



Hornsea Three Sandbank Implementation Plan

Appendix Three:
Indicative Disposal Location Study,
Sandwave Levelling and Seabed Preparation

Document Control

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Acronyms

Acronym	Definition
BEIS	Department for Business, Energy & Industrial Strategy
CSIP	Cable Specification and Installation Plan
DCO	Development Consent Order
MMO	Marine Management Organisation
NNSSR	North Norfolk Sandbanks and Saturn Reef
SAC	Special Area of Conservation
SBIP	Sandbank Implementation Plan
WNNC	The Wash and North Norfolk Coast

1 Introduction

1.1 Project background

1. A Development Consent Order (DCO) was awarded to Hornsea Three on 31st December 2020.
2. Part 2 of Schedule 14 of the Hornsea Three DCO (the DCO) outlines the required benthic compensation measures which must accord with the Sandbanks Compensation Strategy¹ and be drafted into separate Sandbank Implementation Plans (SBIPs) for the Wash and North Norfolk Coast (WNNC) Special Area of Conservation (SAC) and North Norfolk Sandbanks and Saturn Reef (NNSSR) SAC and submitted to the Secretary of State for approval.
3. The SBIPs should include those requirements listed in Schedule 14 Part 2 requirement 13 which includes:
(b) details of the locations for the disposal of dredged material, and evidence that the disposal mechanism will allow sediment to be retained within the sandbank system and avoid impacts to other features, particularly reef habitats

1.2 Purpose of this document

4. This document presents a summary of further information required to discharge Schedule 14 Part 2 requirement 13 (b). This document represents the formal submission which is being submitted to the Secretary of State for approval, as Appendix Three of the NNSSR and WNNC SBIPs.
5. This document provides the indicative information on the potential sediment disposal locations which Hornsea Three has identified at this stage of project refinement, sufficient to discharge requirement 13 (b). The Hornsea Three Cable Specification and Installation Plan (CSIP) will draw on this document, in addition to pre-construction survey data which will be collected, in order to identify final disposal locations in consultation with the MMO and Natural England.

1.2.1 Questions posed by Natural England

6. Hornsea Three note that further detail was provided to Hornsea Three by Natural England in relation to the information that Natural England would appreciate being provided within the SBIPs² in relation to this document. The additional information requested is:
 - *'Information on potential sediment disposal locations. If the exact locations cannot be provided at this stage, Natural England requested evidence (e.g., modelling) to demonstrate that there are options within the red line boundary that would allow the sediment to be retained in the system without affecting areas of reef;*
 - *Evidence that the sediment disposed of will be retained within the system (for instance, through a commitment to dispose upstream so that sediment is not lost);*
 - *Proposed mechanisms for sediment disposal which will best achieve how sediment will be retained within the SAC; and*
 - *Confirmation that the sediment disposal sites will be of the same sediment grain size range as the sediment being deposited to ensure that there will be no change in sediment within the SACs'.*
7. This appendix provides this additional information requested by Natural England, alongside the information requested by the Secretary of State pursuant to requirement 13 (b) of Schedule 14 Part 2 of the DCO.

1.3 Scope

8. The scope of this appendix to the SBIPs presents indicative sediment disposal locations across the Hornsea Three offshore Order Limits, including the array site and export cable corridor. Hornsea Three notes that appropriate sediment disposal is of particular importance in terms of ensuring the sediment is retained within the specific systems which sustain sediment transport in the WNNC and NNSSR SACs.
9. This technical study has been completed using expert-based interpretation and conceptual analysis of existing bathymetry and seabed sediment data collected in the Hornsea Three offshore Order Limits in

¹ EN010080-003190-HOW03_CON02_Appendix2A_SandbanksCompensationStrategy.pdf (planninginspectorate.gov.uk)

² Submitted to Hornsea Three via email on 24/06/2021

2016 and 2018. Numerical modelling has not been undertaken because the existing empirical evidence base and the use of conceptual analysis including an understanding of bedforms and their functionality is sufficiently robust to identify indicative disposal areas.

10. This appendix provides detailed information in relation to:
 - Potential areas where sandwaves may need to be levelled;
 - Indicative disposal areas and their rationale including;
 - Retention of sediment in the system (particularly in relation to WNNC SAC and NNSSR SAC) and bedform recovery;
 - Avoidance of *Sabellaria spinulosa* reef; and
 - Similarity of source and receiver sediment particle size;
 - Approaches to sediment disposal; and
 - Conclusion and Hornsea Three commitments.

2 Potential areas where sandwaves may need to be levelled

2.1 Bedforms across the export cable corridor

11. The 2016 and 2018 multibeam bathymetry survey of the export cable corridor has been used to delineate seabed dominated by sandwaves (**Figure 1** to **Figure 9**). **Table 1** describes the characteristics of the sandwave fields in the export cable corridor and **Figure 10** illustrates sections across selected sandwaves.
12. The bathymetry data describes a variety of sandwave geometries. The sandwaves are up to 6m high with crest orientations ranging from north-south through to east-northeast to west-southwest. Although there is some local variation, the steep slopes of the sandwaves face towards the west to north-northwest sector and are migrating in that direction. This migration direction is supported by comparison of the 2016 and 2018 bathymetry data, where individual crests appear to have either shifted towards the west to north-northwest sector or have remained stationary. This means that in most cases, the up-current locations are to the east to south-southeast of each sandwave.

2.2 Bedforms across the array site

13. The 2018 data described sandwave fields in the western and south eastern parts of the array site (**Figure 1** to **Figure 9**). **Table 2** describes the characteristics of two of the fields in the array site and **Figure 10** illustrates a section across the southeast field. Here, the sandwaves are up to 2.5m high and migrating to the southeast.

