GREENLINK INTERCONNECTOR LIMITED

CML1929 - Response to Second Phase of Consultee Comments

Marine Licence Application for the Greenlink Interconnector

Greenlink - an interconnector between GB and the Republic of Ireland

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Marine Licence Application for the Greenlink Interconnector

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1. Introduction

1.1 Objective of this report

Greenlink Interconnector Limited (GIL) submitted a Marine Licence Application (MLA) (ref: CML1929) on the 24 June 2019 to Natural Resources Wales (NRW). The statutory consultation period on the MLA commenced on 13 November 2019 and finished on 08 January 2020. On 24 February 2020, NRW provided GIL with comments received from seven consultees. GIL provided a full response to the comments within document 'CML1929 – Response to Consultee Comments' (Document Reference: P1975_R5015_Rev1) submitted to NRW on 20 May 2020. This document was accompanied by the following supporting documents (with any changes made in the documents highlighted in yellow):

- Greenlink Marine Habitats Regulations Assessment (HRA) Revision F2 (reference P1975_R4710_RevF2).
- Greenlink Habitat Compensation Plan (reference P1975_R5029_Rev0) (appended to HRA).
- Greenlink Marine Environmental Statement Technical Appendix D – Underwater Sound Modelling Revision F2 (reference P1975_R4484_RevF2) (appended to HRA).
- Greenlink Marine Mammal Mitigation Plan (reference P1975_R5028_Rev0) (appended to HRA).

NRW and consultees have reviewed the submitted Response documents and issued a second Request for Clarification/Further Information dated 03 July 2020. This Report has been prepared to address the comments received from NRW Technical Experts (NRW TE), the Centre for Environment Fisheries and Aquaculture Science (Cefas) and the Joint Nature Conservation Committee (JNCC). Meetings were held with the respective organisations between 08 July and 16 July 2020 to discuss clarification requests and agree responses.

In view of the clarification requests, and at the request of NRW Marine Licensing changes have been made to the following supporting documents which have been submitted with this report. All changes made in the documents resulting from the second Request for Clarification have been highlighted in blue.

- Greenlink Marine Habitats Regulations Assessment (HRA) Revision F3 (reference P1975_R4710_RevF3).
- Greenlink Marine Environmental Statement Technical Appendix D – Underwater Sound Modelling Revision F3 (reference P1975_R4484_RevF3) (appended to HRA).
- Greenlink Marine Mammal Mitigation Plan Revision 1 (reference P1975_R5028_Rev1) (appended to HRA).

1.2 Project background

The Proposed Development comprises the Welsh Marine components of Greenlink from mean high-water springs (MHWS) at the Welsh landfall at Freshwater West, Pembrokeshire to the UK / Republic of Ireland median line. It comprises:

- Two high voltage direct current (HVDC) electricity power cables;
- A smaller fibre-optic cable for control and communication purposes;
- All associated works required to install, test, commission and complete the aforementioned cables; and
- All associated works required to operate, maintain, repair and decommission the aforementioned cables, including five repair events over the 40-year lifetime of Greenlink.

The Proposed Development includes the following phases:

- Installation;
- Operation (including repair and maintenance activities); and
- Decommissioning

Kilometre points (KPs) have been assigned to the route to aid with the description; running from KP0 at MHWS, Freshwater West to KP73.8 at the UK/Ireland median line.

2. Response to Comments

Please note the comments from consultees have been paraphrased where appropriate.

2.1 *NRW (letter dated 03 July 2020)*

NRW Comment 1 - Benthic Habitats

Responses were received from NRW Technical Experts (NRW TE) in relation to Benthic Habitats. A number of clarifications have been requested. These can be seen in NRW consultation response date 24 June 2020. Clarification should be provided to all points raised.

Response

Please see Section 2.2 for all responses on clarifications raised by NRW TE in letter dated 24 June 2020.

NRW Comment 2 - Benthic Habitats

Following discussions with NRW TE, concerns have been raised with regard to the lack of evidence of alternatives to avoid adverse effects on the Annex I Reef [1170], specifically the option of burying the cable instead of the use of rock mattressing over the biogenic reef (KP43 and KP44). A robust test of alternatives is required before the next step of the habitats regulation assessment is undertaken. NRW needs to understand if the cable burial is a viable alternative for that area. Please provide the cable burial assessment report and further information detailing why rock protection over this area cannot be ruled out.

Response

Section 6.6.6 of the Greenlink Marine HRA (reference P1975_R4710_RevF3) provides a robust discussion of the alternative techniques available for cable installation and protection. This discussion is pertinent to avoiding adverse effects on all habitat types.

For the section of cable between KP43 and KP44 where potential biogenic reef has been identified by survey, the preference will be to bury the cables in sediment as this offers the best protection, is typically the most economical option and is recognised by the industry and Regulators as the best environmental practice. The benefits of burial in seabed versus the use of external cable protection is discussed in detail in Section 6.6.6.3 of the Greenlink Marine HRA (reference P1975_R4710_RevF3). Greenlink are committed to pursuing burial in sediment as the primary option for all sections of the cable where this is feasible. This is outlined in Table 6-12 where it states the primary installation technique to be considered will be cutting followed by remedial jetting, or jetting with a remedial pass.

However, as acknowledged in Section 6.6.6.3 soil conditions may not be suitable for burial in all locations. This is typically where underlying bedrock is close to the surface, or sediments have a high shear strength e.g. stiff clays. In these instances, external cable protection is considered as a contingency alternative.

Indicative locations where it may be necessary to use external cable protection were defined based on initial interpretation of the Greenlink cable route survey geophysical and geotechnical data. The assessment took into consideration soil conditions, depth of bedrock, the target depth of lowering (TDOL) and the capabilities of burial equipment, to identify locations where burial may not be achieved. A precautionary approach was taken to ensure the HRA presented the worst-case.

Although burial in sediment is a viable alternative between KP43 and KP44 it cannot categorically be ruled out at this stage that external cable protection will not be required. Table 2-1 provides additional information as to why burial may not be achieved at the location between KP43 and KP44. As can be seen from this table the geotechnical testing (cone penetrometer test, CPT) reached a maximum depth of 0.52m. When a CPT does not penetrate the underlying strata, it is an indication that soil conditions may be too stiff for cable trenching. As a TDOL at the location is 1m (to protect against external aggressors), the current data suggests that the necessary burial depth to achieve cable protection may not be achieved and some level of external cable protection may be required. The Greenlink Cable Burial Risk Assessment (CBRA) Revision 3 (October 2019), from which this information is taken, is provided as Appendix A to this report.

Table 2-1 Additional information on burial feasibility between KP42 and KP44

KP start	KP end	Primary Feature	Maximum CPT depth	TDOL	Depth and description of top layer	Depth and description of 2nd layer	Depth and description of 3rd layer
KP 43	KP 44	Potential Biogenic Reef	0.52m	1.0m	0.18m - gravelly sand	0.3m - silty sand	0.04m silty sand

Preliminary burial assessment studies have also been completed by the Installation Contractors as part of the Engineering, Procurement and Construction (EPC) Tender Process. This is commercially sensitive information and cannot currently be released with the Marine Licence Application. The Preferred Tenderer has indicated that there is 'moderate confidence' that burial will be achieved between KP43 and KP44 with the caveat that additional cable protection may be required. This suggests that if full burial in sediment is not achieved then at least a certain degree of burial in sediment will be attained. In this scenario, and on review of the cable burial risk assessment (CBRA), agreement would be reached between the

Installation Contractor and GIL as to whether the burial depth achieved is enough to forgo any additional cable protection. For example, and as an indication only, possible alternatives would be a) agree that 0.5m burial depth is sufficient to protect the cable from external aggressors and that external cable protection is not required; b) agree that 0.5m burial depth does not offer sufficient protection and that an additional depth (e.g. 0.5m) of cable protection is required to achieve the target burial of 1.0m.

To present a worst-case precautionary assessment the HRA assumed that no level of burial in sediment is achieved and that the full 1.0m protection is required through external cable protection. As outlined above, between KP43 and KP44 this is unlikely to be the case, but based on available data, it cannot be categorically ruled out at this stage.

Based on the findings of the MMT Environmental Survey Report (MMT 2019[1]), the potential biogenic reef between KP42 and KP44 is likely to be aggregations of *Sabellaria spinulosa*. Frequent occurrence of *S.spinulosa* was noted at the closest grab sample site S24. The introduction of hard substrata in the form of external cable protection can assist the creation of biogenic reef. According to the Marine Life Network (MarLIN), Sabellaria reef habitats have no resistance, very low resilience, and high sensitivity to a change in seabed type; however, it also notes that *S.spinulosa* is considered not sensitive based on studies of habitat preferences. While there will be a permanent change from the existing seabed type to a novel hard substrate, it is noted that *S.spinulosa* can colonise bedrock and artificial structures, therefore an increase in availability of hard substratum may be beneficial in providing areas for colonisation (Tillin *et al*. 2020)[2]. Wider evidence suggests that *S.spinulosa* has been recorded on a variety of substrates including artificial surfaces such as pipelines, wave-breakers, seawalls and artificial reefs (Pohler 2004[3]; Braithwaite *et al*. 2006[4]; Chen and Dai 2009[5]; Ponti *et al*. 2010[6]).

While existing *S.spinulosa* reef aggregations would be lost if external cable protection is used, evidence has shown that cable protection measures can be considered a positive effect, stimulating the development of biological communities and increasing local diversity (Coolen 2017[7]). Furthermore, evidence suggests that *S.spinulosa* reefs can recover quickly from short-term or intermediate levels of

[1] MMT (2019). Greenlink Environmental Survey Report. Revision A. June 2019. Reference: 102953-GRL-MMT-SUR-REP-ENVIRORE
[2] Tillin, H.M., Marshall, C., Gibb, N. & Garrard, S.L. (2020). [Sabellaria spinulosa] on stable circalittoral mixed sediment. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews. [Online]. Plymouth: Marine Biological Association of the United Kingdom. [cited 16-06-2020]. Available from:
https://www.marlin.ac.uk/habitat/detail/377 (Accessed June 2020)
[3] Pohler, S.M.J. (2004) The Sabellariid worm colonies of Suva Lagoon, Fiji. South Pacific Journal of Natural History 22: 36-42.
[4] Braithwaite, C.J.R., Robinson, R.J., Jones G (2006) Sabellarids: a hidden danger or an aid to subsea pipelines? Quarterly Journal of Engineering Geology and Hydrogeology 39: 259-265
[5] Chen, C. and Dai, C-F. (2009) Subtidal sabellarid reefs in Hualien, eastern Taiwan. Coral Reefs 28: 275-275.
[6] Ponti, M., Fava, F., Fabi, G. and Giovanardi, O. (2010). Benthic assemblages on artificial pyramids along the central and northern Adriatic Italian coasts. Biol. Mar. Mediterr. 17 (1): 177-178.
[7] Coolen, J. W. P (2017). North Sea Reefs. Benthic biodiversity of artificial and rocky reefs in the southern North Sea. PhD thesis, Wageningen University and Research, Wageningen, NL

disturbance, with recovery accelerating if some of the reef is left intact following disturbance which will promote larval settlement of the species (Tillin *et al*. 2020). The presence of *S.spinulosa* surrounding external cable protection location may facilitate some level of recovery following disturbance. The introduction of artificial substrate will involve the removal of areas of *S.spinulosa* reef which may result in localised changes to the characteristic biological communities that rely on *S.spinulosa* reef habitat. However, the introduction of hard substrate will not be outside the natural variability of habitats within the Pembrokeshire Marine /Sir Benfro Forol SAC, therefore while there may be localised changes to biological communities, the biological communities that do colonise external cable protection (if required) will still be characteristic of the Pembrokeshire Marine /Sir Benfro Forol SAC.

NRW Comment 3 - Benthic Habitats

NRW TE understand that until a final selected installation contractor undertakes their own engineering feasibility studies, intertidal trenching cannot categorically be ruled out, but is considered unlikely. Until this is confirmed, NRW TE consider that it may potentially impact the SAC habitat "Mudflats and Sandflats not covered by seawater at low tide" in Freshwater West. If intertidal trenching is still a possibility, further information would be required to ensure that such works can take place to avoid any significant impacts on the SAC habitat feature.

