langstone Harbours is comprised of mostly mudflats, with some saltmarsh. Saltmarsh habitat has been eroding in both harbours since the 1940s, although the rate of loss has slowed since the mid-1980s (Section 4.2.3.1). There is also evidence of mudflat lowering on the eastern side of Langstone Harbour (Figure 4.19). In terms of coastal erosion inside the harbours, the evidence presented in this report suggests that the coastline is relatively stable. Due to the narrow harbour entrances, large swell and wind waves are not easily able to propagate along the entrance channels into the harbours. Therefore, the risk of coastal damage, flooding and erosion from wave attack inside the harbour is limited. However, due to the low-lying land, the risk from still water level flooding is still significant, especially given the predicted future sea level rise.

The open beach along the south coast of Hayling Island has a long history of high energy wave action, which results in significant beach drawdown, cutback and loss of material. This in turn leads to hotspots of erosion, overtopping and flooding along the frontage. There is a drift divide at Creek Road car park along the Eastoke frontage, where a third of material tends to move east round to the Ness and Chichester Harbour entrance and the remaining two thirds moves west along the Open Beach and towards the Langstone Harbour entrance. There is a significant volume of accretion at Gunner Point where a large proportion of this material accumulates. The South Hayling Beach Management Plan (BMP) takes material from the accretion spots such as Gunner Point and the Open Beach and places it along the Eastoke frontage to help maintain the beach as the primary flood defence.

Given the wealth of monitoring data available since 2003 for the open coast, this report includes an update to the sediment budget and goes a step further by incorporating the ebb deltas features for the first time, adding to the understanding of the Open Coast dynamics. This has informed the update of erosion zones and will feed into option selection for each Option Development Unit (ODU).

The EA East Solent flood model was updated and used in the Strategy as the best available information at a strategic scale. It has been used determine a broad analysis of risk, conservative estimates of damages and to set the direction for the recommended strategic management options. However, given the impact of long period swell waves and bi-modal waves on the south coast of Hayling Island, **further work is recommended to refine the overtopping and flood modelling during the next stage of the FCERM process.** This additional information will not impact on the strategic options recommended by the strategy however it will be crucial when considering future scheme development and to inform both design requirements and benefit analysis. This work is one of the priority tasks recommend by the strategy action plan and is already being taken forward to inform the development of the south Hayling Beach Management Plan.

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Appendix A: Introduction

This appendix presents supporting information to Section 2 in the main report.

A1 West Beach Monitoring

Figure A1 and A2 show the evolution of West Beach as sections of the timber revetment have been removed over time. In 2013, the first western portion was removed, which can be clearly seen (Figure A1). In July 2020, the next two groyne bays to the east of this original section were removed and monitoring continues to assess how the area is changing (Figure A2). Since the removal in July 2020 the eastern section of the West Beach has started to cutback, while the western end has come forward. There has been minimal change along the central western section between July and September 2020.