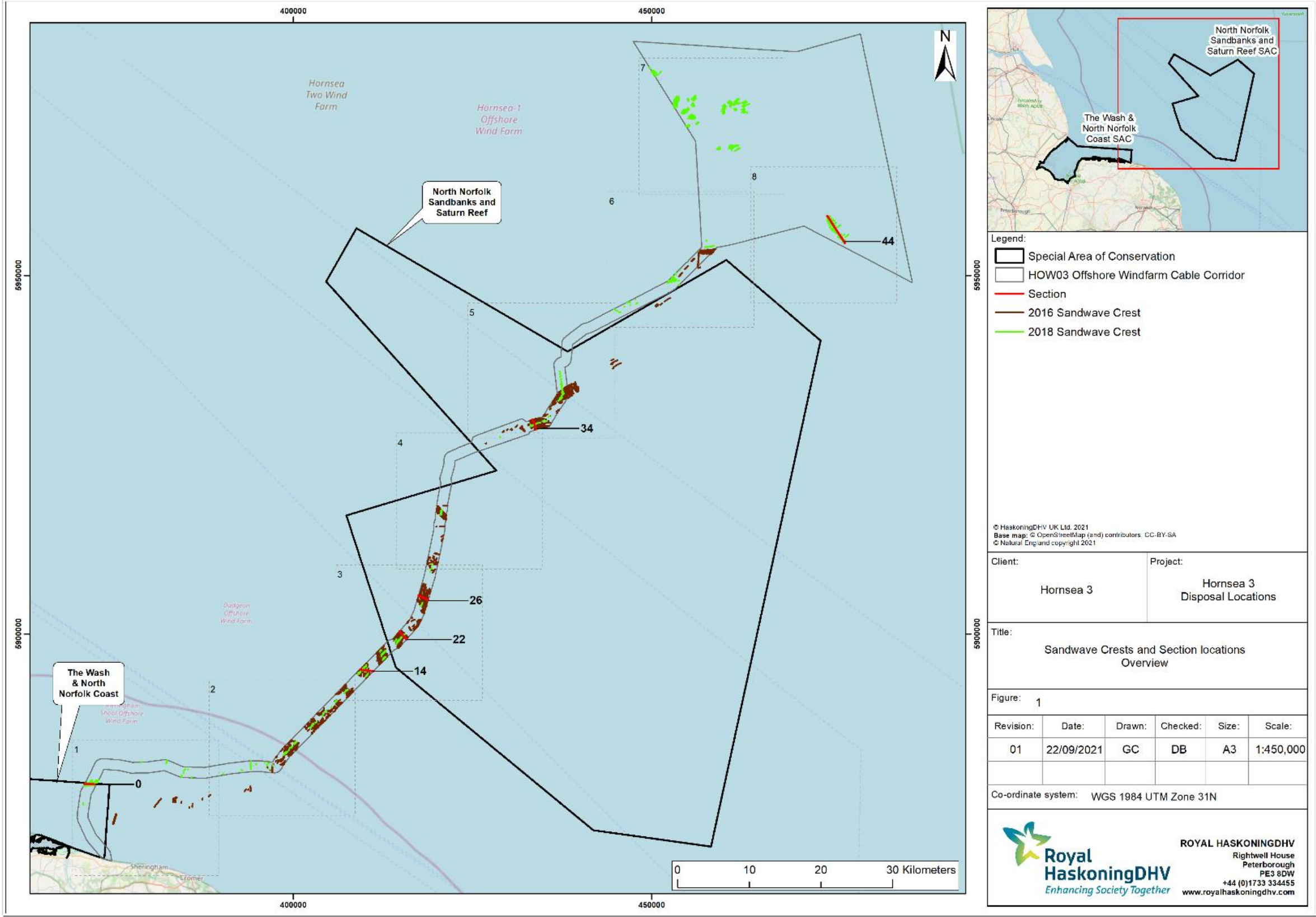


Figure 1: Overview of locations of the crests of sandwaves and sections across selected bedforms³.

³ Red numbers and letters are the sandwave fields referred to in Table 1 and Table 2. Black numbers are the sections shown in Figure 5 and referred to in Table 1 and Table 2. Details of their geometries are provided in Table 1

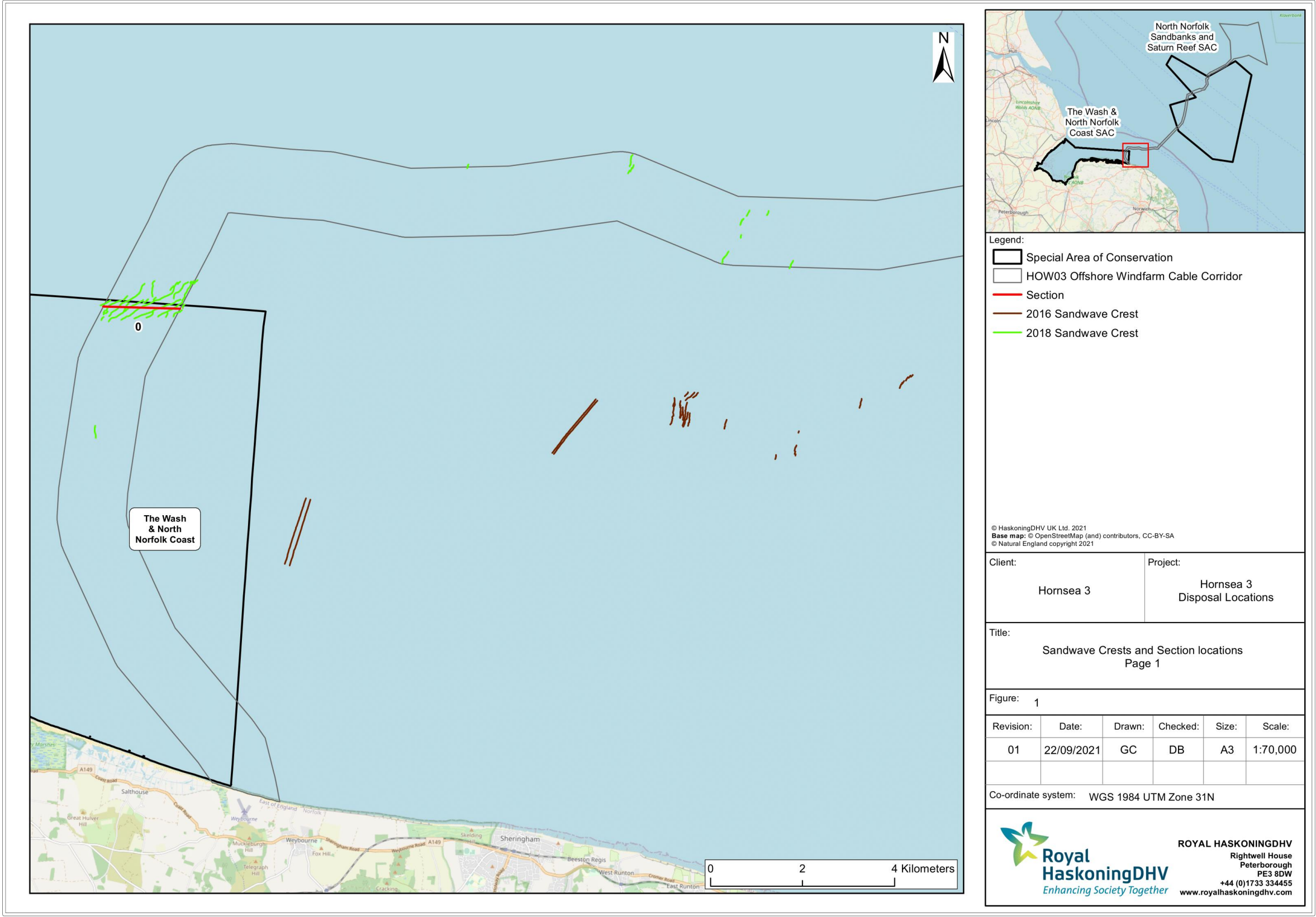


Figure 2: Location of the crests of sandwaves and sections across selected bedforms – Page 1.