Response

Greenlink can confirm that intertidal trenching has been categorically ruled out and will not be required.

NRW Comment 4 - Benthic Habitats

NRW TE agree that the compensation plan is broadly suitable to compensate for the Annex I reef type and condition of habitat lost in the SAC…. Although NRW TE do not have any major concerns with the principles of the plan itself, they do have comments which will help refine subsequent revisions to the plan.

Response

NRW Marine Licensing have confirmed (pers comm. Thomas, J, 07 July 2020) that it will be possible to finalise the compensation plan post-consent. This would be secured through discharge of licence conditions. Greenlink therefore anticipate that licence conditions similar to the below will be included on the consent:

1.1 The Licence Holder must submit a Final Compensation Plan to NRW acting on behalf of the Licensing Authority for written approval prior to commencement of the Licensable Activities. No Licensable Activities may be undertaken prior to written agreement from NRW acting on behalf of the Licensing Authority.

1.2 The Licence Holder must ensure that any actions outlined in the documents detailed in condition 1.1 are implemented as approved in writing by NRW acting on

behalf of the Licensing Authority. Any proposed changes to the actions outlined in the documents must be submitted to and agreed in writing by NRW acting on behalf of the Licensing Authority prior to any changes being enacted.

There is a significant benefit in delaying finalisation of the compensation plan to post-consent in that by this point an Installation Contractor will have been selected and will be able to inform the plan. Information likely to be available from the installation contractor will include the detailed burial assessment study which will identify final locations for cable protection material and potentially additional survey data.

Greenlink are committed to continuing to work with NRW TE to close out all comments raised on the Habitat Compensation Plan. Section 2.2.2 outlines the comments raised on the Habitat Compensation Plan and Greenlink's initial progress.

NRW Comment 5 - Benthic Habitats

Please update the shadow HRA and compensation plan accordingly and resubmit addressing all points raised. You will need to make clear the provision of any compensation being proposed.

Response

The Greenlink Marine HRA (reference: P1975_R4710_RevF3) has been updated and re-submitted to address all points raised in the request for clarification. As agreed with NRW, the Pembrokeshire Marine SAC Habitat Compensation Plan will not be re-submitted at this stage, but approval for the contents will be sought in writing from NRW prior to any Licensable Activity taking place.

NRW Comment 6 - Marine Mammals

Responses were received from NRW TE and JNCC in relation to Marine Mammals. A number of concerns have been raised and clarifications have been requested. These can be seen in NRW consultation response date 24 June 2020 and JNCC consultation response dated 25 May 2020. Clarification should be provided to all points raised. Please update the HRA accordingly and resubmit addressing all points raised and within NRWs consultation response attached.

Response

Please see Section 2.2.1 for all responses on clarifications raised by NRW TE. Please see Section 2.3 for all responses on clarifications raised by the JNCC. The request for clarification has led to updates in the following documents, with all changes highlighted in blue:

- Greenlink Marine HRA (reference P1975_R4710_RevF3);

- Greenlink Marine Environmental Statement Technical Appendix D – Underwater Sound Modelling Revision F3 (reference P1975_R4484_RevF3) (appended to HRA); and
- Greenlink Marine Mammal Mitigation Plan (reference P1975_R5028_rev1) (appended to the HRA).

NRW Comment 7 - Underwater Noise Assessment

Responses were received from CEFAS in relation to the Underwater Noise Assessment. A number of concerns have been raised and clarifications have been requested. These can be seen in the CEFAS consultation response date 19 June 2020. Clarification should be provided to all points raised.

Response

Please see Section 2.4 for all responses on clarifications raised by Cefas. The request for clarification has led to updates in the following documents with all changes highlighted in blue:

- Greenlink Marine HRA (reference P1975_R4710_RevF3);
- Greenlink Marine Environmental Statement Technical Appendix D – Underwater Noise Modelling Revision F3 (P1975_R4484_RevF3) (appended to the HRA); and
- Greenlink Marine Mammal Mitigation Plan (reference P1975_R5028_rev1) (appended to the HRA).

Implementation of additional mitigation has led to reduced ranges of effect to marine mammals.

NRW Comment 8 - WFD Assessment, Water Quality and Bathing Waters

Responses were received from NRW TE in relation to the WFD assessment, Water Quality and Bathing Waters. A number of concerns have been raised and clarifications have been requested. These can be seen in NRW consultation response dated 24 June 2020. Clarification should be provided to address all points raised.

Response

Please see Sections 2.2.3 and 2.2.6 for all responses on clarifications raised by NRW TE.

NRW Comment 9 - Coastal Processes

Responses were received from NRW TE in relation to Coastal Processes. A number of concerns have been raised and clarifications have been requested. These can be seen in NRW consultation response dated 24 June 2020. Clarification should be provided to address all points raised.

Response

Please see Sections 2.2.5 for all responses on clarifications raised by NRW TE.

NRW Comment 10 - Fish and Fisheries

NRW TE note that the impact of the cable EMF on crustaceans such as the edible crab (*Cancer pagurus)* has not be considered. NRW TE advise that crabs are attracted to EMF and reduce their roaming time; this will affect crabs both behaviourally and physiologically (Scott *et al.*, 2018). This should be considered and it is advised that assessment of the effect of the EMFs generated by the cable on crustacean species is provided.

Response

Please see Sections 2.2.4 for all responses on clarifications raised by NRW TE with respect to fish and fisheries.

2.2 NRW TE (letter dated 24 June 2020)

NRW TE provided comments dated 24 June 2020 to NRW Marine Licensing Team on six receptor topics; namely - marine mammals, benthic, Water Framework Directive (WFD), fish and fisheries, coastal processes and water quality. The comments are addressed in turn below but have been paraphrased where appropriate.

2.2.1 Marine Mammals

NRW TE Marine Mammal Comment 1

Please could the applicant explain how low-order detonation would result in neutralisation of the larger charges.

Response

Neutralisation of the UXO in the context of the response refers to the use of a low order method - deflagration - whereby the explosive in the UXO is burnt out rather than blown up, in effect neutralizing the charge. The deflagration process is described in Cheong *et al.* (2020)[8] as *"the UXO casing is penetrated by a shaped charge that generates insufficient shock to detonate. The explosive material inside the UXO reacts with a rapid burning rather than a chain reaction that would lead to a full explosion. Deflagration is a much less energetic process and anecdotal evidence has suggested that it is "quieter" than traditional high-order detonation."*

Cheong *et al.* (2020)[8] goes on to say that US test studies show that low-order detonation procedures are very effective in reducing blast effects with a yield

[8] Cheong, S., Wang, L., Lepper, P and Robinson, S. (2020). Final Report: Characterisation of acoustic fields generated by UXO removal – Phase 2. BEIS Offshore Energy SEA Sub-Contract OESEA-19-107. National Physical Laboratory Report AC19. June 2020. [online] Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/893773/NPL_2020_-_Characterisation_of_Acoustic_Fields_Generated_by_UXO_Removal.pdf (Accessed July 2020)

reduction exceeding 97% in comparison to the equivalent high-order detonation. Cheong *et al.* (2020)[8] reports the results of an experimental trial conducted in Limehillock Quarry, Scotland to study the acoustic characteristics of underwater explosions, including low order detonation by deflagration. The study observed a more than 20dB reduction in peak sound pressure levels (SPL) and sound exposure levels (SEL) between high-order detonations and low-order detonations of the same charge size. The data clearly showed that low-order detonations *"offer a much lower amplitude of peak sound pressure than high-order detonations (by a factor of approximately 10 [in our trials])"* Cheong *et al.* (2020)[8]. The study concluded that deflagration is an effective mitigation measure.

JNCC Comment 1 has advised that Greenlink consider using deflagration for all UXO charge sizes requiring detonation. Having consulted a UXO expert[9], Greenlink can commit to this process for all UXO that would require detonation thereby reducing the potential for physical injury to marine mammals. However, it should be noted that the process cannot ever guarantee (although it is highly unlikely) that the UXO will not detonate in a high-order manner due to the age of the UXO and the unstable nature of the explosives involved.

NRW TE Marine Mammal Comment 2

NRW Underwater Noise Comment 6 concerned the potential for physical injury (blast trauma). The updated Appendix D does not address the issue and therefore there is no assessment of the range of physical trauma potential from UXO.

Response

This comment was discussed with Ceri Morris (NRW TE) on 09 July 2020 and subsequent guidance was provided by email.

Physical injury to marine mammals such as crushing, fracturing, hemorrhages and rupture of body tissue, caused either directly or indirectly by the blast wave, resulting in immediate or eventual mortality, is possible from underwater explosions. However, most research including von Benda-Beckmann *et al.* (2015)[10] into effects of underwater explosions, focuses on the sound levels that are high enough to cause hearing loss i.e. a permanent threshold shift (PTS), as it is acknowledged that this is likely to occur at lower sound pressure levels than would cause the physical trauma injuries listed above. The justification is that if mitigation can be proposed to avoid PTS level effects this will also effectively mitigate for blast injuries.

In conclusion, it is acknowledged that physical injury through blast trauma is a possible consequence of UXO detonation, but the range over which physical trauma

[9] Welch, D (2020). Telephone conversation between Anna Farley, Intertek and Dave Welch, Ramora UK, 07 July 2020.
[10] Von Benda-Beckmann, A.M., Aarts, G., Sertlek, H.Ö., Lucke, K., Verboom, W.C., Kastelein, R.A., Ketten, D.R., van Bemmelen, R., Lam, F.A., Kirkwood, R.J. and Ainslie, M.A. (2015). Assessing the Impact of Underwater Clearance of Unexploded Ordnance on Harbour Porpoises (Phocoena phocoena) in the Southern North Sea. Aquatic Mammals, 41(4).

might occur will be smaller than the range calculated for PTS effects. Therefore, the ranges calculated for PTS in the Greenlink Marine Environmental Statement Technical Appendix D – Underwater Noise Modelling also encompasses that range of physical trauma. Consequently, mitigation proposed to reduce the risk of animals being exposed to PTS will also mitigate the risk of other physical injury.

NRW TE Marine Mammal Comment 3

Underwater Noise Comment 9: We strongly recommend that noise abatement mitigation would be required to avoid adverse effect - such as low-order detonation to reduce the noise at source, and/or noise abatement to attenuate the noise at close range to significantly reduce the noise injury and disturbance footprints. The timing of UXO detonation should also be considered and discussed further with NRW to potentially avoid sensitive periods for marine mammals.

Response

There are three categories of noise mitigation which can be applied to UXO detonation, namely:

1. Noise abatement / reduction i.e. methods that reduce the sound energy emitted into the environment, namely:
   - Deflagration which reduces the source level.
   - Barrier methods which attenuate the emitted sound, for example bubble curtains.
2. Spatial – temporal restrictions i.e. dictating when the licensable activity can take place to minimise effects on sensitive receptors, including:
   - Real time restrictions during the licensable activity for example, halting the activity temporarily in response to detection of marine mammals using visual or passive acoustic monitoring.
   - Seasonal restriction determining when the licensable activity can occur based on known density distributions of sensitive species.
3. Acoustic deterrents i.e. methods that introduce additional noise of lower intensity before the more harmful noise with the intention of dispersing animals, including:
   - Use of acoustic deterrent devices (ADD).
   - Use of small scare charges (often referred to as soft-start charges) deployed before the main charge is initiated.

With respect to the above categories, Greenlink had committed to the following in the Greenlink Marine ES (submitted June 2019) and the Request for Clarification report and Marine Mammal Mitigation Plan (submitted in May 2020):

- Avoid the need for detonation

- Deflagration on all charges of 50kg or larger.
- Real time restrictions during the activity in response to detection using visual and passive acoustic monitoring.
- Use of ADDs specifically the Lofitech seal scarer (or similar)
- Use of small scare charges (if appropriate)

Following discussion with NRW TE (09 July 2020) and further review of noise abatement techniques and their effectiveness, Greenlink will now commit to the following additional mitigation:

- Deflagration will be undertaken on all charge sizes.
- Deflagration will only be carried out during the winter season - between 01 October and 31 March.
- A big bubble curtain (BBC) will be used for deflagration in water depths equal to or less than 40m i.e. between KP0 and KP9.4.
- If a UXO is identified in water depths of 40-70m advice would be sought as to practicalities and cost of deploying a BBC in winter at the specific location. A BBC will be used if the contractor concludes it will be effective.
- If deflagration is required, Greenlink will undertake underwater noise measurements to add to the body of research that can be used to inform future assessments of effects on marine mammals.