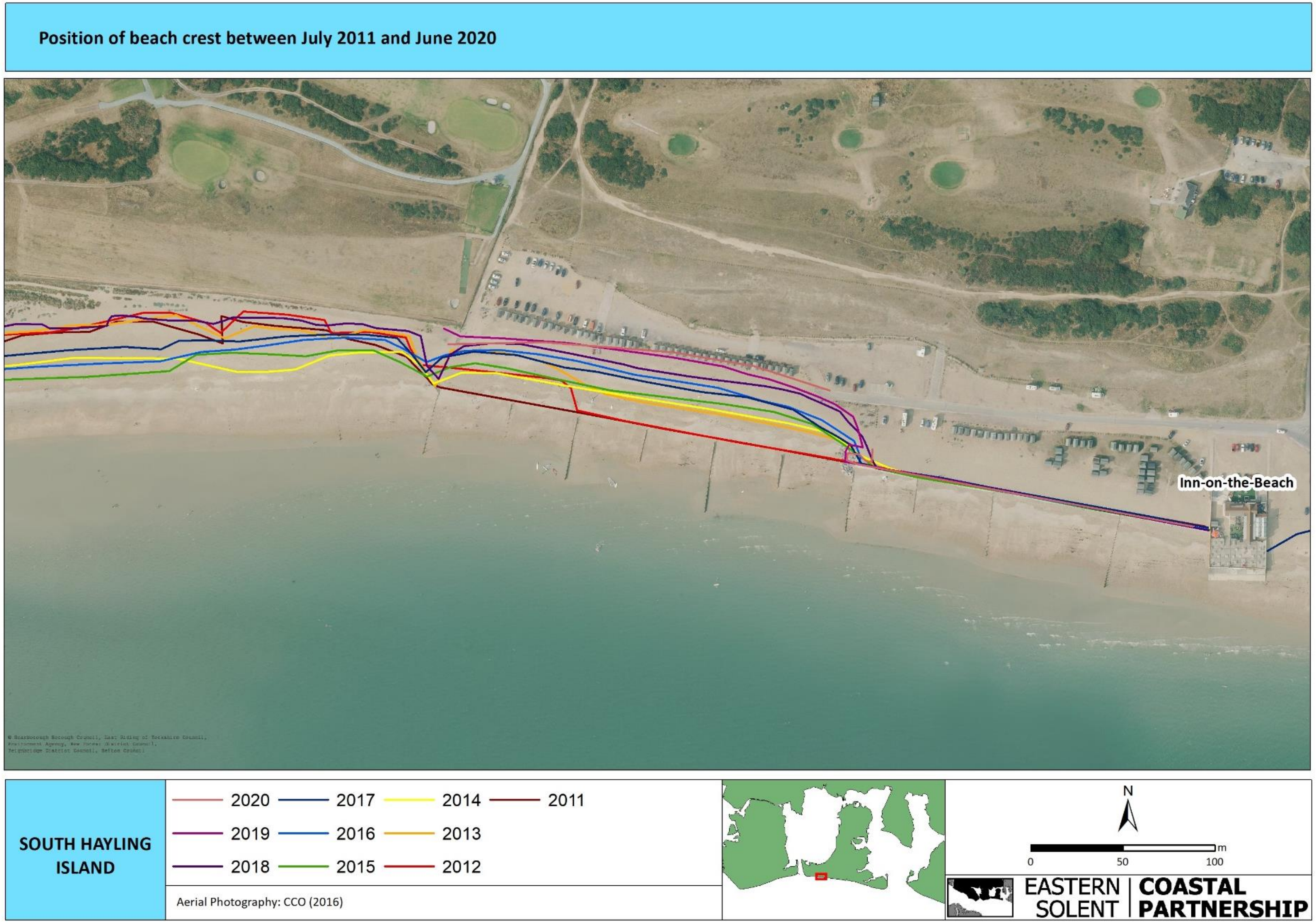

Figure A1 Position of beach crest at West Beach between July 2011 and June 2020

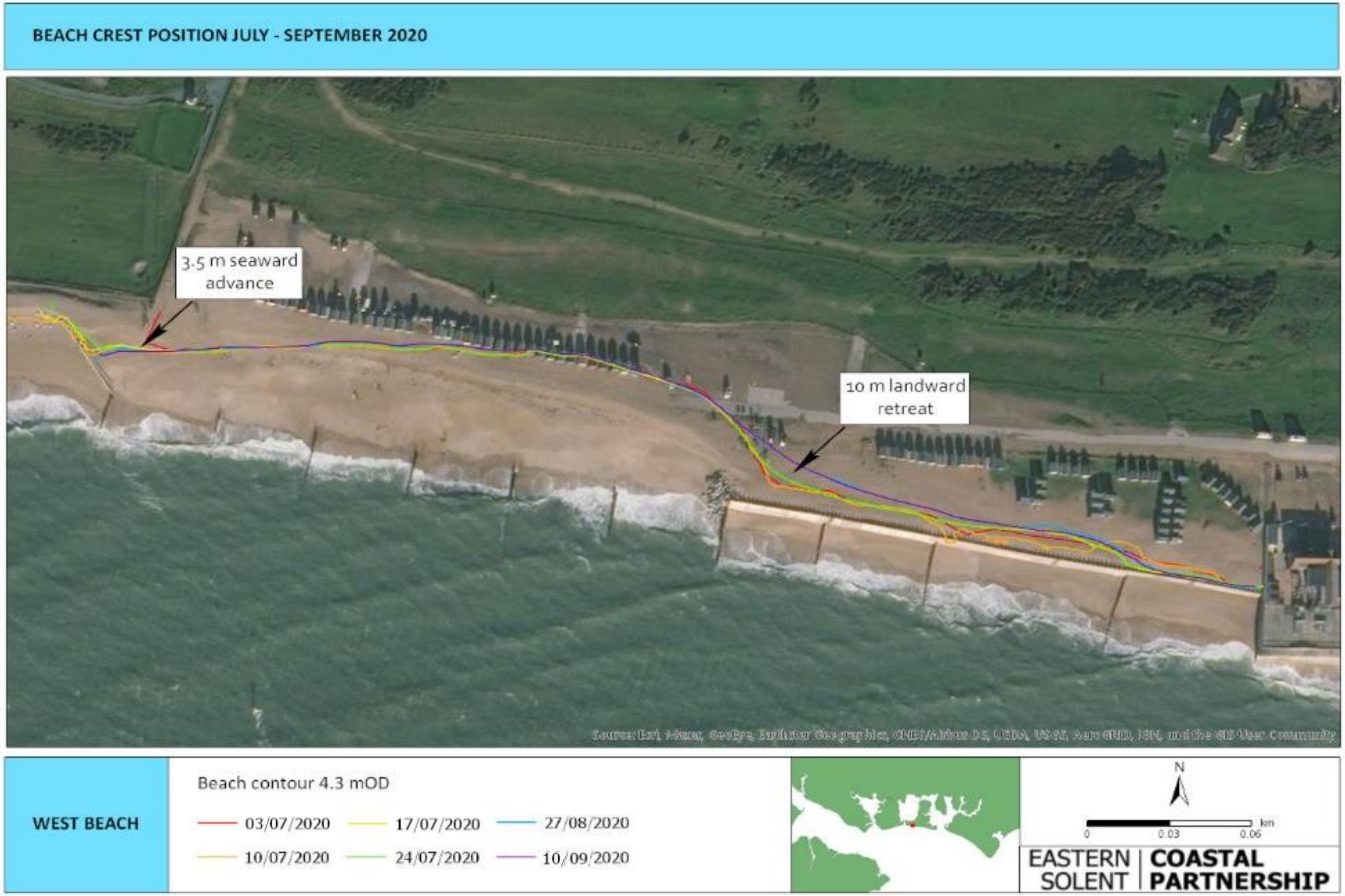

Figure A2 Position of beach crest at West Beach between 3rd July 2020 and 10th September 2020

Appendix B: Hydrodynamics

This appendix presents more information on sea level rise and tidal currents that links to Section 3 in the main report.