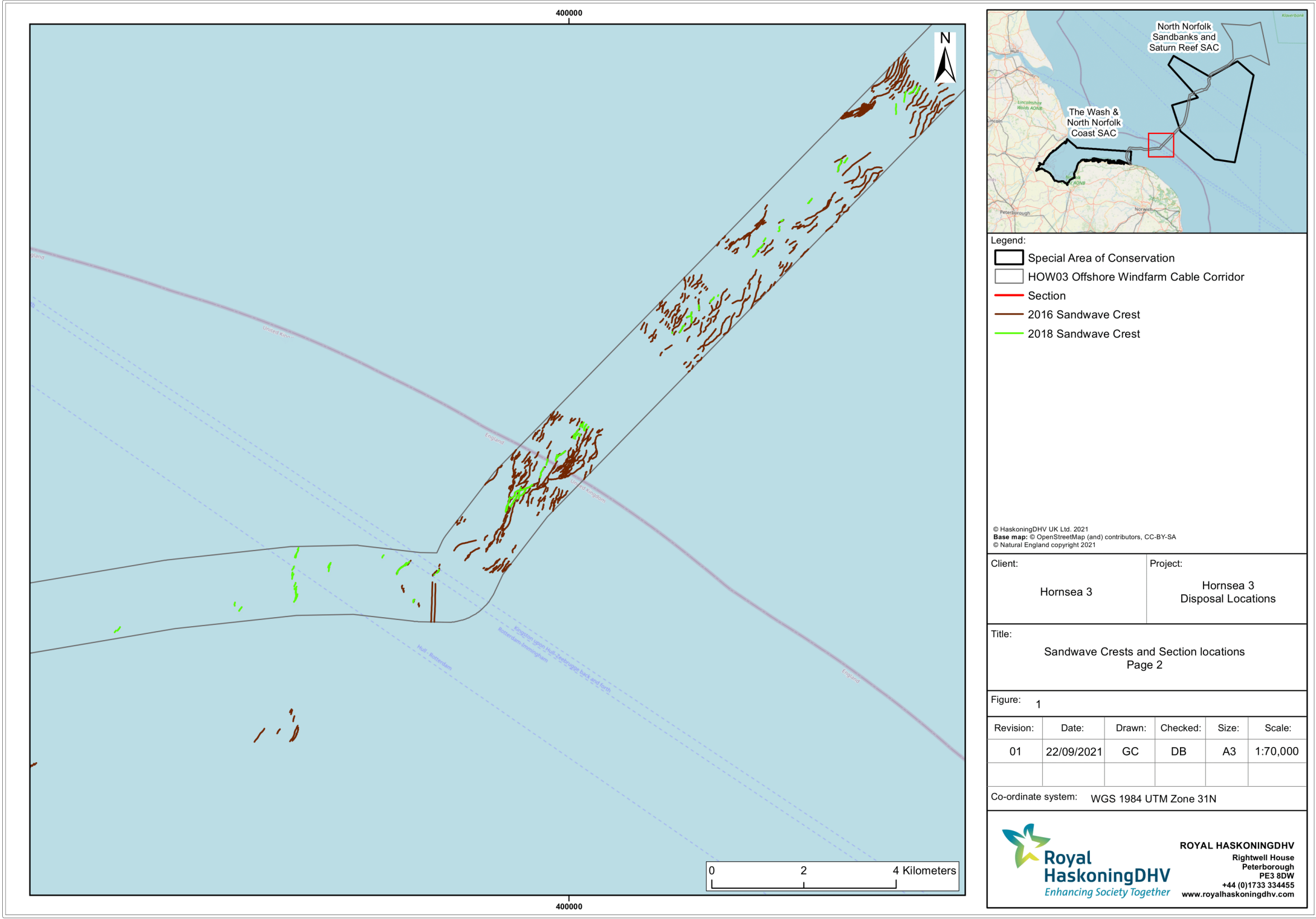


Figure 3: Location of the crests of sandwaves and sections across selected bedforms – Page 2.

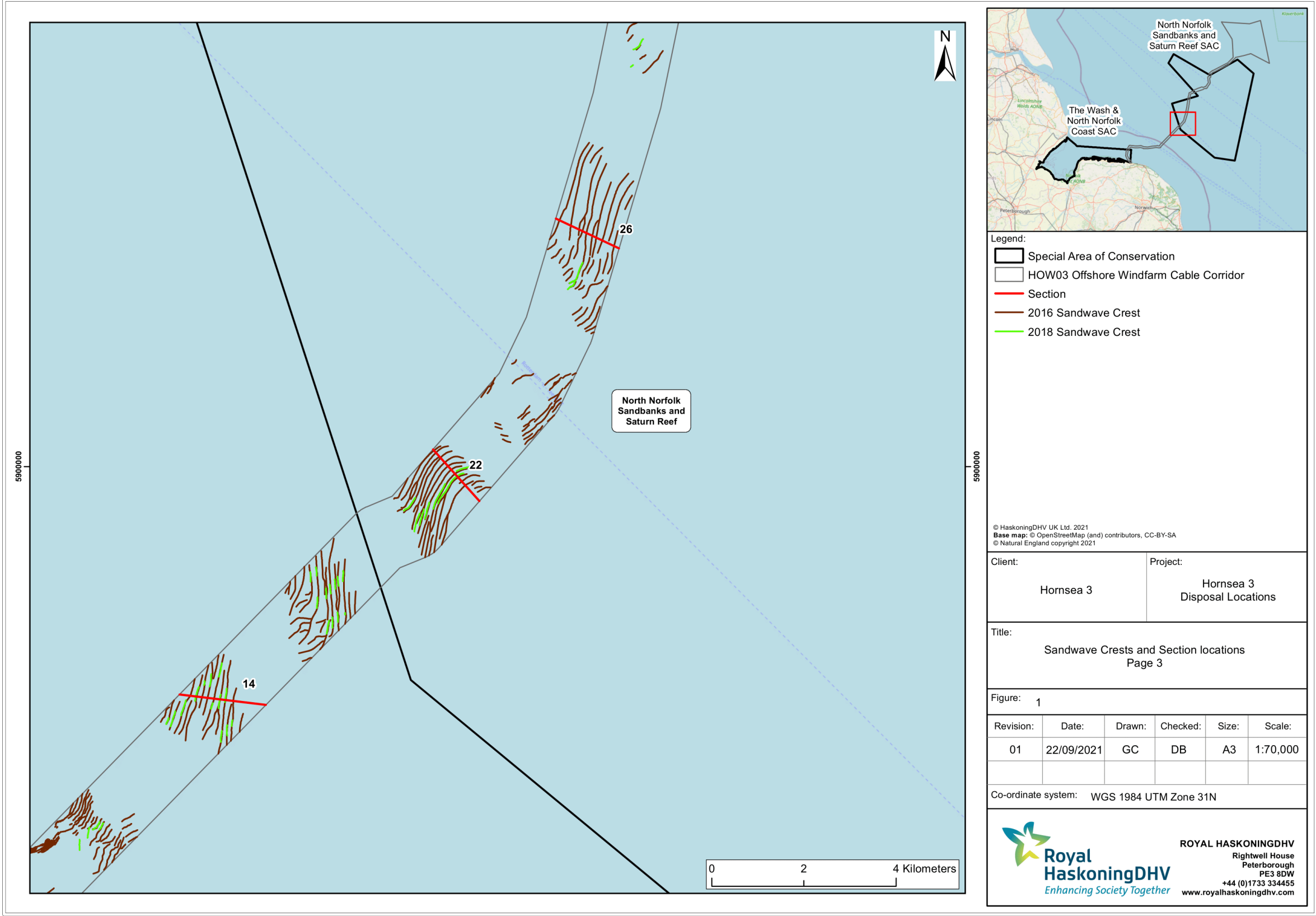


Figure 4: Location of the crests of sandwaves and sections across selected bedforms – Page 3.