These changes have been reflected in the Greenlink Marine HRA (reference P1975_R4710_RevF3) and Greenlink Marine Mammal Mitigation Plan (reference P1975_R5028_rev1).

NRW TE Marine Mammal Comment 4

Underwater Noise Comment 10: We question what would happen if more than one detonation is required.

Response

This clarification request was discussed during a teleconference between NRW TE, Greenlink and Intertek (09 July 2020) and it was agreed that should additional UXO deflagration be required, Greenlink will apply for this as a variation to the Marine License and EPS License once specific details of the UXO were known.

Greenlink are currently applying for one UXO deflagration as a precaution. It is acknowledged that given the historic and current use of the Proposed Development, UXO are likely to be present within the Application Area, however Greenlink believe that there is sufficient space to be able to route around any UXO identified. The Installation Contractor will undertake a UXO survey of the entire cable route ahead of installation activities. At this stage potential UXO will be identified and investigated and the decision taken as to whether any UXO will require deflagration,

or if more than one UXO deflagration will be necessary. The UXO survey and subsequent visual inspection of the UXO will identify the position and size of the UXO. Once these details are known NRW will be consulted and a variation to the Marine Licence and EPS Licence will be applied for.

It was agreed by NRW, Greenlink and Intertek (09 July 2020) that this was the most pragmatic approach for the project.

Greenlink understand the risks with this approach i.e. that the programme may be delayed if the Installation Contractor does not allow enough time between UXO identification and planned deflagration to apply for the required licence variations. This risk will be managed through the Project Risk Register and the Installation Contractors / Greenlink Contract Management process.

NRW TE Marine Mammal Comment 5

HRA comments: Cardigan Bay SAC: grey seal should be screened in.

Response

Grey seal from the Bae Ceredigion / Cardigan Bay SAC has been screened through to HRA Stage 1 and Stage 2 assessment. The Greenlink Marine HRA (reference P1975_R4710_RevF3) has been updated accordingly, with all changes highlighted in blue.

In making this change Greenlink also noted that the Bristol Channel Approaches SAC should have been screened through to Stage 2 assessment as it cannot be concluded at Stage 1 that UXO detonation within the Proposed Development will not lead to a likely significant effect on harbour porpoise. This correction has also been made.

2.2.2 *Benthic*

NRW TE Benthic Comment 1

3.7 If intertidal trenching is still a possibility, further information would be required to ensure that such works can take place to avoid any significant impacts on the SAC habitat feature.

Response

Greenlink can now confirm that intertidal trenching has been categorically ruled out and will not be required.

NRW TE Benthic Comment 2 – this comment has been summarised. Please refer to letter dated 24 June 2020 for direct wording.

Compensatory Habitat Plan

"We do however query the statement in the Executive Summary that: "*It is proposed that the Final Plan and the quantity of compensatory habitat required will be agreed with NRW post-installation*".

This would need to be discussed with the Marine Licensing team to ensure that this is compliant within the HRA derogation process.

Response

NRW Marine Licensing have confirmed (pers comm. Thomas, J, 07 July 2020) that it will be possible to finalise the compensation plan post-consent. This would be secured through discharge of licence conditions as outlined in Section 2.1 Response to Comment 4 above.

The Pembrokeshire Marine SAC Habitat Compensation Plan will be updated over the next few months, in consultation with NRW TE. The statement referred to above will be updated at this time as we accept it should state "will be agreed with NRW post-consent".

NRW TE Benthic Comment 3

Compensatory Habitat Plan – 4.1 We note that there is no species list table for biogenic reef. Will this be provided to use for the success indicators?

Response

The presence of biogenic reef was identified from side scan sonar imagery. The Greenlink marine survey did not acquire faunal grab samples near to the biogenic reef, nor were video transects acquired across the habitat. It is therefore not possible to provide species lists for the biogenic reef. It is proposed that this comment is deferred until a later date. The Pembrokeshire Marine SAC Habitat Compensation Plan (reference: P1975_R5029_Rev1) states (Section 5.4.2, page 34) that:

"*Once the Installation Contractor has undertaken their BAS and confirmed likely locations for external cable protection the transect locations will be confirmed.*

A *transect will be acquired at each agreed location prior to installation to establish the current baseline environment.*"

The species table for biogenic reef will be compiled once the first monitoring transects have been acquired. This will be agreed with NRW prior to any Licensable Works being undertaken.

NRW TE Benthic Comment 4

Compensatory Habitat Plan – We therefore advise considering other artificial reef types which present a more similar structure to that encountered locally, if any are available.

Has sourcing of local/similar quarried rock been investigated as potential new reef?

We recommend contacting the Ecostructure group (www.ecostructureproject.eu/) for further advice on the use of artificial reefs in this area. We also advice looking at the Conservation Evidence website which has compiled peer reviewed research on the efficacy of artificial reefs (https://www.conservationevidence.com/).

Response

Consultation with NRW TE (09 July 2020) concluded that the Pembrokeshire Marine SAC Habitat Compensation Plan would benefit from two additional appendices; one that outlined the different artificial reef structures considered by Greenlink - providing justification for why one was selected above the others; and one that identified the pros and cons for each of the zones selected as potential locations for compensatory habitat. These two appendices will be added to the Compensation Plan as Appendix B and C respectively. With respect to Appendix B (different artificial structures considered) the Conservation Evidence website will be used in the assessment of efficacy.

Advice has been sought from the Ecostructures Group (telephone conference held 13 July 2020) and several avenues to explore have been identified with respect to alternative solutions. These will be investigated and evaluated over the next few months. Further consultation will be held with NRW TE once all alternatives have been evaluated.

NRW TE Benthic Comment 5

Compensatory Habitat Plan – Table 3.2 Stony reef: "*Typically, the most abundant species found in this habitat is Pomatoceros triqueter, a calcareous tube worm. Analysis of the transect recorded during the environmental survey for the Proposed Development, however, shows that the species was not recorded as present at any point within this section of the cable route.*" It appears that this species is present on the example photo. Have the calcareous tubes in the photo been identified as a different species?

Response

This species has not been identified to species level along any of the transects. However, the family of *Pomatoceros triqueter,* Surpilidae had been recorded along the transect T01 and the MMT (2019)[1] survey report notes that epifaunal coverage was similar between all five transects (T01-T05). It therefore can be assumed that *Pomatoceros triqueter* has been recorded in all of the transects and classified into the family Surpilidae.

The final revision of the Pembrokeshire Marine SAC Habitat Compensation Plan will clarify this.

NRW TE Benthic Comment 6

Compensatory Habitat Plan – 6.2 If measures fail, is there sufficient budget to cover further action i.e. more artificial reefs?

Response

Yes. Within the Project Risk Register Greenlink have identified the potential that extra spend will be required after the 5-years should habitats not be established. The Risk Register forms part of the Final Project Assessment submitted to Ofgem therefore Ofgem and Greenlink are aware of the potential additional cost.

The final revision of the Pembrokeshire Marine SAC Habitat Compensation Plan will clarify this.

NRW TE Benthic Comment 7

Compensatory Habitat Plan – Monitoring strategy and success indicators:

1. *Assemblage composition - The epibenthic assemblage between the cable and the controls should be statistically similar as demonstrated by permutational multivariate analysis of variance, Bray Curtis similarity or similar.*

This is a community structure analysis and the level of similarity would need to be defined and agreed as a threshold e.g. 80% similar?

Response

The level of similarity will be analysed using the PRIMER statistical package and presented as a percentage of similarity. A defined threshold percentage will be agreed with NRW prior to monitoring.

The final revision of the Pembrokeshire Marine SAC Habitat Compensation Plan will clarify this.

NRW TE Benthic Comment 8

Compensatory Habitat Plan – Monitoring strategy and success indicators:

2. Taxa - The top five most abundant species identified in the controls should be present on the compensatory habitat.

This indicator is only looking for presence on the compensatory habitat, what about abundances of the top 5 taxa? The top 5 taxa to be identified should also focus on epifaunal/low mobility species, not mobile species if possible. Depending on the final choice for artificial reef, there may a need to be further thought on feasibility of this success indicator should the artificial reef been structurally different to local reef.

Response

This additional success indicator will be added to the final revision of the Pembrokeshire Marine SAC Habitat Compensation Plan.

NRW TE Benthic Comment 9

Compensatory Habitat Plan – Monitoring strategy and success indicators:

"3. Number of taxa - the number of taxa on the cable should be statistically similar or increased in comparison to the controls."

This related to species richness. As for indicator 1, a level of similarity would need to be defined to act as a threshold.

Response

This analysis will be undertaken using PRIMER to determine a level of similarity. The level of similarity will be agreed with NRW prior to monitoring. The final revision of the Pembrokeshire Marine SAC Habitat Compensation Plan will clarify this.

NRW TE Benthic Comment 10

Compensatory Habitat Plan – Monitoring strategy and success indicators:

"4. Abundance - There should be an equal or increased level of biodiversity than that present in the controls, as determined by biodiversity measures (e.g. Simpson's index)."

The description for this is not an abundance measure, but a diversity one. We will need to consider which measure is best suited to the standard we want to achieve.

Response

This point will been amended to state it is a measure of diversity. This measure will be agreed with NRW prior to monitoring. The final revision of the Pembrokeshire Marine SAC Habitat Compensation Plan will clarify this.

2.2.3 WFD

NRW TE WFD Comment 1

In relation to Section 2.5 WFD Comment 1, we maintain that the proper process would have been to scope in migratory fish for Milford Haven Inner water body but then to conclude there would be no risk of deterioration based on the conclusions of the assessment of potential impacts to migratory fish.

Response

An Environment Agency Scoping Template for the Milford Haven Inner transitional water body (GB531006114100) was not previously provided with the Marine Licence Application as the Proposed Development does not cross the water body, and lies approximately 15km distant, outside of the Milford Haven Estuary.

Consultation with NRW TE (09 July 2020) concluded that NRW does require an assessment to be provided. The Environment Agency Scoping Template for the water body has been provided as Appendix B to this Report.

In line with advice from NRW TE, scoping concluded that an impact assessment is required with respect to migratory fish and the potential that the Proposed Development could impact normal fish behaviours like movement, migration or spawning. The Proposed Development will generate underwater noise which has the potential to act as a barrier to fish moving from the Milford Haven Inner transitional water body to coastal waters e.g. for spawning.

Underwater noise modelling indicates that continuous sound levels generated by vessel movements, cable trenching and placement of deposits on the seabed will not exceed ambient background sound levels outside of the Marine Licence Application Area. Impulsive sound levels from geophysical survey have the potential to exceed thresholds for disturbance level effects in fish 586m from the Marine Licence Application Area. Impulsive sound levels from deflagration of a UXO has the potential to exceed thresholds for disturbance of fish within 1.8km of the Marine Licence Application Area.

The Proposed Development lies at least 15km from the Milford Haven Inner water body and therefore there will not be an overlap between the zone of influence for underwater noise and the water body. The Proposed Development also lies 3.5km from the mouth of Milford Haven and therefore the zone of influence for noise will not act as a barrier at the estuary mouth.

The Greenlink Marine ES Wales, Chapter 8 concluded that underwater noise from the Proposed Development will not prevent fish entering or migrating through nearby estuaries or coastal waters. This includes movement into and out of the Milford Haven Estuary. This conclusion is further supported by the Habitats Regulations Assessment which specifically assessed the potential for a likely significant effect on the Qualifying Features Allis shad, Twaite shad, Sea lamprey and River lamprey of the Pembrokeshire Marine / Sir Benfro Forol Special Area of Conservation (SAC). The SAC overlaps with the boundaries of the water body, and therefore the conclusions are pertinent with respect to the four species of migratory fish. The HRA concluded no Likely Significant Effects on the Qualifying Features and that Appropriate Assessment was not required.