B1 Sea Level Rise

The Sea Level Rise (SLR) values for the RCP8.5 70th and 95th percentiles are presented in Table 3.6 Expected values for sea level rise over the next 100 years according to UKCP18 RCP8.5 are added to the present-day tide levels (Portsmouth and Chichester tide gauges) to illustrate what the levels are predicted to be in 20, 50 and 100 years' time (Table and Table). The present-day extreme values are presented in Section 3.2.2.

A comparison of the UKCP09 and UKCP18 information is shown in Figure . The RCP8.5 projections (red lines on Figure) are equivalent to the high emissions scenario in UKCP09 (dark grey line on Figure).

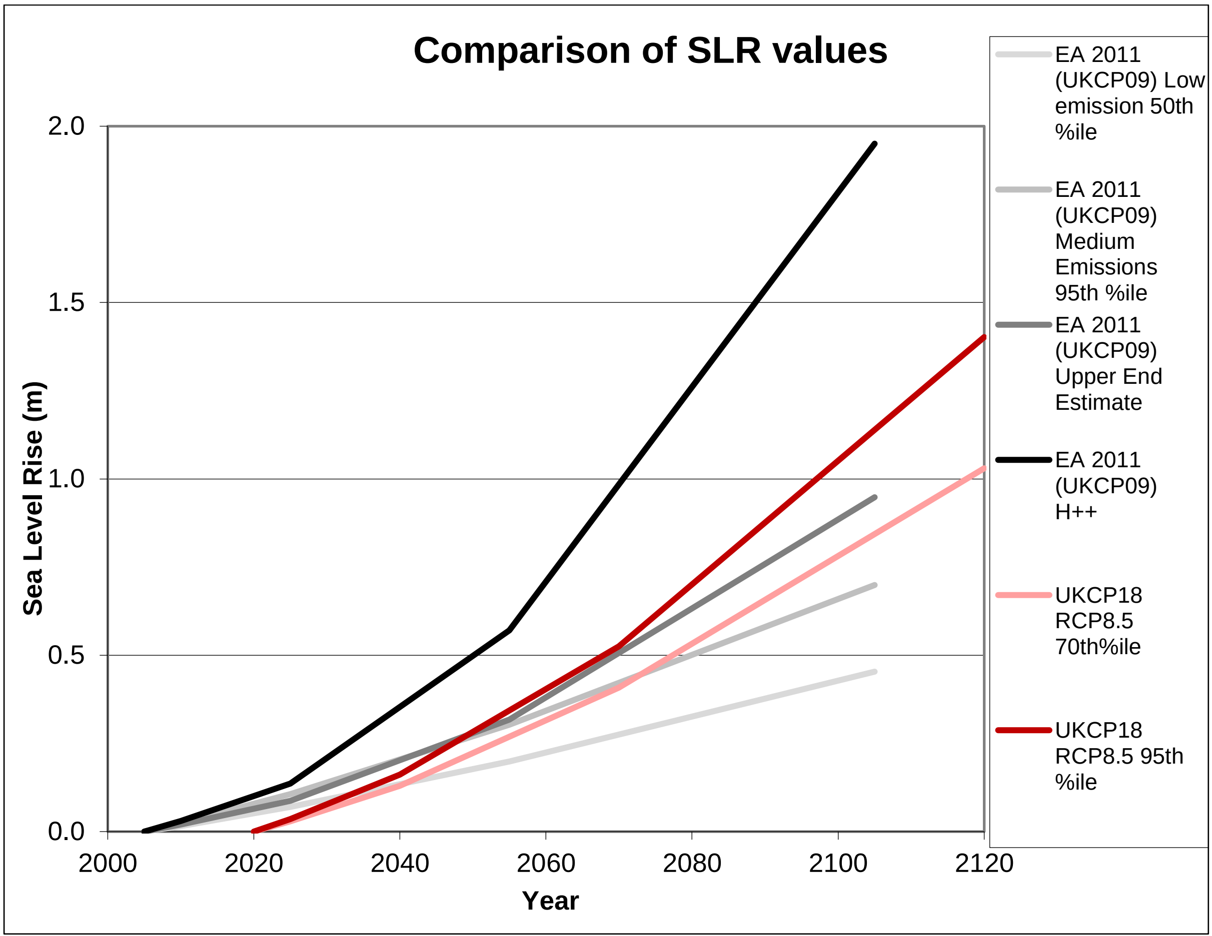

Figure B3 Comparison of SLR Values from UKCP09 and UKCP18

Table B4 The expected increase in tidal values (mOD) at Chichester over the next 100 years according to UKCP18 RCP8.5