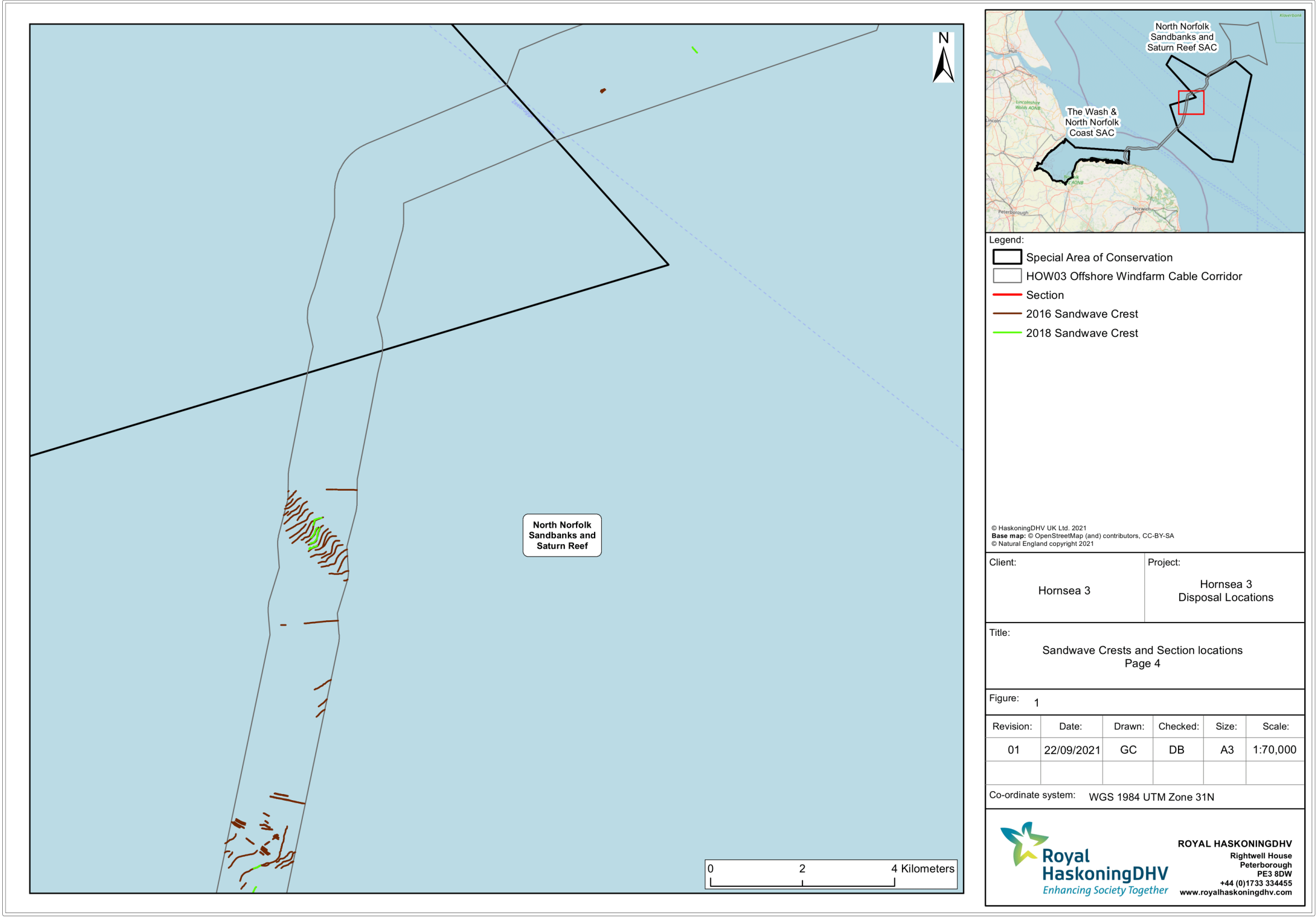


Figure 5: Location of the crests of sandwaves and sections across selected bedforms – Page 4.

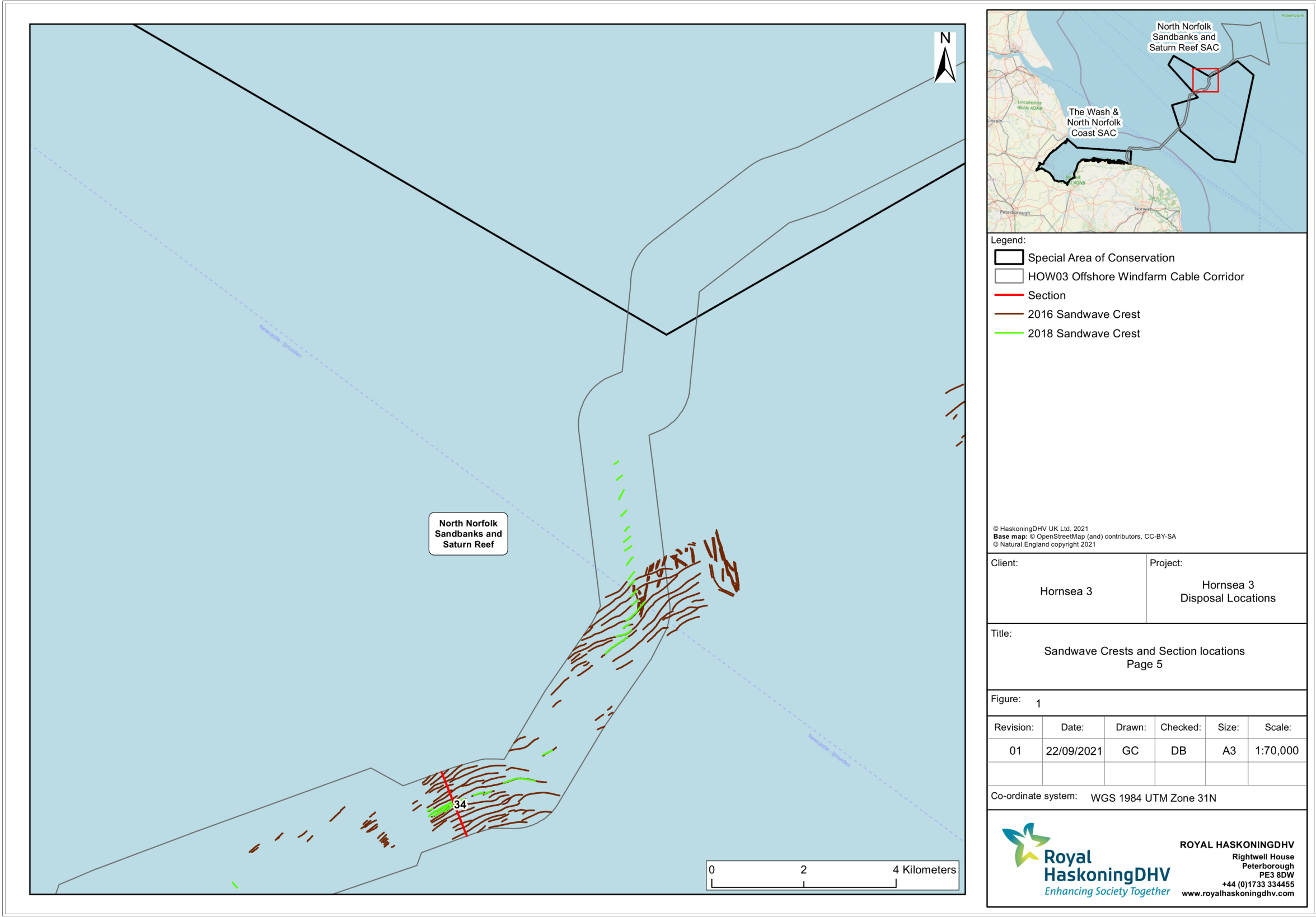


Figure 6: Location of the crests of sandwaves and sections across selected bedforms – Page 5.