Based on the conclusions of the assessment outlined within the Greenlink Marine ES Wales, Chapter 8 and within the Greenlink Marine HRA there will be no specific risk to the deterioration of the Milford Haven Inner water body as a result of effects to fish.

NRW TE WFD Comment 2

Regarding Section 2.5 WFD Comment 2: we welcome clarification regarding the extent of direct impact arising from the cable route in Pembrokeshire South water body. However, we ask what evidence is there to base the assumption of a 15m wide footprint on? It is still not clear if the total footprint of effect arising from cable route and associated disturbance to the seabed has been calculated, i.e. the direct footprint and secondary effects arising from this.

We note this information is provided in the response to Comment 5 but question if it covers all effects.

Response

With respect to the clarification request the direct footprint of the cable installation is 15m and the indirect effects of this i.e. suspended sediment deposition, is 500m. The cable route passes through the Pembrokeshire South Water Body for 6.7km.

The direct footprint of cable installation is quoted in the Greenlink Marine ES as 15m. The 15m wide area of disturbance was used in determining the direct footprint of effect within the Pembrokeshire South Water Body; 10.05 hectares (6.7km x 15m). This figure does not include secondary effects (which are described below).

The 15m wide footprint is based on standard information associated with the cable installation equipment. A typical mechanical trencher has an overall footprint of approximately 5-15m, therefore the 'worst-case' (15m) has been used to provide an estimate of the direct footprint of effect. Evidence for this is provided in the links below; given in the form of specifications for different industry standard cable ploughs.

https://globaloffshore.co.uk/wp-content/uploads/2020/06/Global-Offshore-Q1400-Datasheet-GO002-v4.pdf

https://www.smd.co.uk/wp-content/uploads/2017/01/MD3.pdf

https://www.smd.co.uk/wp-content/uploads/2017/01/STANDARD-CABLE-PLOUGH.pdf

In addressing NRW TE Water Quality Comment 2 (Report reference: P1975_R5015_Rev1) the SSC calculations were revisited and checked. It was concluded that the 100m used previously does not represent the secondary footprint of the effect; within 100m suspended silt concentrations could still be significantly above natural background levels of SPM.

The extent of impact on the waterbody was recalculated in NRW TE Water Quality Comment 2 (Report reference: P1975_R5015_Rev1) to be 335 hectares assuming a 500m width of effect. This is a secondary effect arising from the direct effect of trenching/jetting to install the cables. The extent estimated relates to the extent of a possible sediment plume. Water depth, dilution and dispersion will all play an important role in determining the extent of the sediment plume. At 500m distance from the centerline suspended sediment concentrations (SSC) will reduce to 112mg/l at a water depth of 10m and 22mg/l at 50m water depth. 500m is a realistic footprint where changes in SSC will be detectable from cable burial under all tidal conditions and is representative of elevated SSCs in all directions from the location of cable burial.

It is acknowledged that calculations presented in Section 6.6.3 of the Greenlink Marine ES indicate silt particles will travel further than 500m and may remain in suspension for up to 14 hours before settling out. In this time, they could travel 7.6km from the centreline assuming that the water direction and speed was constant. However, as the tidal cycle off Pembrokeshire is 12-hourly it is likely that particles will not travel as far, instead being transported back in the general direction of the centreline as the tide turns. Conservatively, it can be assumed that sediment suspended by the burial process could settle up to 7.6km either side of the centreline. However, as discussed above at distances greater than 500m from the cable the changes in SSC will not be discernible above background levels of sediment deposition and therefore 500m is considered a more realistic footprint for the secondary effects of cable installation on the water body.

NRW TE WFD Comment 3

In relation to Section 2.5 WFD Comment 3; The information provided here appears to contradict the calculations provided in response to WFD Comment 2. A 15m average width has been used in the calculations, however the information provided in response to Comment 3 states that when considering secondary effects from the cable installation, the area arising from increased SSC as a result of cable burial may extend for up to 500m from the cable footprint, however this has not been considered in the calculations. A reasonable worst-case scenario must be used in all instances and where any potentially affected area has been discounted, robust evidence must be provided to justify this.

Response

The 15m wide area of disturbance was used in determining the direct footprint of effect within the Pembrokeshire South Water Body; 10.05 hectares (6.7km x 15m). This figure does not include secondary effects.

The total footprint of effect (i.e. the direct footprint and secondary effects) as calculated in the comment referred to, is approximately 335 hectares; assuming a 500m wide area of effect as described in Response to NRW TE WFD Comment 2

above for the 6.7km that the route passes through the Pembrokeshire South Water Body.

2.2.4 Fish and Fisheries

NRW TE Fisheries Comment 1

It is advised that assessment of the effect of the EMFs generated by the cable on crustacean species is provided.

Response

The Greenlink cables will be installed in direct contact with each other (bundled configuration, embedded mitigation EM15), with currents flowing in opposite directions. Magnetic (B) fields will emanate into the surrounding environment; although they will attenuate with distance (both horizontally and vertically). The effect will be present along the Proposed Development.

The background static magnetic field generated by the earth ranges from approximately 25 µT at the equator to 65 µT at the magnetic poles. It is approximately 50µT in the southern Irish Sea.

WSP (2020) (provided as Appendix C of this Report) calculates the static magnetic field strength for three different burial scenarios for Greenlink; 0.6m, 1.0m and 1.5m. The resultant magnetic field strengths at the seabed immediately above the cables are 67 µT, 53 µT and 7.9 µT, respectively. At burial depths of 1.0m and 1.5m the magnetic field at the seabed will not be detectable above the normal static background magnetic field generated by the earth. Where the cables are buried to 0.6m depth the magnetic field generated by the cables will reduce to 5 µT i.e. within background levels, within 2m from the cables.

Many marine invertebrates are magnetically sensitive and those which may be present within the Proposed Development include commercially important taxa such as crabs, lobsters and molluscs.

The concern with EMF emissions is that the generation of anthropogenic magnetic fields above the earth's background geomagnetic level could result in the disorientation of magnetically sensitive species. However, there is little and contradicting evidence of interactions with anthropogenic sources of magnetic fields.

Albert *et al.* (2020)[11] recently published a synthesis on the effects of electric and magnetic fields emitted by submarine power cables on invertebrates. Table 2-2

[11] Albert, L., Deschamps, F., Jolivet, A., Olivier, F., Chauvaud, L. and Chauvaud, S., (2020). A current synthesis on the effects of electric and magnetic fields emitted by submarine power cables on invertebrates. Marine Environmental Research, 159, p.104958.

below shows a summary of studies investigating the effects of artificial magnetic fields on Crustaceans; this has been adapted from Table 2 as published in Albert *et al*. (2020)[11]. This splits the existing studies by response type; including survival, physiological and behavioural responses.

To our knowledge, there is currently no evidence to suggest that EMF effects the survival of crustacean species. A study by Bochert and Zettler (2006)[12] investigated the survival of several marine crustacean species when exposed to static B fields of 3.7mT for several weeks. They found no differences in the survival rate of North Sea prawn (*Crangon crangon*), two isopod species (*Saduria entomon* and *Sphaeroma hookeri*) or round crab (*Rhithropanopeus harrisii*) in comparison to the control.

There is little evidence of physiological responses of crustaceans to EMF. Bochert and Zettler (2006)[12] found that when exposed to a static B-field of 3.2mT for three hours, there was no effect on oxygen rate consumption for two North Sea prawn species (*Palaemon squilla* and *Crangon crangon*). However, a study by Scott *et al*. (2018)[13] found that when exposed to simulated EMF (2.8 mT – 40 mT) the circadian rhythmic processes of haemoolymph L-Lactate and D-Glucose levels were disrupted, suggesting EMF could affect crustaceans on a hormonal level. However, the study found no effects of EMF on stress-related parameters, including oxygen rate consumption and haemocyanin concentrations.

In terms of behavioural responses, several studies have reported behavioural changes in well-studied crustacean species when exposed to EMF (Albert *et al*. 2020)[11]. Behavioural changes observed include attraction, repulsion and effects on spatial distribution. For example, Scott *et al*. (2018)[13] observed a clear attraction of edible crabs (*Cancer pagurus*) to shelters exposed to a 2.8 mT B-field and a significant reduction in natural roaming time as a result. Similarly, Tanski *et al*. (2005)[14] and Rosaria and Martin (2010)[15] observed similar attraction behaviours in spiny cheek crayfish (*Oronectes limosus*) and freshwater crab (*Barythelphusa canicularis*) species respectively.

Other studies observed no effects of EMF on the behaviours of crustacean species. For example, Love *et al*. (2017)[16] found no evidence that the catchability of two commercially important crab species; Dungeness crab (*Metacarcinus magister*) and red crab (*Cancer productus*), was influenced by EMF emitted by energised

[12]Bochert, R. and Zettler, M.L., (2006). Effect of electromagnetic fields on marine organisms. In Offshore Wind Energy (pp. 223-234). Springer, Berlin, Heidelberg.

[13] Scott, K., Harsanyi, P. and Lyndon, A.R., (2018). Understanding the effects of electromagnetic field emissions from Marine Renewable Energy Devices (MREDs) on the commercially important edible crab, Cancer pagurus (L.). Marine pollution bulletin, 131, pp.580-588.

[14]Tański, A., Formicki, K., Śmietana, P., Sadowski, M. and Winnicki, A., (2005). Sheltering behaviour of spinycheek crayfish (Orconectes limosus) in the presence of an artificial magnetic field. Bulletin Francais de la Peche et de la Pisciculture, (376-377), pp.787-793.

[15]Rosaria, J.C. and Martin, E.R., (2010). Behavioral changes in freshwater crab, Barytelphusa cunicularis after exposure to low frequency electromagnetic fields. World Journal of Fish and Marine Sciences, 2, pp.487-494.

[16]Love, M.S., Nishimoto, M.M., Clark, S., McCrea, M. and Bull, A.S., (2017). Assessing potential impacts of energized submarine power cables on crab harvests. Continental Shelf Research, 151, pp.23-29.

submarine power cables. Similarly, a more recent study by Taormina *et al*. (2020)[17] found that European lobsters (*Homarus gammarus*) did not alter their exploratory or shelter seeking behaviours when exposed to EMF. As shown in Table 2-2**Error! Reference source not found.**, no behavioural effects of EMF were also observed in North Sea prawn (*Crangon crangon*), isopod (*Saduria entomon*), round crab and yellow rock crab (*Metacarcinus anthonyi*).

One study reported repulsion behaviour of spiny lobster (*Panulirus argus*) in response to EMF (Ernst and Lohmann 2018[18]), and one reported disruption to orientation behaviours in amphipod (*Gondogenia antartica*) in response to EMF (Tomanova and Vacha 2016[19]).

It is noted that the majority of studies investigating the effects of EMF on crustacean species are controlled experiments made at an individual level. Therefore, as highlighted by Albert *et al*. (2020)[11], caution should be observed in the interpretation of these results.

Whilst further research has reported relatively subtle physiological and behavioural effects of EMF on certain crustaceans, considerable post-consent monitoring of benthic communities has occurred in relation to the offshore wind industry in the UK and elsewhere and has not identified detectable population level effects. Moreover, the Marine Management Organisations response to an independent review of environmental data collected at UK and European offshore wind farms did not see fit to recommend any post-construction monitoring relating to EMF and benthic ecology (MM0 2014[20]).

As discussed above, B fields generated by the Proposed Development will attenuate to below background geomagnetic field levels within 2m of the cables. Potential effects will largely be negated by cable burial; burial to at least 0.6m will prevent most invertebrates from encountering the strongest fields present on the cable surfaces. In addition, embedded mitigation EM15, bundling of the cables, also significantly reduces the magnitude of the effect. Therefore, the magnitude of the effect has been assessed as low, as although it will be a long-term change, the alteration will be extremely localised, and the underlying character of the baseline will be similar to the pre-development situation.

The overall significance of the effect has been assessed as **Negligible** and is **Not Significant**.

[17]Taormina, B., Di Poi, C., Agnalt, A.L., Carlier, A., Desroy, N., Escobar-Lux, R.H., D'eu, J.F., Freytet, F. and Durif, C.M., 2020. Impact of magnetic fields generated by AC/DC submarine power cables on the behavior of juvenile European lobster (Homarus gammarus). Aquatic Toxicology, 220, p.105401.