Chichester							
		2040		2070		2120	
	2020	70th	95th	70th	95th	70th	95th
LAT	-2.54	-2.41	-2.38	-2.13	-2.01	-1.51	-1.14
MLWS	-1.84	-1.71	-1.68	-1.43	-1.31	-0.81	-0.44
MLW	-1.34	-1.21	-1.18	-0.93	-0.81	-0.31	0.06
MLWN	-0.84	-0.71	-0.68	-0.43	-0.31	0.19	0.56
MSL	0.16	0.29	0.32	0.57	0.69	1.19	1.56
MHWN	1.26	1.39	1.42	1.67	1.79	2.29	2.66
MHW	1.71	1.84	1.87	2.12	2.24	2.74	3.11
MHWS	2.16	2.29	2.32	2.57	2.69	3.19	3.56
HAT	2.56	2.69	2.72	2.97	3.09	3.59	3.96

Table B5 The expected increase in tidal values (mOD) at Portsmouth over the next 100 years according to UKCP18 RCP8.5

Portsmouth							
		2040		2070		2120	
	2020	70th	95th	70th	95th	70th	95th
LAT	-2.63	-2.5	-2.47	-2.22	-2.1	-1.6	-1.23
MLWS	-1.93	-1.8	-1.77	-1.52	-1.4	-0.9	-0.53
MLW	-1.38	-1.25	-1.22	-0.97	-0.85	-0.35	0.02
MLWN	-0.83	-0.7	-0.67	-0.42	-0.3	0.2	0.57
MSL	0.17	0.3	0.33	0.58	0.7	1.2	1.57
MHWN	1.07	1.2	1.23	1.48	1.6	2.1	2.47
MHW	1.52	1.65	1.68	1.93	2.05	2.55	2.92
MHWS	1.97	2.1	2.13	2.38	2.5	3	3.37
HAT	2.37	2.5	2.53	2.78	2.9	3.4	3.77

B2 Tidal Currents

Generally, tidal currents within the harbours, where the bathymetry is shallow, are weaker than the tidal currents found at the harbour entrances which are relatively strong due to deep narrow channels. The information included in the following section on tidal currents relates to the harbour-wide area.

Tidal current and water level data is shown in Figure (image taken from the Langstone Scheme Coastal Processes Report (ESCP, 2019)). The current speed data have been taken from the Admiralty Tide Diamond D (Admiralty Chart no. 3418) and the tidal heights were extracted from POLTIPS – they represent a typical spring and neap tide from April 2018.

The data shows that during Spring tides, it takes approximately 6 hours for the flood tide to peak, slack water lasts approximately 2-2.5 hours and then there is a 3.5-4-hour ebb tide. This short ebb tide corresponds with the faster flows seen between 3-5 hours after high water. Although less pronounced, the effect is the same for the neap tides. The tide flows north-east

(45°) on the flood and south-west (225°) on the ebb. The NSSMP (2010) states that nearshore currents are typically less than 0.5m/s.

Previous modelling work undertaken by HR Wallingford for Chichester harbour in 1994, and later for the Eastoke Point Coastal Defence Study (2009), examined tidal currents within Chichester Harbour and around the south-east coast of the Hayling Island (HR Wallingford, 2009). Tidal flows were simulated using TELEMAC-2D, a depth averaged finite-element tidal flow model. Figure and Figure show the resulting spring and neap tidal current speeds and directions across five locations within Chichester Harbour entrance and nearshore around Eastoke.