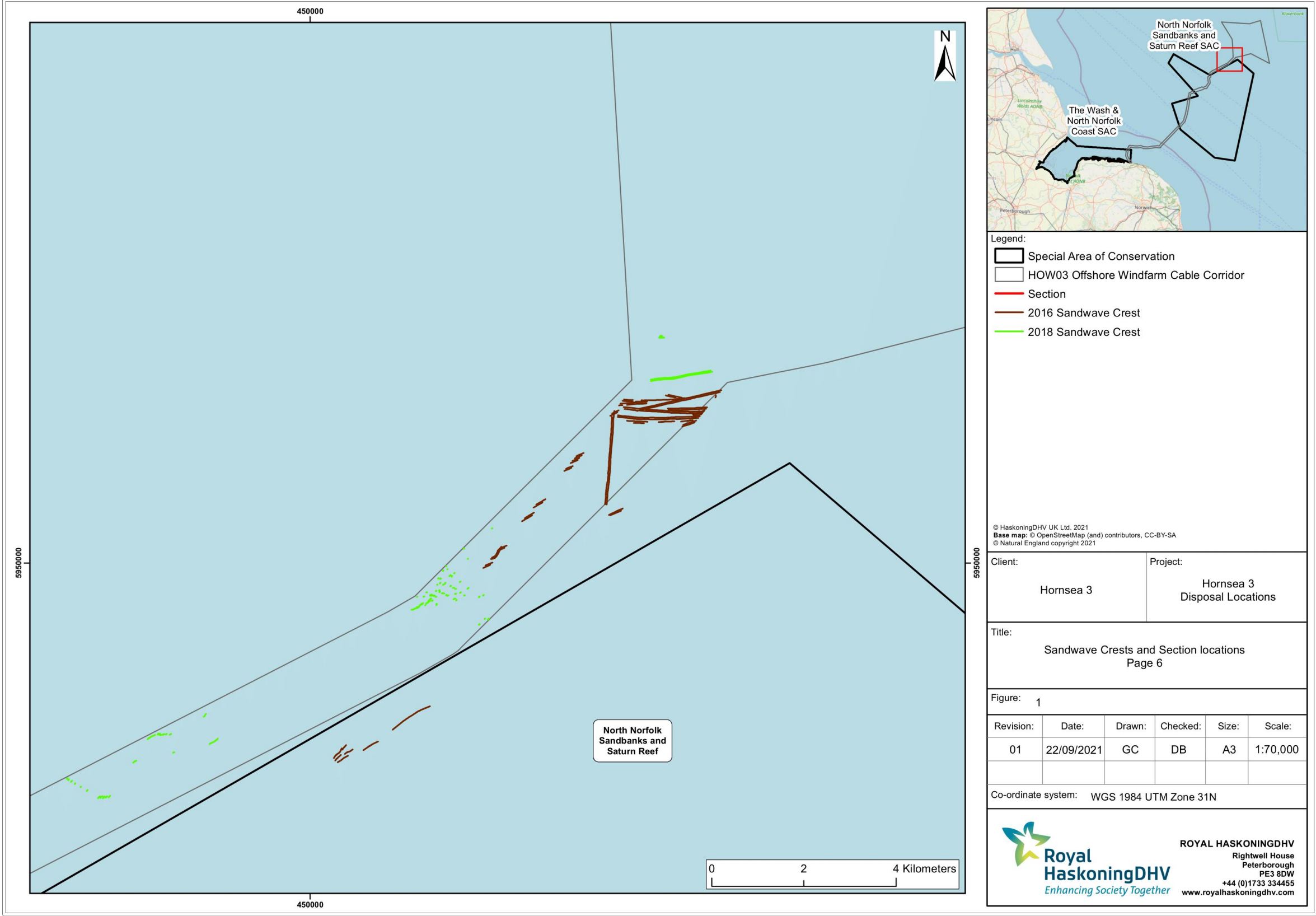


Figure 7: Location of the crests of sandwaves and sections across selected bedforms -Page 6.

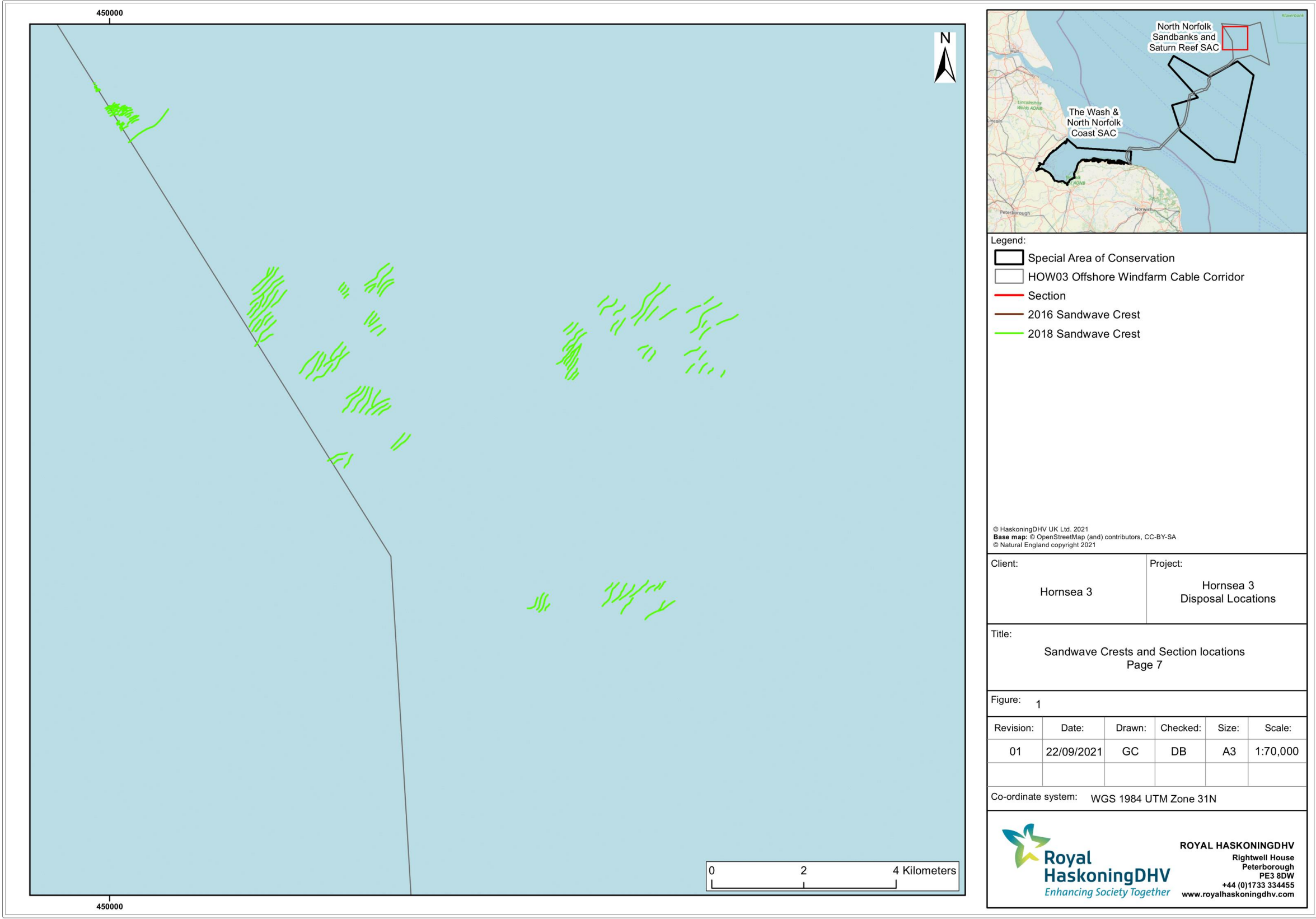


Figure 8: Location of the crests of sandwaves and sections across selected bedforms – Page 7.