[18] Ernst, D.A. and Lohmann, K.J., (2018). Size-dependent avoidance of a strong magnetic anomaly in Caribbean spiny lobsters. Journal of Experimental Biology, 221(5).

[19] Tomanová, K. and Vácha, M., 2016. The magnetic orientation of the Antarctic amphipod Gondogeneia antarctica is cancelled by very weak radiofrequency fields. Journal of Experimental Biology, 219(11), pp.1717-1724.

[20]MMO (2014) The Marine Management Organisation (MMO) Response to an Independent Review of Environmental Data Collected at UK and European Offshore Wind Farms and 22 Recommendations for Future Post-Consent Monitoring.

Table 2-2 Summary of studies investigating the effects of artificial magnetic fields on crustacean species; adapted from Albert *et al.* (2020)

Type of response considered	Species	Life stage	Lifestyle	Duration	Characteristics of magnetic field exposure		Reference
					Magnetic induction (mT)	Observed effects	
Survival	North Sea prawn (*Crangon crangon*)	Adult	Vagile epifauna	49 days	3.7 mT DC	None	Bochert and Zettler (2006)
	Isopod (*Saduria entomon*)			93 days			
	Ispod (Sphaeroma hookeri)			34 days			
	Round crab (*Rhithropanopeus harrisii*)			57 days			
Physiological	North Sea prawn (*Crangon crangon*)			3 hours	3.2 mT DC and 50 Hz AC	No effects on oxygen rate consumption	
	Baltic prawn (*Palaemon squilla*)						
	Edible crab (*Cancer pagurus*)			6 hours	2.8 mT DC	No effects either on oxygen consumption rate or haemocyanin concentrations. Suppression of night rises in D-lactate and D-glucose concentrations.	Scott *et al.* (2018)
Behavioural	European lobster (*Homarus gammarus*)	Juvenile	Vagile epifauna	One week or 45 minutes	220 µT 50 Hz AC and DC	No effect on the exploratory and shelter-seeking behaviours.	Taormina *et al.* (2020)
	Edible crab (*Cancer pagurus*)			7 hours	2.8 mT DC	Attraction behaviour	Scott *et al.* (2018)
				24 hours		Suppression of side selection behaviour	

	Spiny cheek crayfish (*Oronectes limosus*)	Adult		24 hours	0.8 mT	Attraction behaviour	Tanski *et al.* (2005)
	Spiny lobster (*Panulirus argus*)			15 minutes	703.1 mT	Repulsion behaviour	Ernst and Lohmann (2018)
	Freshwater crab (*Barythelphusa canicularis*)			2.5 hours	50 Hz AC	Attraction and aggregation behaviour	Rosaria and Martin (2010)
	North Sea prawn (*Crangon crangon*)			1.5 hours	2.7 mT DC	No effects on spatial distribution	Bochert and Zettler (2006)
	Isopod (*Saduria entomon*)						
	Round crab (*Rhithropanopeus harrisii*)			1.5 hours	2.7 mT DC	No effects on spatial distribution	Bochert and Zettler (2006)
	American lobster (*Homarus americanus*)			12-24 hours	*In situ* Real cable: 0.01 to 0.1 mT	Behavioural changes	Hutchinson *et al.* (2018)
				24 hours	1.01 mT DC	No effects on spatial distribution	Woodruss *et al.* (2012, 2013)

	Dungeness crab (*Metacarcinus magister*)			3-4 days	1.01 mT DC	No effects on spatial distribution and no effect of the level of agitation	
	Red crab (*Cancer productus*)				*In situ* Cable 1: 0.014 to 0.12 mT 60Hz AC Cable 2: 0.025 to 0.043 kV 60Hz AC	No effect on catchability	Love *et al.* (2017)
				1 hour	*In situ* Real cable: 0.042 to 0.08 mT 60 Hz AC	No effect on spatial distribution	Love *et al.* (2015)
	Yellow rock crab (*Metacarcinus anthonyi*)						
	Amphipod (*Gondogenia antartica*)			1 minute	2.10-9 to 20.10-9 mT 1 MHz AC	Distribution of orientation abilities	Tomanova and Vacha (2017)

NRW TE Fisheries Comment 2

It is advised that further detail of the EMF calculations undertaken is provided.

Response

The methodology and calculations to determine the effects of EMF are provided in Appendix C of this Report: Greenlink Interconnector Offshore HVDC Cable Route – Magnetic Fields. The magnetic field profiles were generated by the CYMCAP® cable rating programme.

The static magnetic field strength for three different burial scenarios for Greenlink has been calculated, namely; 0.6m, 1.0m and 1.5m. The resultant magnetic field strengths at the seabed immediately above the cables are 67 µT, 53 µT and 7.9 µT, respectively. At burial depths of 1.0m and 1.5m the magnetic field at the seabed will not be detectable above the normal static background magnetic field generated by the earth. Where the cables are buried to 0.6m depth the magnetic field generated by the cables will reduce to 5 µT i.e. within background levels, within 2m from the cables.

It may be noted that a single cable conducting 797A would generate a magnetic field of 240µT at the seabed, which indicates the cancelling effect of the two bundled cables.

NRW TE Fisheries Comment 3

It is advised that the magnetic field intensity quoted may underestimate the actual magnetic field intensity that could be experienced by fish, and that the distance from the cable that effects may occur is greater than 2m.

Response

Revised EMF calculations have been provided as Appendix C of this Report, and as indicated in Response to NRW TE Fisheries Comments 1 and 2 at 0.6m burial depth (the shallowest target depth of lowering) the static magnetic field strength generated by the cables will not be detectable above the normal static background magnetic field generated by the earth within 2m of the cables. Therefore, the conclusions in the EIA are still valid.

2.2.5 *Coastal Processes*

NRW TE Coastal Processes Comment 1

Section 6.6.4 Water flow (tidal currents) changes-local: We advise that the applicant should specifically assess the likely stability of the seabed sediments at locations where rock protection works are required.

Scour could also arise in the future where external cables protection may be required to protect cables which were previously buried in soft sediment e.g. cable

repair, exposure from sand wave movement. GIL acknowledge in section 3.8.3 Maintenance and Repair of the Marine HRA Rev2 that the Proposed Development includes five discrete cable repairs, each 1km in length and assumes as a worst case that external cable protection up to 10m wide will be required to protect the new section of cables if they cannot be buried into the sediment. There is clearly a potential for scour to occur where external cable protection measures are implemented in soft sediments and as a result we disagree with GIL's conclusion of Section 6.6.4 of the ES that for the Proposed Development the overall significance of the effect is Negligible.

Response

Greenlink discussed this comment with NRW TE (Joanna Ibrahim) on 08 July 2020. It was agreed that NRW's primary concern is that there is the potential for scour to develop around cable protection used in soft sediments e.g. at the crossing with Pan European Cable 1. NRW requested that Greenlink consider periodic monitoring of cable protection to identify scour and if appropriate propose mitigation to minimise the development of scour pits. It was agreed that no additional assessment was required at this stage.

Regular inspection surveys of cable protection are standard practice to ensure structural integrity is maintained. Greenlink are currently planning inspections in years 2, 4 and 6 of operation, with added environmental monitoring as part of the Habitats Compensation Plan proposed for the Pembrokeshire Marine SAC. Inspection surveys will be carried out on all cable protection in Welsh waters with a monitoring report provided to NRW after each survey reporting on any scour development.

After year 6 the frequency of inspection surveys may continue as proposed frequency, decrease if trends suggest a longer inspection regime is sufficient, or increase if conditions have changed. NRW will be informed of any planned changes to the inspection regime.

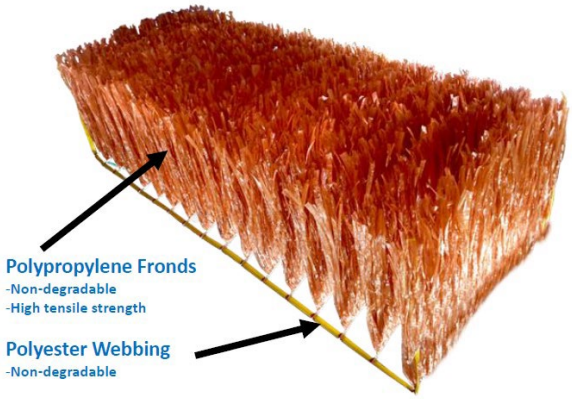
If scour is identified during the inspection surveys, appropriate mitigation will be discussed with NRW. At the meeting the potential to use frond mats in soft sediments was discussed as an anti-scour mechanism. Frond mats are constructed from UV stabilised polypropylene fronds secured to polyester webbing. When these mats are laid the fronds float and resemble natural seaweed. As local currents transport sediment through the fronds, the fronds locally interrupt and reduce the velocity of the near bottom currents. Transported sediment drops out of suspension due to the velocity change and builds up to form an embankment on and around the mats.

The mats can either be deployed attached to concrete mattresses or using a gravity system. In the gravity system, the perimeter of the mat will consist of a hollow tube filled with shingle (small particle sized sand and gravel. The weight of the tube anchors the mat to the ground. Mats can be custom made to any size, but the standard size is 5m x 2.5m. The standard length of the fronds is 1.25m. This would

allow up to 1m of sediment to be captured in the mats, completely burying them, and filling in any scour pits that develop.

Deposition of the mats would require a variation to the Marine Licence, accompanied by the necessary environmental assessment. This would be discussed with NRW should the inspection surveys identify it may be required.

Frond mat



NRW TE Coastal Processes Comment 2

GIL calculated that 16,628m^3 of sediment will be suspended in Welsh waters by cable burial through jetting. NRW require further clarification as to what the total volume of fines in suspension would be arising from pre-sweeping activities which involve dredging or mass flow excavation amounting to 496000m^3 of sediment and whether the SSC dispersed would not have any significant effects on sensitive receptors.

Response

The Greenlink Marine ES indicated that pre-sweeping activities may be required at two locations: between KP25.8 and KP26.4; and between KP64 and KP69. In response to NRW TE Coastal Processes Comment 3 (below) Greenlink have committed to routeing the cables around the sand wave at KP25.8 to KP26.4, avoiding the requirement for pre-sweeping at this location.

With respect to the sandwaves between KP64 and KP69, sediments comprise of between 3% and 6% fines[21]. Assuming a maximum volume of 400,000m^3 of sediment is removed and re-deposited the anticipated volume of fines mobilised has been calculated as 24,000m^3 (based on sediment comprising 6% fines).

Sediments suspended by pre-sweeping will travel with the tide and therefore will head generally northwest or southeast depending on the state of the tide at any given time. The calculations presented in Section 6.6.3 of the Greenlink Marine ES, Wales indicated silt particles will travel further and may remain in suspension for

[21] PSA data for grab sample 953_FR_DG_B3_S19 (located at KP61.5) indicates composition is 6% fines (3% clay and 3% silt). Grab sample 953_FR_DG_B4_S18 (located at KP67) indicates composition is 4% fines (4% silt). Grab sample 953_FR_DG_B3_S17 (located at KP71.5) indicates composition is 3% fines (3% silt).

up to 14 hours before settling out. In this time, they could travel 7.6km from the centreline assuming that the water direction and speed was constant. However, as the tidal cycle off Pembrokeshire is 12-hourly it is likely that particles will not travel as far, instead being transported back in the general direction of the centreline as the tide turns. Conservatively, it can be assumed that sediment suspended by the burial process could settle up to 7.6km either side of the centreline. However, once particles settle out of suspension the depth of the deposition is very small as the volume disturbed is spread over such a large area and is typically undiscernible from background sediment suspension and deposition levels. Based on the above, there would be no significant effects on sensitive receptors.

NRW TE Coastal Processes Comment 3

We advise against sand wave clearance where possible. Sandbanks are Annex 1 habitats that support a wide range of species upon which the conservation objectives of a SAC may be based, all of which can be sensitive to disturbance and changes in morphology. We recommend that these features are avoided where possible within Welsh SACs. Sand removal from the marine environment would further constitute a permanent loss of sediment to the coastal sediment budget. We advise that all disturbed sediment from jetting/trenching/sandwave clearance will be retained within the marine environment and not removed.