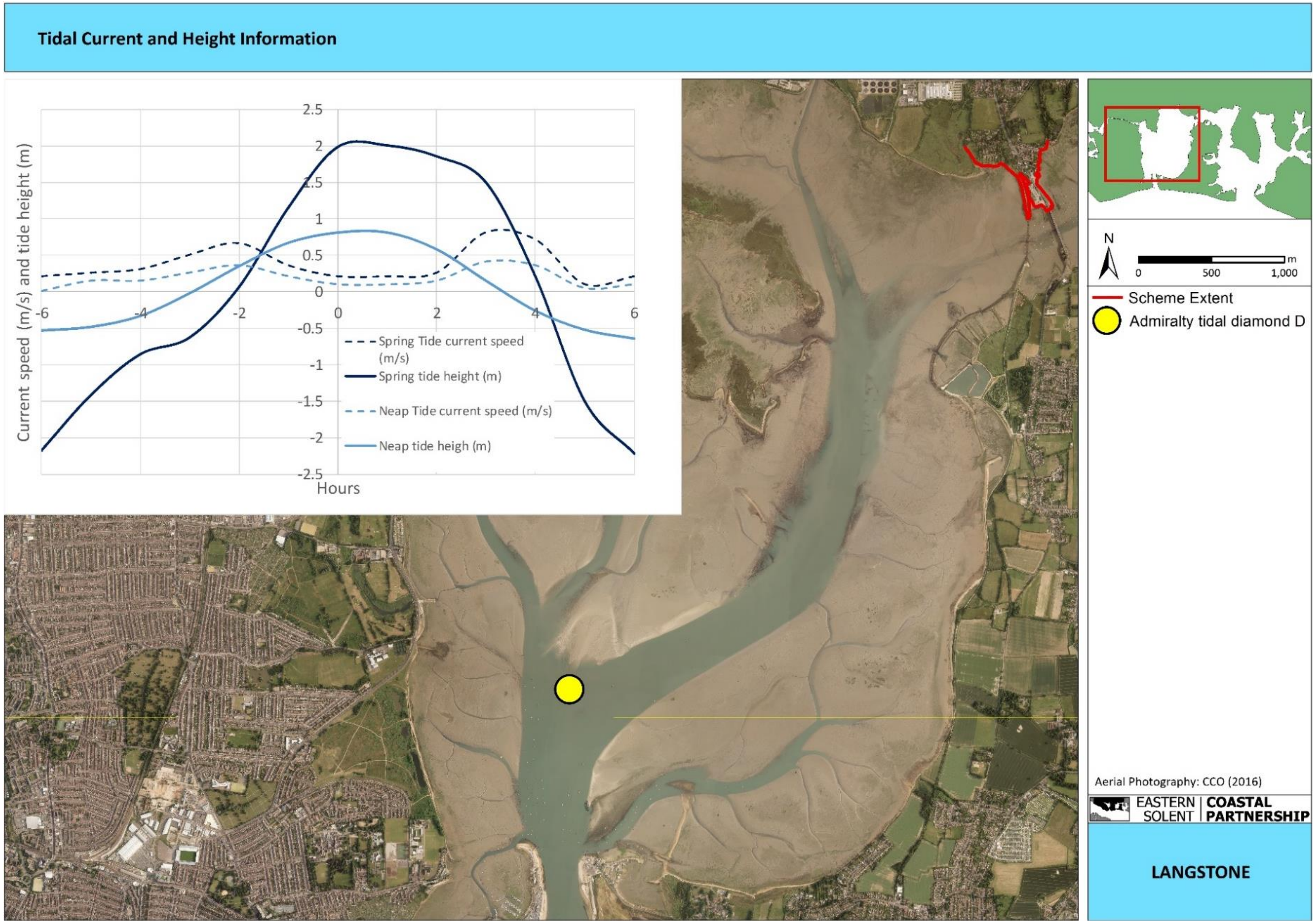

Figure B4 Tidal current data at Tidal Diamond D and water level data for Langstone Harbour, (image lifted from Langstone Scheme Coastal Process Study, ESCP 2019)