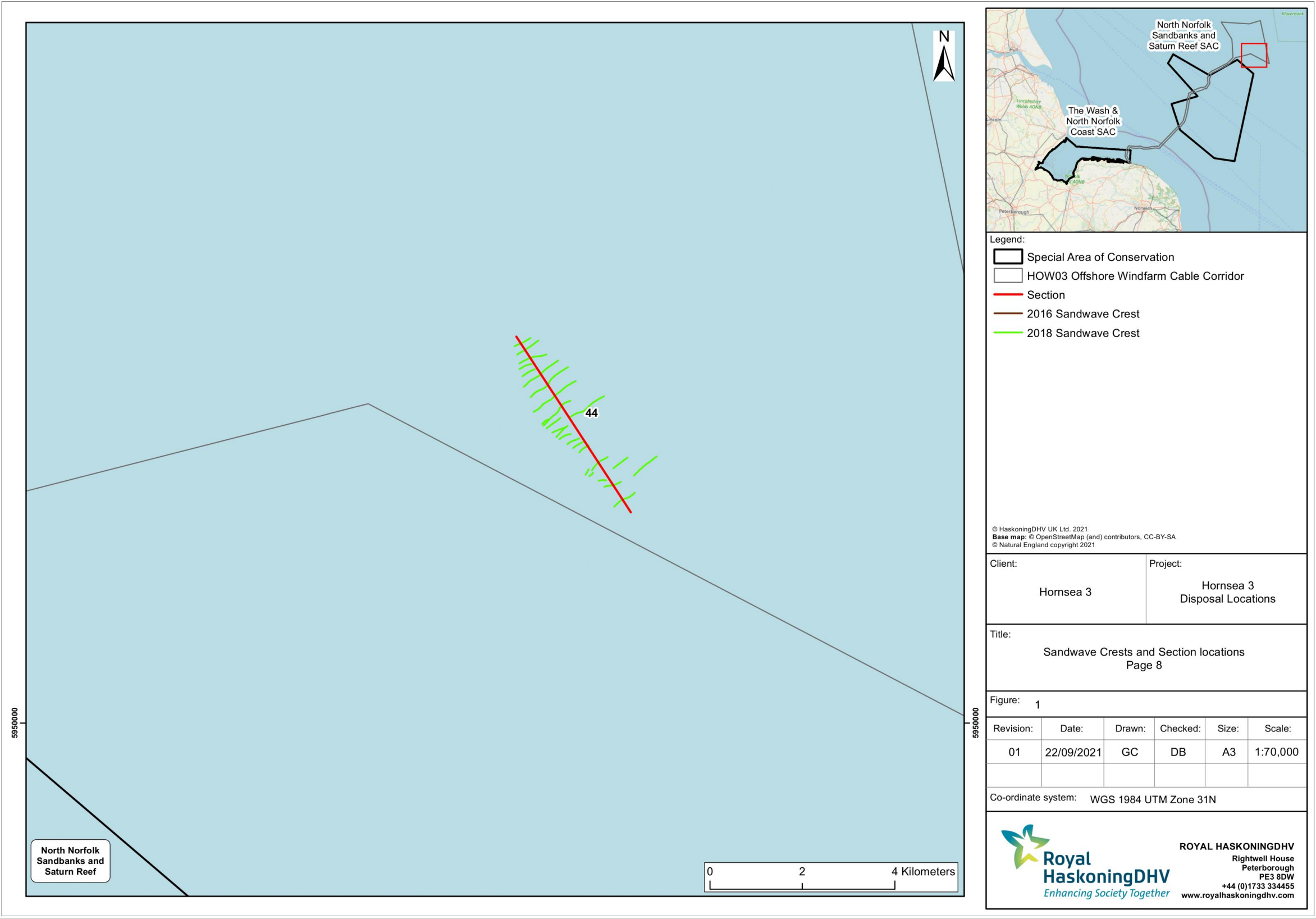


Figure 9: Location of the crests of sandwaves and sections across selected bedforms – Page 8.

Table 1: Sandwave geometries in the export cable corridor. Locations of the sandwave crests are shown in Figure 1 to Figure 9.

Field (South to North)	Example Section (Figure 2)	Type	Crest Orientation	Height	Steep-side Facing	Migration based on 2016/2018 comparison of crest position
0	0	Sandwaves	Mainly northeast to southwest	Up to 4m	Variable	Indeterminate
1		Complex sandwaves and megaripples	Between north-south and northeast to southwest	Up to 6m	Variable	Indeterminate
2		Complex sandwaves and megaripples	Between north-south and north-northeast to south-southwest	Up to 6m	Indeterminate	Indeterminate
3		Complex sandwaves and megaripples	Mainly northeast to southwest	Up to 2m	Variable	Northwest
4	14	Low-order sandwaves and megaripples	Mainly north-south	Up to 2m	Variable	West
5		Sandbank with sandwaves and megaripples	Mainly north-south	Up to 6m	Variable	West
6	22	Sandbank with sandwaves and megaripples	Mainly north-northeast to south-southwest	Up to 2.5m	West-northwest	West-northwest
7		Low-order sandwaves	Northeast to southwest	Up to 2.5m	Northwest	Indeterminate
8	26	Low-order sandwaves	North-northeast to south-southwest	2.5m to 4m	West-northwest	Indeterminate
9		Low-order sandwaves	Northeast to southwest	Up to 2.5m	Northwest	Indeterminate
10		Sandbank with sandwaves	Northeast to southwest	3m to 4.5m	Northwest	Northwest
11	34	Sandwaves	East-northeast to west-southwest	Up to 4.5m	North-northwest	Indeterminate
12		Sandwaves	Between northeast to southwest and east-northeast to west-southwest	Up to 6m	Variable	Indeterminate

Table 2: Sandwave fields in the array site. Locations of the fields is shown in Figure 1 to Figure 9.

Field	Sections	Type	Crest Orientation	Height	Steep-side Facing	Migration based on 2016/2018 comparison of crest position
A	44	Sandwaves	Northeast to southwest	Up to 2.5m	Southeast	Indeterminate
B		Sandwaves and megaripples	Northeast to southwest	Up to 2m	Variable	Indeterminate