Response

Two indicative areas of sand wave clearance where indicated in the Greenlink Marine ES, namely at: KP25.8 to KP26.4; and KP64 to KP69.

Following discussion of this clarification request with NRW TE (Joanna Ibrahim, 08 July 2020), Greenlink can confirm that they will commit to routeing the cables around the sand wave at KP25.8 to KP26.4, avoiding the requirement for pre-sweeping.

The sand waves between KP64 to KP69 are outside of the Pembrokeshire Marine SAC in an extensive area of sand waves. Water depths are approximately 110m to 116m. The sandwaves cannot be routed around, although effort will be made to micro-route the cables through the field so that the sand waves are crossed at the lowest elevations. The highest sand wave in this section of the Proposed Development is 3m (trough to crest). The Greenlink Marine ES assesses the use of either a mass flow excavator (MFE) or trailing suction hopper dredger (TSHD). Should MFE be used the sediment will not be removed from the seabed and will remain within the sediment cell. Should a TSHD be required, Cefas has approved a section of the Application Area 2km distance either side of the sandwave feature i.e. from KP64 to KP72, for the disposal of the dredged material. This will ensure that there will be no permanent loss of sediment if sand wave clearance is required.

NRW TE Coastal Processes Comment 4

Advise to use LAT as the lower limit for HDD seaward exit.

Response

Greenlink will commit to using the lowest astronomical tide as the lower limit for the HDD seaward exit. This requirement will be passed on to the HDD contractor for inclusion in the design of the HDD.

NRW TE Coastal Processes Comment 5

HRA Section 4.3.1.4 - We would like further clarification to support this assumption and to be provided with calculations to confirm that the location of the external protection measures at KP 2.38 would remain below the closure depth during high waves and longer wave periods and that sediment transport near the bed would not be affected by wave current interaction and remain dominated by hydrodynamic tidal flows.

Response

It is agreed that the depth of closure calculation, which was based on the simplified Hallermeier approach, is relatively crude. In discussion with NRW TE, it was agreed that the inner and outer depth of closure should be re-calculated based on the approach detailed below:

1. Inner Depth of Closure

The more detailed Hallermeier (1978)[22] equation has been used to calculate the inner depth of closure, which can be defined as the seaward limit of the littoral zone and accounts for wave period as well as significant wave height, namely:

$$h_c = aH_e + b(H_e^2/gT_e^2) \qquad (22)$$

where H_e is the nearshore significant wave height that is exceeded for only 12 hours a year, T_e is the associated wave period, and g is the gravitational acceleration (9.81 m/s^2). Coefficients a and b are given by 2.28 and -68.5 respectively. Further details can be found at: https://www.nature.com/articles/s41598-020-59718-5.

It should be noted that the Turbot Bank wave buoy (station 62303) has been employed to calculate both the inner and outer depth of closure based on a time series between 2010-2015.

In order to determine the significant wave height, the significant wave heights over this period were ranked largest to smallest and the 60th (5*12) highest significant wave height (7.3 m) was used in the Eq. 1. The corresponding wave period of 9 s was also used. This gave an inner depth of closure of 12.1 m. In order to adopt a precautionary approach, Intertek also looked at the highest significant wave height (9.3 m) and corresponding wave period (11 s) over this record, which gave an inner

[22] Hallermeier, R. J. Uses for a calculated limit depth to beach erosion. Proc. 16th International Conference on Coastal Engineering.
1493–1512 (1978).

depth of closure of 16.2 m. The shallowest point of the rock in the vicinity of the external protection measures at KP 2.38 is approximately 22.1 m below LAT and, therefore, below the inner closure depth.

2. Outer Depth of Closure

In addition to the inner depth of closure, the outer closure depth has also been calculated, which can be defined as the seaward limit of the shoal/buffer zone. In addition to significant wave height and wave period, the equation used to calculate the outer closure depth considers the grain size.

It was agreed with NRW TE, that the US Army Corps of Engineers[23] approach should be used, namely:

$$d_i = (\overline{H_s} - 0.3\sigma_s)\overline{T}_s(g/5000D)^{0.5} \qquad (23)$$

where $\overline{T}_s$ is the average period associated with the average significant wave height. The term $\overline{H}_s - 0.3\sigma_s$ is also defined as the yearly median significant wave height. The same dataset from the Turbot Bank wave buoy has been used to derive the median significant wave height over the five year record, which is 1.4 m. The average wave period associated with this median significant wave height is 5.6 s. Grab samples have been taken along the Proposed Development and a particle size analysis subsequently undertaken. The sediment closest to KP 2.38 was defined as slightly silty very sandy GRAVEL with the following sediment fractions:

- Silt – 1%
- Sand – 37%
- Gravel – 62%

Intertek tested a range of particle sizes in the calculations and, adopting a precautionary approach, have used a particle size of coarse silt/fine sand of 0.06 mm. Based on Eq. 2, this gives an outer depth of closure of 1.4 m. If $\overline{H}_s$ and $\overline{T}_s$ is replaced with values used for the inner depth of closure equation (Eq. 1), the outer depth of closure is 11.8 m. Furthermore, if $\overline{H}_s$ and $\overline{T}_s$ is replaced with the highest significant wave height (9.3 m) and corresponding wave period (11 s) over the 5-year record, the outer depth of closure is 18.5 m. Based on these calculation, it is, therefore, evident that the shallowest point of the rock in the vicinity of the external protection measures at KP 2.38 is below the outer closure depth.

2.2.6 Water Quality

NRW TE Water Quality Comment 1

While we agree coarse material produced via cable burial will not have an impact on Bathing Water quality, we consider that HDD outputs have not been considered.

[23] Brutsché, K. E., Rosati, J. and Pollock, C. E. Calculating Depth of Closure Using WIS Hindcast Data. USACE (2015). https://cirp.usace.army.mil/products/files/doc/CHETN-VI-DOC_120315_DRAFT.pdf

Potentially fine-grained material could be produced which will protect bacteria sourced from the river from harmful UV radiation.

Response

This response was discussed in a teleconference between NRW TE, Greenlink and Intertek on 09 July 2020 and again on 16 July 2020. It was agreed that data (from literature review) on suspended sediment concentrations (SSC) during storm conditions could be informative for the assessment of effects from the HDD. It was also agreed that to close out the comment information should be provided on the HDD process e.g. where the exit location will be in relation to the Bathing Water, the potential for suspended sediments, whether drilling fluid will be discharged at the exit point and if so how much, and the timing of works in relation to the Bathing Water season.

The information requested is not currently available to Greenlink as the process of securing an Installation Contractor is currently underway. Although general principles have been discussed, currently a highly conservative approach to mitigation would need to be assumed that would overstate the risks to water quality and bathers.

Greenlink are confident that a range of suitable risk-based mitigation can be provided, and as outlined in detail in Response to Comment 4 below, are proposing that a licence condition is agreed that requires Greenlink to submit a Bathing Water Mitigation Plan, to be approved by NRW prior to any licensable works being undertaken.

NRW TE Water Quality Comment 2

The applicant has stated that mitigation will come in the form of no works at Freshwater West in July and August. Whilst we welcome this, it does not fully cover the Bathing Season which runs from 15/05 to 30/09 and therefore we question the dates selected.

Response

The dates selected were identified as the main tourist season through public consultation. In recognition of the importance of Freshwater West as a public resource Greenlink has committed to Project Specific Mitigation (PS1) which states "No intrusive works will be undertaken at Freshwater West between mean high-water springs and mean low-water springs." However, it was felt that the presence of vessels in the nearshore area during the peak tourist season may also have negative effect on beach users from the visual aspect. It was therefore proposed that works in the nearshore will also be avoided between July and August.

Following discussions with NRW TE, Greenlink will also commit to avoiding works which generate a sediment plume during and two days before and after bank holidays; namely Easter, May Day, Spring Bank Holiday (end of May) and August Bank Holiday (end of August).

NRW TE Water Quality Comment 3

We remain concerned about bathers (or beach users) safety on the beach if there are to be plant there.

Response

Greenlink stated in the Greenlink Marine ES, Section 4.8.1.4 that there will be no works required on the beach. This was further supported by Project Specific Mitigation PS1 which states "No intrusive works will be undertaken at Freshwater West between mean high-water springs and mean low-water springs." And PS17 which states "No works to be undertaken on beach at Freshwater West during July and August (inclusive)." There is no intention to place equipment or plant on the beach and therefore beach users' safety will not be compromised.

NRW TE Water Quality Comment 4

The use of an early warning system for Freshwater West Bathing Water is not appropriate. The Applicant should avoid works during the Bathing Season (15th May to 30th September) to protect human health and the Bathing Water classification; however, if this is not agreed upon an Abnormal Situation could be applied and should be discussed with the NRW Water Policy team and the local NRW Environment Officer. Appropriate signage should be placed at the Bathing Water.

Response

As discussed, in a teleconference between NRW TE, Greenlink and Intertek on 09 July 2020, Greenlink do not believe a restriction for the entire Bathing Water Season (15th May to 30th September) would be appropriate. The optimal timing for cable installation is from April through to October due to weather conditions. Greenlink are already balancing other seasonal restrictions to avoid effects on environmental receptors (e.g. to Castlemartin Firing Range), have committed to avoid where feasible nearshore works in May to account for the surfing competitions held at Freshwater West and are committed to avoiding the peak bathing season (July to August) when the beach is especially important for tourism. The addition of a restriction for the entire Bathing Water Season further limits the cable installation window and potentially pushes it into months when it would be more exposed to delays due to weather. Although it is not unfeasible that cable installation could take place across winter months there is a great risk of delays extending the installation window and potentially extending effects on receptors such as navigation and commercial fisheries.

Intertek understand from teleconferences held on 09 July and 16 July 2020 that the main concern NRW TE have is that heightened sediment loads e.g. from HDD or trenching could cause bathing water quality issues if it decreased the degradation rate of biological contaminants in the water. Greenlink will not cause biological contamination. The main risks to the bathing water catchment are from runoff of

surface water draining surrounding pastoral land during wet weather conditions; and the St Twynnells and Castlemartin sewage treatment works which discharge treated sewage effluent in the Freshwater West bathing water catchment[24]. There are no storm water overflows located within the catchment. It is GIL's understanding therefore that the main risk to the bathing water will be after wet weather conditions when there is a heightened risk of biological contaminants in the bathing water.

NRW TE, Greenlink and Intertek discussed that there a number of ways to mitigate effects to the bathing water such as starting works that disturb sediment (e.g. HDD or trenching) on the ebb tide, so that sediment is transported away from the bathing water; declaring a short-term pollution event if the works occurred during wet weather; or declaring an Abnormal Situation. The potential for Greenlink to undertake water quality sampling during works was also discussed.

Key information to inform the selection of mitigation is not currently available as the process of securing an Installation Contractor is currently underway. Although general principles have been discussed, currently a highly conservative approach would need to be assumed that would overstate the risks to water quality and bathers. The following information is needed from the Installation Contractor to select the appropriate mitigation:

1. Exactly where will the HDD exit point be in relation to the Bathing Water.
2. How long will works that disturb sediments (i.e. cable installation and HDD) take place in the Bathing Water.
3. When will the works take place in the Bathing Water.
4. Is there any information available on how the plume will move across the bathing water.
5. What and how much drilling fluid will come out from the HDD exit point.
6. What measures will be in place to manage risks associated with vessels (including jack-up-barge) in the Bathing water.

With respect to points 5 and 6, Greenlink has received additional information from the Preferred Engineering, Procurement and Construction (EPC) Tenderer. Please note this information should be read as indicative since the HDD contractor has not been selected yet. Therefore, there might be some differences between the typical method as outlined below and the final method after completion of detailed engineering phase and HDD contractor selection.