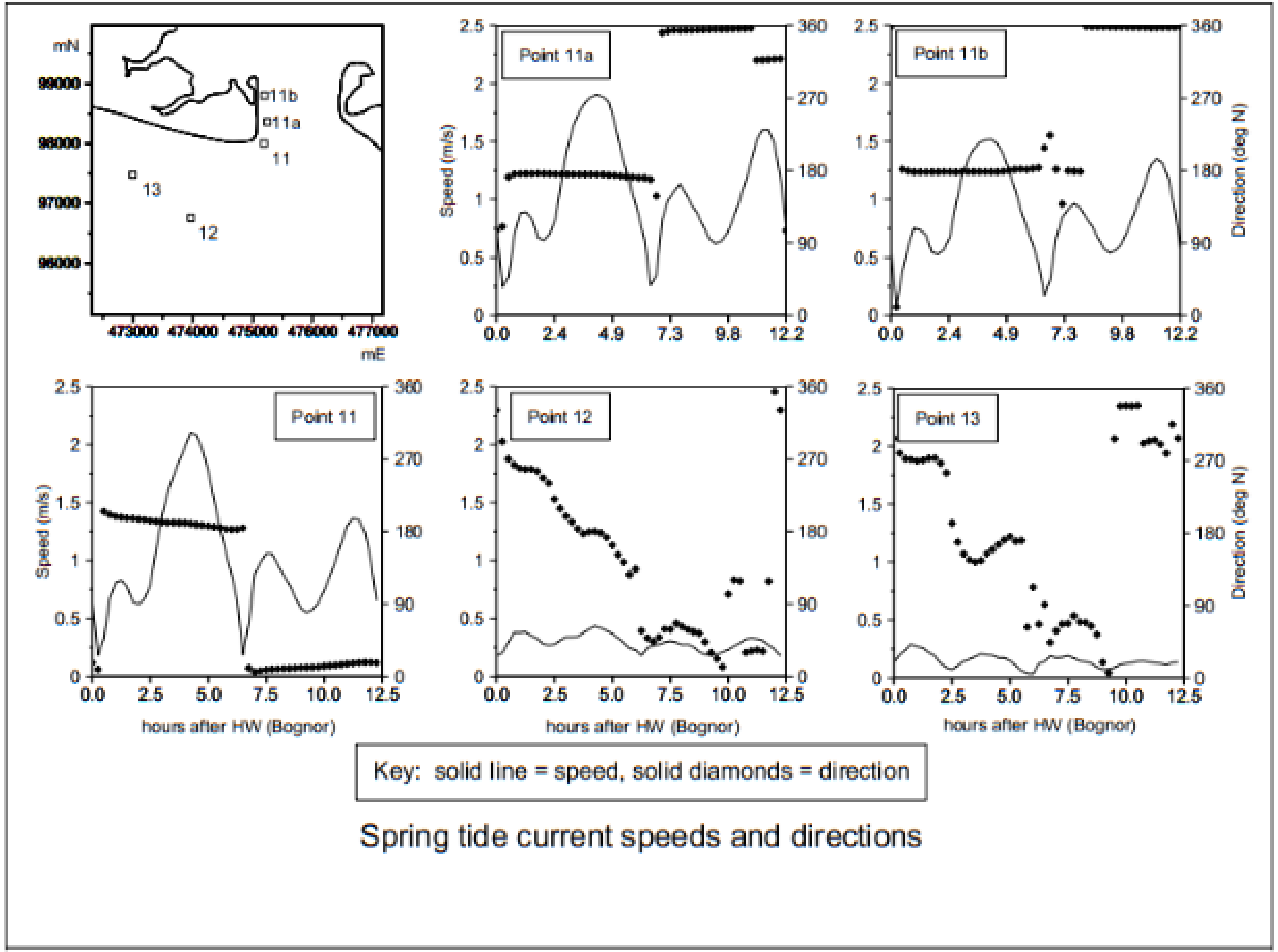

Figure B5 Tidal current information for Eastoke, undertaken by HR Wallingford (2009)

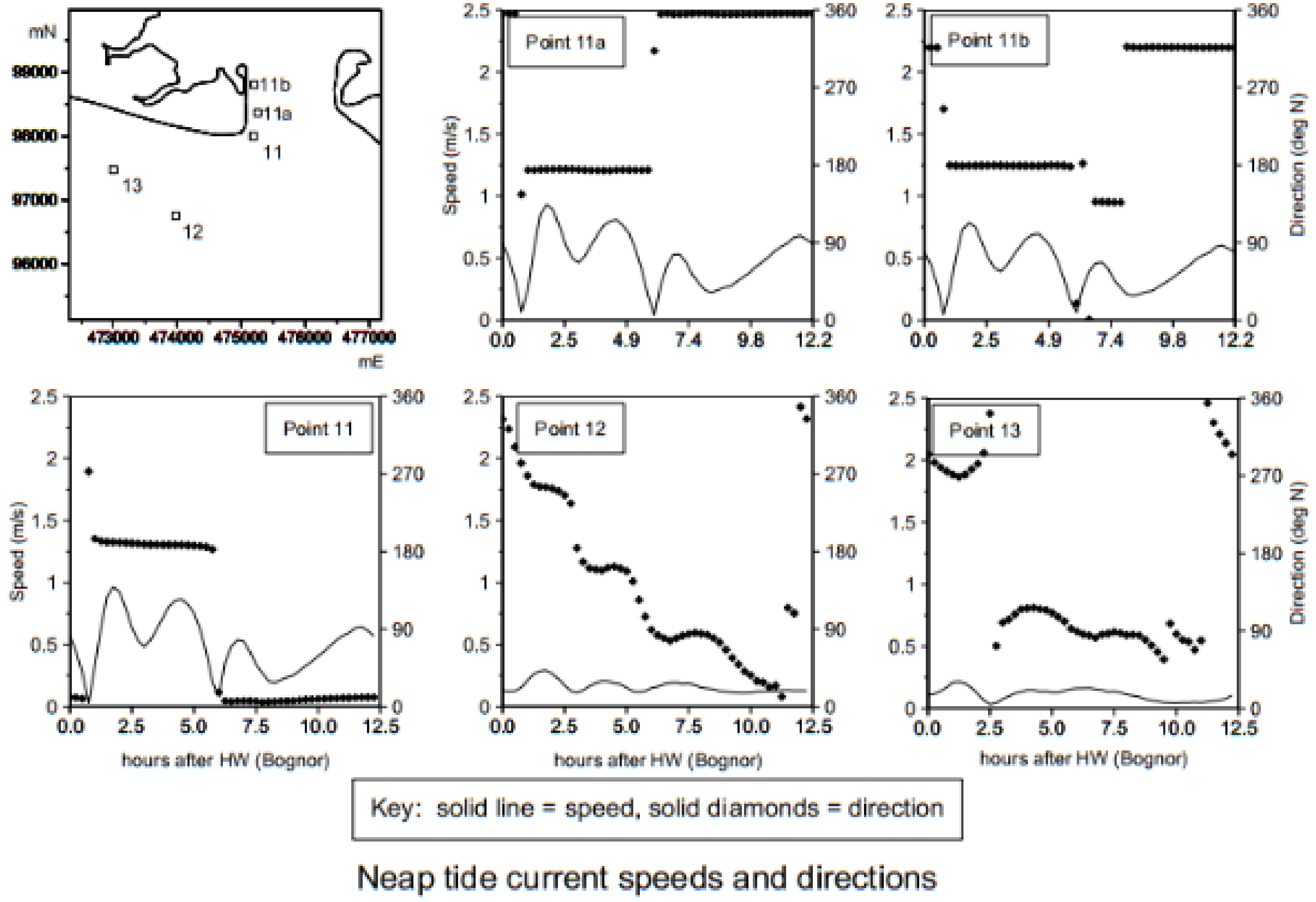

Figure B6 Tidal current information for Eastoke, undertaken by HR Wallingford (2009)

Appendix C: Geology and Sediment Dynamics

This appendix presents the detailed geological and sediment dynamics information for sediment type that links to Section 4. This relates to information for both the harbours and the open coast.