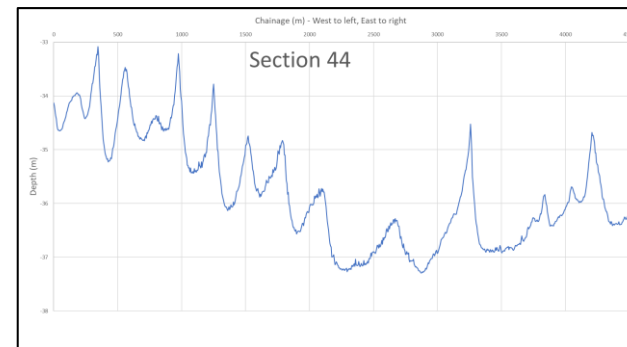
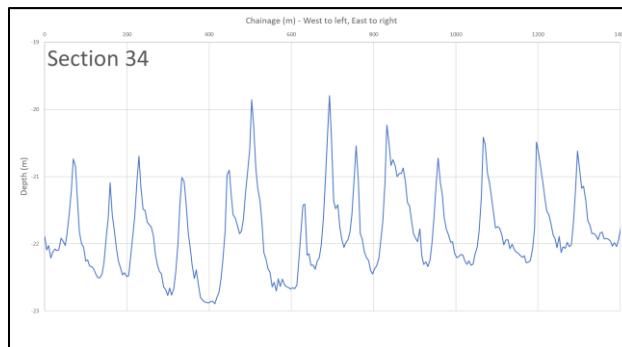
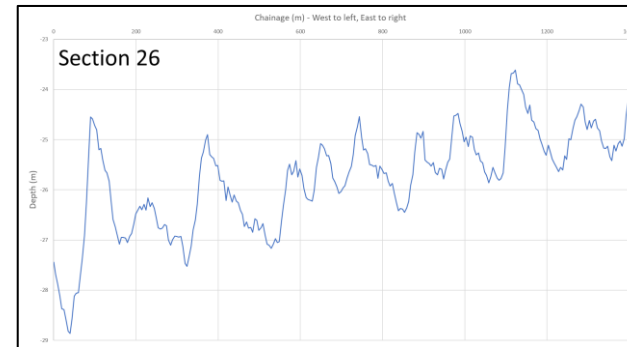
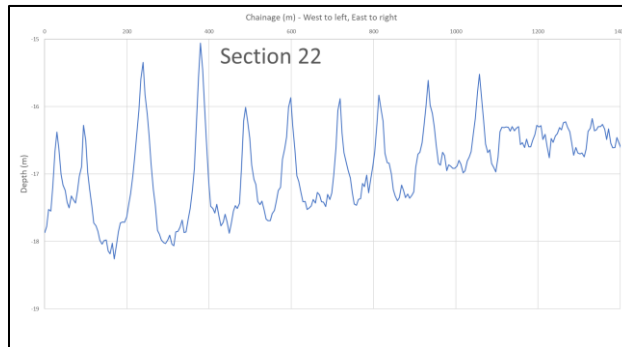
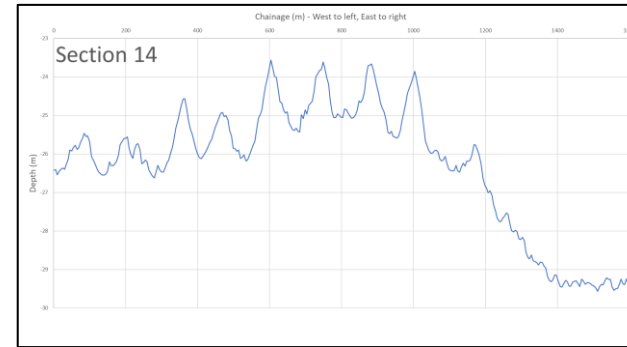
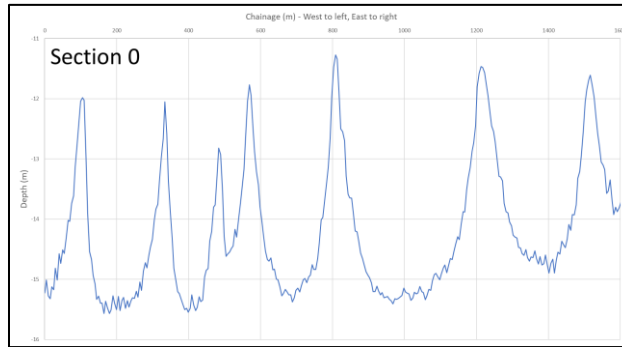


Figure 10: Sections across selected sandwaves in the export cable corridor. Locations of the sections are shown on Figure 1 to Figure 9.

3 Indicative disposal areas and their rationale

14. The indicative areas for disposal of seabed sediment extracted during construction of Hornsea Three are shown in **Figure 11**. The areas along the export cable corridor would be used for disposal of dredged sediment from sandwave levelling to allow installation of the export cable. The areas in the array site would be used for disposal of dredged sediment from seabed preparation for foundation installation and array cable installation where required.
15. The indicative disposal areas are delineated using the seabed morphology mapping of the 2016 and 2018 geophysical data. All the areas are within the boundary of the Hornsea Three Order Limits, are located where the seabed has been interpreted as containing megaripples and/or sandwaves and have been initially sited to avoid any area of historic reef within the NNSSR SAC (**Figure 11**). This will be reviewed and updated in line with the most recent pre-construction survey data for the presence and/or absence of Annex I reef when identifying final disposal locations in the CSIP (**Section 3.2**).
16. The indicative disposal areas shown in **Figure 11** cover a larger extent than the mapped sandwave crests shown in **Figure 1** to **Figure 9**, because the crests of the smaller megaripple bedforms could not be meaningfully mapped. However, megarippled areas that are located between the larger sandwaves still form part of the same bedform system and so are indicative disposal locations.
17. None of the indicative areas overlap with any current or historic disposal sites, as shown in **Figure 11**.
18. Hornsea Three note that as the Hornsea Three array area is not designated as a disposal area within the deemed marine license⁴. At this stage in project refinement, it is appropriate to provide indicative disposal locations as information regarding which sandwaves will require levelling, and which will not, is not yet available. Detail regarding final disposal locations will be provided to the MMO and Natural England pre-construction through consultation on, and approval of, the CSIP which will be informed by both this document and by further detailed site investigation for both sandwave features and Annex I reef which will enable definition of final disposal locations.

⁴ Schedule 12: Deemed Marine Licence under the 2009 Act – Generation Assets <https://www.legislation.gov.uk/uksi/2020/1656/schedule/11>

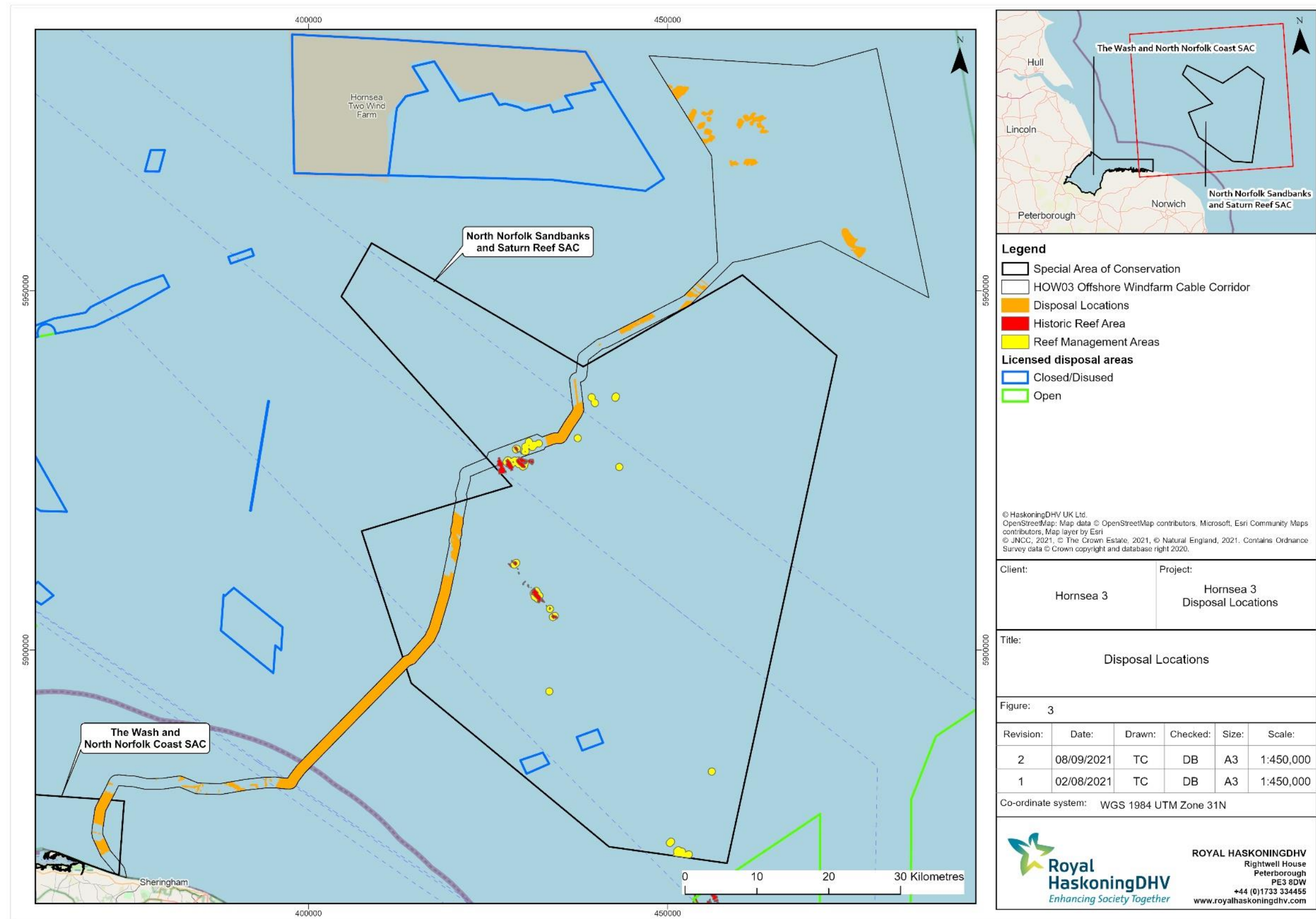


Figure 11: Indicative disposal areas in the export cable corridor and array site.