The HDD exit will be between the -5m and -9m LAT depth contours within the Marine Licence Application Corridor. If the HDD exit is between -5m and -8m LAT it is possible that a controlled flow excavator will be used to bury the cables from the HDD exit point to the -9m LAT contour at which point the offshore jetting /trenching

[24] 2017 Bathing Water Profile for Freshwater West [online] Available at: https://environment.data.gov.uk/wales/bathing-waters/data/bathing-water-profile/ukl1403-38248/2017:1 (Accessed July 2020)

equipment can be mobilised. The controlled flow excavators generate columns of seawater which travel vertically down towards the seabed fluidizing the sediment and allowing the cables to sink into the sediment to the required depth. The technique will create a sediment plume. However, the potential distance requiring the technique is short (250m – 300m) and can be completed within one day (with a contingency for an additional day to account for operational or weather delays). The activity could also be controlled so that the controlled flow excavator is only operational on an ebbing tide i.e. the sediment plume is directed away from the beach and bathing water. The -5m LAT contour lies approximately 476m from the low water mark.

The drilling fluids to be used for the HDD are likely to be 'Bentoniet – HV[25]' (a modified bentonite), 'Bio Polymer' (a biodegradable drilling fluid additive) and 'Vis Reg' (a modified natural cellulosic polymer), or similar. All are certified as being environmentally friendly. Bentonite is classified by Cefas as posing little or no risk to the marine environment.

HDD contractors are developing a mud collection container unit (MCCU) which can be placed over the exit point on the seabed. The MCCU contains the drilling fluid exiting at the seabed. Pumps installed inside the MCCU will then pump the contained drilling fluid to the surface where it can either be transported to the shore either by hoses or stored inside fluid containers on a barge. The later storage method is most likely at Freshwater West.

Currently, it is proposed that the duct openings on the seabed will be drilled during the final reaming. This means that no additional excavation would be required e.g. by back-hoe dredger. During the punch-out at the seabed the drilling fluid inside the borehole will be level with the sea level. Based on available information and drilling profiles, the Preferred EPC Tenderer has estimated that approximately 17m^3 per 100m of bore could flush into the sea at the punch-out unless the MCCU is installed. For a 1600m long HDD bore this would equal 272m^3 per bore; 544m^3 in total. With the set-up of the MCCU 90% of this volume can be contained and pumped to the surface for disposal; 10% or approximately 54.4m^3 would be discharged to sea.

An additional source of drilling fluid discharge is when the drill pipe is pushed inside the borehole. Approximately 62m^3 of drilling fluids per borehole could be discharged at this stage – total of 124m^3 for two bores, but again the set-up of the MCCU would prevent 80% of this volume being discharged to sea. Approximately 24.8m^3 would be discharged to sea.

Greenlink also understand that should signage be required at the Bathing Water e.g. if a short-term pollution event or Abnormal Situation is declared this would require agreement from the Pembrokeshire Coast National Park Authority. Greenlink are already in discussion with the Authority for similar signage requirements related to

[25] Note this is the product name for a modified bentonite.

the onshore construction works. Greenlink is confident that agreement can be reached should it be required.

In conclusion, Greenlink are confident that a range of suitable risk-based mitigation can be provided but currently as the final design information is not available from the Installation Contractor, discussions are theoretical and trying to cover worst-case situations which may not arise. It is therefore proposed that a license condition is agreed that requires Greenlink to submit a Bathing Water Mitigation Plan, to be approved by NRW prior to any licensable works being undertaking. Wording is suggested below:

1.1 The Licence Holder must submit a Bating Water Mitigation Plan to NRW acting on behalf of the Licensing Authority for written approval prior to commencement of the licensable works. No licensable works may be undertaken prior to written agreement from NRW acting on behalf of the Licensing Authority.

1.2 The Licence Holder must ensure that any actions outlined in the documents detailed in condition 1.1 are implemented as approved in writing by NRW acting on behalf of the Licensing Authority. Any proposed changes to the actions outlined in the documents must be submitted to, and agreed in writing by NRW acting on behalf of the Licensing Authority prior to any changes being enacted.

2.3 JNCC

JNCC Comment 1

We commend the applicant's commitment to use low-order detonation techniques (also known as deflagration) should any UXOs >50kg require clearing during the cable installation; emerging evidence suggests this method is a viable alternative for clearing UXOs (Merchant & Robinson 2020). However, we advise this technique is applied for any UXO removed, not just those over 50kg.

Response

Greenlink have discussed this point with a UXO expert[26] and can commit to using deflagration for any UXO charge that would otherwise require detonation.

JNCC Comment 2

Should a UXO be removed using low-order detonators, we request a detailed account of the operation is included in the MMO report and request consideration is

[26] Welch, D (2020). Telephone conversation between Anna Farley, Intertek and Dave Welch, Ramora UK, 07 July 2020.

given to collecting underwater noise measurements to add to the ongoing work in this area.

Response

The requirement to provide JNCC with a report detailing an account of the operation should deflagration be used has been included in the Marine Mammal Mitigation Plan Revision 1 (submitted with this report).

Should a UXO require deflagration, Greenlink commits to undertaking underwater noise measurements to add to the body of research that can be used to inform future assessments of effects on marine mammals. Measurements will be undertaken following the 'Good Practice Guide for Underwater Noise Measurement[27]' including following best practice for in-situ measurement of underwater sound, for processing the data, and for reporting the measurements using appropriate metrics.

A Noise Measurement Procedure will be agreed with NRW and JNCC and will be appended to the Marine Mammal Mitigation Plan. It will outline:

- The objectives that the measurements seek to fulfill;
- How the measurement system performance will be checked to ensure it is fit for purpose;
- How the system will be calibrated;
- The procedure for deployment;
- How deployment noise will be managed;
- How ambient sound measurements will be taken alongside measurements of the UXO deflagration and acoustic mitigation;
- What auxiliary measurements will be required to support the data e.g. sea-state, wind speed, water depth, seabed type etc.
- Steps that will be taken to protect recorders and data from loss;
- Data analysis procedures;
- Reporting procedures e.g. what information will need to be reported (frequency, received levels at recording locations, estimated source level of activity, etc)

It is proposed that this would be secured through discharge of license conditions. Greenlink therefore anticipate that licence conditions similar to the below will be included on the consent:

1.1 The Licence Holder must submit a Noise Measurement Procedure to NRW acting on behalf of the Licensing Authority for written approval prior to commencement

[27] National Measurement Office, Marine Scotland, The Crown Estate, Robinson, S.P., Lepper, P. A. and Hazelwood, R.A. (2014). NPL Good Practice Guide No. 133, ISSN: 1368- 6550, 2014. https://www.npl.co.uk/special-pages/guides/gpg133underwater

of the Licensable Activities. No Licensable Activities may be undertaken prior to written agreement from NRW acting on behalf of the Licensing Authority.

1.2 The Licence Holder must ensure that any actions outlined in the Noise Measurement Procedure detailed in condition 1.1 are implemented as approved in writing by NRW acting on behalf of the Licensing Authority. Any proposed changes to the actions outlined in the documents must be submitted to, and agreed in writing by NRW acting on behalf of the Licensing Authority prior to any changes being enacted.

JNCC Comment 3

We reiterate our previous advice that the work can only go ahead if undertaken in conjunction with an EPS licence to cover the risk of injury.

Response

Greenlink Interconnector Limited are committed to applying for an EPS Licence to cover the risk of injury and disturbance associated with the UXO detonation (deflagration). As previously advised the application will be submitted to NRW Species Licensing once it is established that all comments with respect to marine mammals on the Marine Licence Application have been closed out.

JNCC Comment 4

JNCC provide the following comments on the Marine Mammal Mitigation Plan (MMMP).

- We highlight that the JNCC web page is being updated and the mitigation guidelines and data forms are now in new locations:

- Geophysical surveys: https://hub.jncc.gov.uk/assets/e2a46de5-43d4-43f0-b296-c62134397ce4
- Explosive guidelines: https://hub.jncc.gov.uk/assets/24cc180d-4030-49dd-8977-a04ebe0d7aca

- Section 2.1.1 Mitigation Team: this section states that it is acceptable under JNCC guidelines for an individual to fulfil both the MMO and PAM role during the same activity. While this is correct, we emphasize these roles cannot be undertaken by the same individual at the same time.

- Section 2.1.1.3 EOD Supervisor: this section states the EOD supervisor will have the authority to delay detonation 'if they consider it necessary'. We highlight that the role of the MMO/PAM operators is to advice the operator of when a marine mammal is within the mitigation zone and that a delay is required under the guidelines. If the EOD considers a delay is unnecessary after being informed of this, they will be in breach of the MMMP and JNCC guidelines. We recommend the

applicant reconsider the wording of this section so the requirements of the MMMP are clear.

- Section 2.2.2.5 Soft Start: we highlight that in the JNCC guidelines, a soft start for the geophysical equipment that may be used by the applicant can be the same as described in the guidelines for airguns with a volume of <180 cubic inch e.g. can be between 15 and 25 minutes.

- Section 2.3.3.3 Mitigation zone: It should be noted that the mitigation zone is that within which injury/PTS onset may occur, not that which will be visually or acoustically observed. While for geophysical surveys these areas are usually the same, in this instance the mitigation zone is larger than can be visually/acoustically monitored, hence the requirement for additional mitigation measures e.g. ADD deployment. We suggest the applicant consider the wording in this section to make this clear.

- Section 2.3.3.7 Use of low order detonation as soft start: we recommend the title of this section is changed to remove reference to low order. While the charges used for a soft start procedure are small, low order detonation typically refers to the deflagration of explosive devices i.e. the procedure the applicant has committed to undertaking if devices >50kg explosive weight are undertaken. This method of detonation is very different from that where small charges are detonated as a soft start.

- 2.3.5 Reporting: Thank you for including JNCCs email address to which the report should be submitted. We highlight that a different address may be required for NRW.

- Low-order detonation of UXOs: We advise this method is utilised for all UXOs not just those greater than 50kg. This is due to the predicted injury ranges for a 1.54kg UXO being greater than that which can be mitigated using ADDs.

- In addition, it is not clear in the MMMP whether the mitigation measures described e.g. the pre-detonation search and ADD deployment, would also be carried out prior to deflagration. We highlight that the pre-/post-detonation search and deployment of the ADD will still need to be undertaken prior to this technique being used.

Response

The Marine Mammal Mitigation Plan has been updated to address all the comments provided. Revision 1 has been submitted with this report.

To provide clarification; the mitigation measures described (e.g. pre-/post-detonation search and ADD deployment measures) will be carried out prior to any planned detonation, including deflagration.

2.4 Cefas UWN Advice

Cefas Comment 1

Major comment 11 (i): NRW recommended using the threshold of 140 dB (SEL) as a proxy for disturbance for impulsive noise, since this is the threshold for TTS onset in high frequency cetaceans (for impulsive sources) (NMFS, 2018), and the assessment has done so. The 140 dB SEL threshold is based on the SELcum (over a 24-hour period), please note that behavioural effects are instantaneous and generally do not require assessment of the cumulative sound exposure (SELcum). As the source level (and presumably propagation etc.) are based on the SPLpeak, it is unclear how the report derives such impact ranges. (Note, this comment also applies to the UXO modelling).

Response

Whilst a threshold of 140dB was used to calculate the distance at which the onset of behavioral effects may be experienced it is acknowledged that this was incorrectly referenced as SEL in the Greenlink Marine Technical Appendix D Underwater Sound Modelling report. Instead distances at which the SPLpeak propagated to 140dB were presented. The distances calculated are still a valid estimate of the range at which onset of disturbance may occur.

This distinction has been made clear in the Greenlink Marine Technical Appendix D Underwater Sound Modelling (reference P1975_R4484_RevF3) and Greenlink Marine HRA (reference P1975_R4710_RevF3).

Cefas agreed in a teleconference on 10 July 2020 that this would close out the comment.

Cefas Comment 2

Major comment 11 (ii): Secondly, the thresholds for TTS and recoverable injury in fish that are provided in Table 3-6 are based on the SPLrms metric and are for continuous (not impulsive) sources (see Popper *et al.*, 2014).

Response

The Greenlink Marine Technical Appendix D Underwater Sound Modelling (reference P1975_R4484_RevF3) and Greenlink Marine HRA (reference P1975_R4710_RevF3) have been updated to address this comment and the correct thresholds applied.