C1 Data, Information and Methods

Several topographic datasets exist for Hayling Island. Table details the datasets used by the ESCP for this report. The most recent datasets used for the analysis carried out in this report are up to date and follow Environment Agency (EA) guidance. Changes in coastal processes have largely been assessed using Light Detection and Ranging (LiDAR), topographic, bathymetric and aerial photography data. The following sections present findings.

Table C1 Datasets and associated metadata used for analysis in this Coastal Process Report

Type	Dataset	Source/licence/copyright	Vertical Accuracy	Horizontal Accuracy
Aerial Photography	1946	© Crown Copyright/Ministry of Defence (MOD), supplied by the National Monuments Record Centre		
	1979	EA		
	1984	1984 © Hampshire County Council (HCC)		
	1986	Property of the EA, freely available for public use under the SRCMP		
	1994	EA		
	2008, 2013, 2016	South-east Regional Coastal Monitoring Programme (SRCMP)		
Topographic	Profile and baseline surveys 2003-present	Collected by ESCP on behalf of Channel Coastal Observatory (CCO)	+/-3cm	+/-3cm
Bathymetric	2007/08 (single beam)	SRCMP	+/-15cm	+/-5cm
	2013 (multi beam)		0.5m (IHO Order 1a standard)	5m +5% depth (IHO Order 1a standard)
	2015, 2018 (single beam)		+/-15cm	+/-5cm
LiDAR	2005	SRCMP	±0.15m	0.4m
	2007		±0.15m	0.4m (1m grid size)
	2013, 2018		±0.05m	0.4m (1m grid size)

C2 Regional Geological Setting

The following text has been extracted from the SCOPAC Sediment Transport Study (2012). Successive sea level transgressions throughout the Quaternary period resulted in the formation of a flat coastal plain which now dominates much of south east Hampshire and West Sussex, its inshore limit marked by the South Downs Chalk escarpment (Bates *et al.*, 2003). The area currently occupied by Hayling Island and its adjacent harbours forms the southern extent of this flat plain and sits at what was, during the most recent period of glaciation (Devensian) the northern flank of the Solent River valley (Allen and Gibbard 1994). Between 15,000 years before present (BP) to 5,000 years BP rising eustatic sea levels which occurred throughout the Holocene resulted in the valley's inundation forming the modern strait known as the Solent (East Solent SMP, 1997). Deposition associated with previous fluvial processes, combined with the loosening of material due to prior successive sea level transgressions left vast quantities of sand and gravel on the bed of the Solent. These deposits, reworked by wave and current action were driven landward throughout the Holocene creating the barrier beaches which now fringe Hayling Island's southern coastline.

The geometry of Hayling Island is largely a result of its location between two lower relief river valleys which previously drained the surrounding coastal plain. Holocene sea level rise resulted in the flooding of these valleys to form Chichester and Langstone harbours which form its modern east and west coastlines, respectively. Whilst the inundation of Chichester Harbour is thought of have been completed by the Bronze Age (Mills, Corcoran, Bates, 2007) the inundation of Langstone Harbour is understood to have occurred comparatively later. The main Langstone and Broom channels are known to have been deeply incised river channels until as recently as 7-8,000 years BP. These were gradually infilled into the mid Holocene forming a wide alluvial valley with the modern shallow tidal basin not being fully inundated until the sixth or seventh century (Mottershead, 1976).

C2.1 Bedrock

Bedrock geology on Hayling island is comprised of various marine deposits of differing ages. The southern and central sections of the Island are underlain by shallow marine deposits which were laid down in the Paleogene (Eocene) and vary in a sequence of horizontal bands which run East to west. Bedrock underlying the southern extremity of the island is dominated by the Wittering Formation of the Bracklesham beds, comprised of sands, silts and clays. This is banded immediately to its north by the Whitecliff Sand Member. The central section of the island is largely underlain by London Clay which is a deeper marine deposit comprised of Clays, Silts and Sands. This is however intersected by a shallower sandy deposit known as the Bognor Sand Member. To the north of this bedrock geology is dominated by estuarine clays silts and sands of the Lambeth group. The northern extremity of the island is underlain by the Portsdown Chalk Formation formed approximately 72 to 94 million years ago in the Cretaceous Period in an environment previously dominated by warm seas.

C2.2 Drift Geology

Surficial (drift) geology over much of the island is dominated by River Terrace Deposits (undifferentiated) - Sand, Silt and Clay. Superficial Deposits formed up to 3 million years ago in the Quaternary Period. Key areas which vary from this are at Gunner point where aeolian deposits of quaternary sands dominate, and Mill Rythe and the Tournerbury estate which is primarily composed of raised marine deposits of sand and gravel.