3.1 Retention of sediment in the system and bedform recovery

19. The sandwaves along which seabed levelling is proposed are part of dynamic bedform fields including (in places) active sandbanks. A primary aim of the sediment disposal strategy would be to facilitate bedform recovery and to ensure no net loss within the SAC system. Hence, disposal of any dredged sediment would be on the up-current side of the cable route and as close as possible to the location from which it was dredged, enabling the sediment to become retained within the local sediment transport system by natural processes to encourage the re-establishment of bedforms.
20. The rate of recovery would vary in relation to the rate of sediment transport processes; faster infill and recovery rates will be associated with higher local flow speeds. The bedforms might recover to their original condition (e.g., rebuilding a single crest feature, although likely displaced in the direction of natural migration) or might change (e.g., a single crest feature might bifurcate or merge with another nearby bedform). Both outcomes are consistent with the natural processes and bedform configurations that are already present in the offshore Order Limits and would not adversely affect the onward form and function of the individual bedform features.
21. The strategy adopted has been informed by any available evidence regarding recovery from other relevant projects (e.g., Race Bank Offshore Wind Farm, Hornsea One Offshore Windfarm). For example, to install parts of the array and export cables for Race Bank Offshore Wind Farm, the crests of sandwave were reduced in elevation. Orsted (2018)⁵ and Larsen et al. (2019)⁶ reported the results of multibeam echosounder monitoring of pre- (2015/2016), during (2017) and post- (2018) sand-wave levelling to assess the level of disturbance and the rate of natural recovery (restoration) of seabed morphology. Nine areas were chosen (seven array cables routes, two areas in the export cable routes) where significant sediment mobility was expected. The results showed that in the nine study areas, the seabed had completely or nearly completely recovered to pre-construction levels (greater than 75% recovery of sandwaves in all areas).
22. The strategy adopted will ensure retention of sediment, within those systems which sustain the WNNC and NNSSR SAC, is maintained.

3.2 Avoidance of Annex I reef

23. Historic data on the locations of any Annex I reef/potential reef has been used in the first instance to inform the indicative disposal locations as shown in **Figure 11** to demonstrate the approach to micro-siting. Final micro-siting and refinement of disposal locations presented in the CSIP will be informed by pre-construction geophysical and ground truthing surveys and consulted on with MMO and Natural England as to be the most up to date data on the presence/absence of Annex I reef.
24. The final locations of sediment disposal in the Hornsea Three offshore Order Limits would include a minimum buffer of 50m from *Sabellaria spinulosa* reef within WNNC SAC and a 500m buffer within NNSSR SAC as identified within the pre-construction surveys. These buffers are aligned with those defined in the Outline Cable Specification and Installation Plan⁷. For WNNC, the 50m buffer is applied as no evidence of *Sabellaria* reefs has been found in characterisation surveys. The avoidance distance of 500m for NNSSR is based on standard JNCC advice for offshore *Sabellaria* reefs, where there is greater uncertainty about the extents of these habitats in waters further offshore.

3.3 Similarity of source and receiver sediment particle size

25. The levelling of sandwaves would not cover the entire width of the export cable corridor. The levelled length would have a restricted width representing only a small percentage of the full corridor width. Given that most of the fields of sandwaves that would potentially be levelled cover the entire width of the cable corridor, the disposed sediment from a limited width of dredging would be returned to a seabed that contains sandwaves within the same sandwave system from which it was extracted (albeit on the up-current side). Hence, the source and receiver sediment particle sizes would be similar because the seabed at each of the locations is driven by similar processes of similar magnitude.

⁵ [D2_HOW03_Appendix 8 \(planninginspectorate.gov.uk\)](#)

⁶ Larsen, S.M., Rouland, A. and McIntyre, D.L. 2019. Regeneration of partially dredged sandwaves (Coastal Sediments 2019: Proceedings of the 9th International Conference

⁷ [D2_CON02_Appendix 6 \(planninginspectorate.gov.uk\)](#)

26. Similarly, in the array site, the dredged sediment would be disposed in areas occupied by the same sandwave field from which it was extracted.

3.4 Approaches to sediment disposal

27. For the export cable corridor and array cables, the dredged sediment would be disposed in a linear strip close to the seabed and for seabed preparation as close as possible to each foundation. The precise methodology for disposal will be informed by the detailed design following the interim and pre-construction surveys and will be defined in the CSIP.
28. Disposal would be at the seabed (rather than sea surface), where sediment would be pumped through a fall pipe (discharge pipe) employed by the dredging vessel.
29. Use of the fall pipe would allow placement of the sediment in preferred seabed locations. Utilising this methodology alongside the disposal of any dredged sediment on the up-current side of the cable route will ensure that sediment is retained within the wider system and those systems which sustain the WNNC and NNSSR SACs are maintained.

4 Conclusion and Hornsea Three Commitments

30. A technical review of existing bathymetry and seabed sediment data across the array site and export cable corridor of Hornsea Three has identified where sandwave levelling might be needed (**Figure 1** to **Figure 9**) and the locations of indicative disposal areas (**Figure 11**).
31. The disposal of the excavated sediment from cable installation should be at locations within the boundary of the Hornsea Three Order Limits to ensure that it is not lost from the system and provides a feeder of sediment for subsequent recovery of the lowered bedforms, particularly within WNNC SAC and NNSSR SAC. Additionally, seabed preparation (levelling or dredging) may be needed to create a suitable base prior to foundation installation. The dredged sediment should be returned to the seabed at a location close to the foundation and within the boundary of the Hornsea Three site.
32. Hornsea Three would commit to the following mitigation measures should sandwave levelling and seabed preparation be required. These measures would ensure that the overall effect of changes to the seabed would be minimal and include the following:
- Dispose of all sediment within the Hornsea Three Order Limits meaning there would be no net loss of sediment from the site;
 - Dispose of any sediment dredged from the seabed for sandwave levelling in a linear 'strip' as close as possible to the cable routes and for seabed preparation as close as possible to each associated foundation;
 - Dispose of the sediment close to the seabed with a fall pipe close to the seabed rather than at the sea surface;
 - Dispose of the sediment on the up-current side of the dredged area, where tidal currents would, over time, naturally re-distribute the sediment back over the levelled (cable) or prepared (foundation) area (as re-formed sandwaves); and
 - Dispose of sediment no closer than 50m to any *Sabellaria spinulosa* reef within WNNC SAC and 500m within NNSSR SAC.
33. This appendix to the WNNC and NNSSR SBIPs secures the commitments outlined above, and Hornsea Three will develop the CSIP in line with these commitments and ensure that the CSIP prioritises retention of sediment within the system, ensures the source and receiver sediment particle sizes would be similar and maintains avoidance of impacts to reef features. Further detail can be provided in the CSIP once final installation parameters are understood.