C3 Sediment Type

C3.1 Sediment Sampling

Results from the 2017 study that was carried out under the South Haying Island Beach Management Plan (BMP) 2017-22 indicate that at Gunner Point, located in the southwest of Hayling Island (Profile line 5a00385), the lower foreshore was characterised by a substantially higher proportion of sand (9 8% at Mean Low Water (MLW) and 87 % at Mean Sea Level (MSL)), while samples taken at Mean High Water (MHW) and the beach crest showed much higher gravel proportions (83 % and 94 % respectively) (Figure C1). In comparison, the cross-shore distribution of sand and gravel at Sandy Point, located in the Southeast of the Island (Profile line 5a00243) was a notably more even mix of sand and gravel.

Towards Creek Road car park in the southern central section of the open beach (Profile line 5a00304), an area which undergoes deposition during beach management activities, there was a significantly higher percentage of sand at MHW (76 %). Each of the samples analysed were found to contain less than 0.04 % mud.

Within Langstone and Chichester Harbours, extensive mudflats are present comprising of clay, silt and very fine sand particles. Following the decline and erosion of saltmarsh plants which used to cover a higher proportion of the harbours, approximately 24 to 28 % of the harbour is covered by uncolonized mudflat (ABP, 1995).

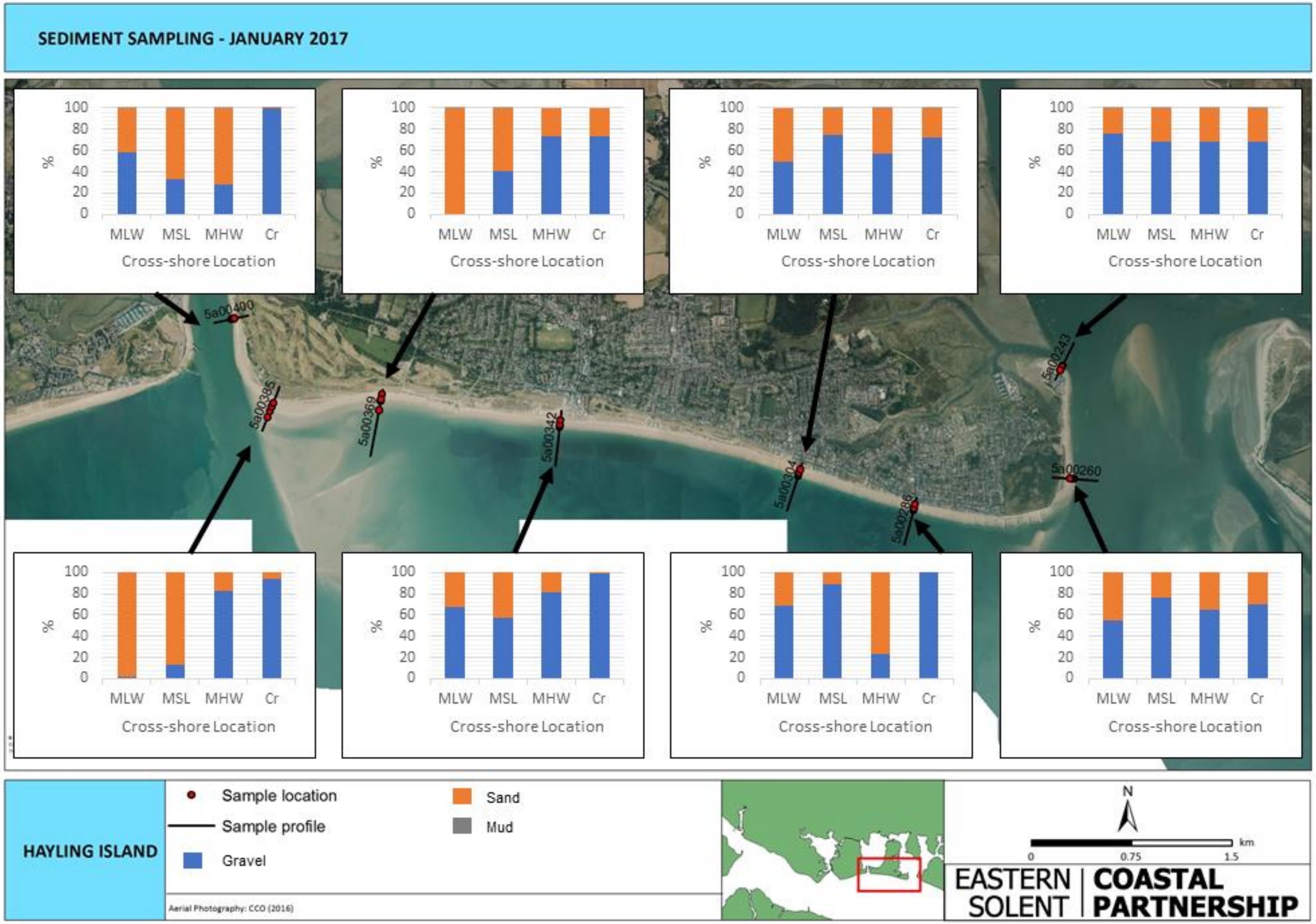

Figure C1 Results of sediment sampling carried out in 2017 under the BMP