Cefas Comment 3

Major comment 13: It appears as though the predicted impact ranges in Table 3-9 are based on the SPLrms and not the cumulative SEL, as the table is suggesting. In other words, the 24-hour exposure has not been added to the SPLrms, meaning that the predictions provided in Table 3-9 are erroneous underestimates. In order to compare model predictions with the marine mammal noise exposure criteria, the predictions should be based on the SEL. I would be happy to provide further advice on this, if this is required.

Response

This comment was discussed at length by Intertek and Cefas during a teleconference on 10 July 2020. Cefas has advised that in order to calculate the predicted distances of effect for continuous noise, 49dB should be applied to the source level values to convert them to SEL.

Intertek disagree with this approach as SEL are receptor exposure levels calculated on the basis of 24hours continuous received signal (i.e. reduction of the SPL threshold by 49.37dB (10log(24*3600)) re 1 s as a base case, adjusted for auditory range of the receptor). Increase of the source level by a similar amount results in a total adjustment of 98.74dB re 1 s. As each 3 dB increase represents a doubling of exposure time, the overall adjustment represents an exposure time of 2(98.74/3) seconds or over 2.2 million hours. This results in distances to SEL thresholds which appear excessive.

Agreement could not be reached during the meeting and therefore Intertek have provided both sets of calculations in the Greenlink Marine Technical Appendix D Underwater Sound Modelling (reference P1975_R4484_RevF3). Table 3-9 now includes both SPL and SEL source levels.

Intertek does not believe this revised assessment to be representative of the relatively minor effects of cable installation on marine mammals. The zones of influence for effects to marine mammals increase significantly with this approach, and far exceed any estimated distances predicted and presented by the industry literature (OSPAR 2008). For instance, the distance over which injurious effects (TTS) to harbour porpoise may be experienced from rock placement increases from 210m to 18km. This would indicate that cable installation has significant effects on marine mammals. This goes against current studies (OSPAR 2009[28] and 2012[29]) which recognise that cable installation activities are relatively minor. A zone of Influence of 18km is more akin to the to the effects from underwater piling activities or UXO detonation.

In conclusion, Intertek questions Cefas' proposed approach which we believe represents a substantial increase in exposure time above the 24hour assumed exposure. Intertek do not agree with the results as re-calculated and Intertek propose that the original calculations are closer to representing sound propagation in the marine environment and are not are erroneous underestimates.

Cefas Comment 4

Major comment 17: I recommend that in order to appropriately apply the Popper criteria, the thresholds should not be adjusted to 24 hours. Based on how long the activities are expected to last, one should make an assessment of how likely recoverable injury and TTS might be to occur. This should be more straightforward

[28] OSPAR (2009), Assessment of the environmental impacts of cables. Publication Number: 437/2009, 19 p.
[29] OSPAR (2012), Guidelines on Best Environmental Practice (BEP) in Cable Laying and Operation Reference 12/22/1, Annex 14

than assessing the SELcum, given that the source levels provided in the assessment are SPLrms values (and also no auditory weightings are required).

Response

Previously Intertek had been advised that SEL should be based on 24 hours exposure hence why the adjustment had been made. This was to provide consistency with the thresholds for marine mammals. The approach has been revised calculations in the Greenlink Marine Technical Appendix D Underwater Sound Modelling (reference P1975_R4484_RevF3). However, it does not change the conclusion that continuous noise from the Proposed Development will have a negligible effect on fish. This is supported by Popper et al. (2014) which identifies that there is no direct evidence of permanent injury to fish species from shipping and other continuous noise (such as cable installation) and OSPAR (2012)[29] that considers the potential for likely significant effects to fish from cable installation activities is minor.

Cefas Comment 5

Minor comment 18: Page 34 of the report states the following: "Southall *et al.* (2019) does not provide the duration for the SEL thresholds however, NMFS (2016) specify 24-hour exposure for the same threshold values expressed as dB re 1µPa-2s. NMFS (2016) specifies that the non-impulsive thresholds should be modified where exposure times are either less or greater than 24-hours. A 3dB change represents a factor of two change in the exposure time e.g. 3dB is added to the threshold when the time is halved (decreasing the sensitivity of the receptor), conversely 3dB is subtracted when the time is doubled (increasing the sensitivity of the receptor)". This is more to note for future assessments (as it doesn't appear as though the thresholds have been adjusted in this case), however, please be aware that the noise thresholds are fixed and there is no flexibility in adjusting them (e.g. they cannot be adjusted to reflect different exposure durations). The cumulative SEL calculation is always based on the maximum cumulative SEL that an animal would accumulate over a 24-hour period, regardless of the duration of the activity.

Response

Noted.

Cefas Comment 6

Major comment 20: Please note that I have not reviewed the HRA or MMMP in detail (as there was not enough time (budget) to allow for this). However, on page 57 of the HRA, I disagree with the following statement: "Modelling suggests that animals could only be exposed to injurious effects within 2m of the installation vessels. However, to put this into context the threshold for onset of injurious effects assumes that the animal must be present within the area for 24-hours for the noise to cause effects. It is implausible that animals will stay within 2m of the installation vessels for 24-hours and therefore it is concluded that there is no risk of the installation causing injurious effects". While I agree that animals are unlikely to remain at distances close to the source for 24 hours, the assessment currently does

not present sufficient evidence to conclude that there is no risk of the installation causing injurious effects. This is primarily because the predicted impact ranges are erroneous (please see previous comments, e.g. point 13).

Response

See response to Comment 3 (Cefas point 13). Intertek propose that the original calculations provided in the underwater noise modelling report are closer to representing sound propagation in the marine environment than the approach proposed by Cefas and are not are erroneous underestimates. The estimates are in line with current studies (OSPAR 2009[28] and 2012[29]) which recognise that continuous noise from cable installation activities is relatively minor. The project vessels proposed are standard ships used for activities throughout the UK continental shelf.

Cefas Comment 7

Comment 23: It is unclear what the report means by "mitigation in the form of a neutralization charge": does the applicant mean that the UXO will be disposed of by low-order detonation (deflagration)? If not, and a high-order detonation is envisaged, then the charge mass of the UXO should be used for the assessment of effect distance, since the original explosive may remain active. It would be helpful if the applicant could clarify this.

Response

To clarify the statement "mitigation in the form a neutralization charge" refers to the use of deflagration. Detail of this technique is provided in Section 2.2.1 in Response to NRW TE Marine Mammal Comment 1.

Greenlink have committed to using deflagration on all charge sizes.

Cefas Comment 8

Comment 24: Further, these statements are vague; injurious effects up to 16.6 km for what species? A reference to the relevant results table would also be helpful.

Response

This comment refers to a statement made on page 106 of the Greenlink Marine HRA Revision F2. The statement is outlining the mitigation proposed to avoid significant effects on the Pembrokeshire Marine SAC Qualifying Feature Grey Seal. The value 16.6km has been taken from Table 3-8 of the Greenlink Marine HRA Appendix A (Greenlink Marine ES Technical Appendix D – Underwater Noise Modelling Revision F2). It represents that largest modelled zone of influence for TTS effects on seal from the two UXO detonation points selected for modelling for the detonation of a 794kg charge. The purpose of the statement was to highlight the benefit of using deflagration in that it reduces the potential zone of effect for TTS from 16.6km to 6.2km in the example presented. The source of the information has been clarified in Revision F3 of the Greenlink Marine HRA (reference P1975_R4710_revF3).

Cefas Comment 9

Comment 27: We would encourage applicants to seek independent, specialist advice/confirmation from operators about the feasibility of deploying bubble curtains at the specific site in question.

Response

Two specialist bubble curtain companies were contacted to understand the technical limitations of bubble curtain deployment. Responses from Hydrotechnik Lübeck suggested the only environmental factor that influences the deployment of bubble curtains is the current speed. However, in a tidally dominated area this could be compensated by deploying the bubble curtain at slack tide.

Additional advice is unlikely to be forthcoming until more specific information requiring the position of a UXO requiring deflagration is provided. Therefore, a review of literature was conducted to determine environmental limitations and efficacy of big bubble curtains (BBC); with reference made to Verfuss *et al*. (2019)[30].

Cheong *et al*. (2020)[8] states that *"increased water depth militates*[31] *against bubble curtains"*. Verfuss *et al*. (2019)[30] supports this statement reporting that the deployment and efficacy of big bubble curtains (BBCs) is more challenging in water depths deeper than 30m. The challenge is to get sufficient air from surface compressors to the hoses lying on the seabed. The report states *"a larger number of compressors and a higher operating pressure are needed for deeper water to generate a higher air flow to ensure that large enough bubbles are released into the water at depth."* However, it does report the commercial deployment of BBCs on windfarms in water depths up to 45m; and that suppliers report commercial deployment of their systems in water depths >70m (with Nord Stream 2 using BBCs during UXO clearance in water depths up to 90m).

Verfuss *et al*. (2019)[30] also reports that for BBC deployment, a significant wave height of 1.5m is the frequent limiting factor for safe deployment. However, information provided by the suppliers to the report authors suggests that deployment and operation is feasible in significant wave heights up to 3m. Other environmental limitations include a water current speed of 1m/s. The report states that "*With a rise velocity of 0.3 m/s, (realistic for a BBC) and a tidal current of 1 m/s, bubbles would drift off by about 70 m when rising from 20 m depth to the water surface. Thus, the resulting bubble curtain would not build up vertically but obliquely. Therefore, to provide a complete shield, the BBC would need to be deployed in an oval shape, with the point of the oval ring greater than 70 m away from the pile position facing the current."* The efficacy of the BBC is therefore impacted by strong currents, especially in deep water.

[30] Verfuss, U.K., Sinclair, R.R. and Sparling, C.E. (2019). A review of noise abatement systems for offshore wind farm construction noise, and the potential for their application in Scottish waters. Scottish Natural Heritage Research Report No. 1070.
[31] Represents a conclusive factor in preventing

At water depths of up to 40m Verfuss *et al*. (2019)[30] states that a reduction of 7-11 dB SEL_{ss} can be achieved with respect to piling noise and the use of a BBC. However, the efficacy decreases with increasing deployment depth. Verfuss *et al*. (2019) [30] also reports that studies undertaken by the German Federal Armed Forces Underwater Acoustics and Marine Geophysics Research Institute concluded that attenuation of more than 10 dB and up to 16dB in peak sound pressure levels could be achieved with 1 to 3 BBCs when detonating a 1kg charge at 13m water depth; and although noise measurements of UXO clearance using BBCs for the Nord Stream 2 gas pipeline in water depths of up to 90m showed that peak pressure levels were less than assessed in the permit application, no evaluation of the effectiveness of the bubble curtain was presented.

With respect to environmental conditions within the Proposed Development the key factors are presented below:

- Water depths within the Proposed Development increase relatively rapidly from the coast with the 40m depth contour reached at KP9.4. The seabed then gradually slopes to the 70m depth contour at KP42.9.
- Spring tidal currents reach peak speeds of 1.0m/s to 1.5m/s generally in a northwest-southeast direction past the Pembrokeshire coast. Currents during neap tides peak at around 0.75m/s (Barne *et al*. 2005)[32].
- The average wave height for the Proposed Development ranges from 1.75m to 2m at the UK/Irish median line increasing to between 2.5m to 4m at the Freshwater West landfall (Barne *et al*. 2005)[32]. Data for South Wales Wave Resource Area (Fairley 2014)[33] which although not located in the Proposed Development provides a good indication of the likely wave climate and indicates mean significant wave height of 1.63m.

Based on the environmental limitations reported in Verfuss *et al*. (2019)[30] this would suggest that wave height, tidal currents and water depth all could be limiting factors within the Proposed Development; especially as a seasonal restriction limiting UXO detonation to winter months is proposed which would decrease the chance of achieving optimal weather conditions for deployment. It can therefore not be guaranteed that the deployment of a BBC is technically feasible.

However, taking the above into consideration, Greenlink will commit to:

- A big bubble curtain (BBC) will be used for deflagration in water depths equal to or less than 40m i.e. between KP0 and KP9.4.
- If a UXO is identified in water depths of 40-70m advice would be sought as to practicalities and cost of deploying a BBC in winter at the specific location. A BBC will be used if the contractor concludes it will be effective.

[32] Barne, J.H., Robson, C.F., Kaznowska, S.S., and Doody, J.P., eds. (1995). Coasts and seas of the United Kingdom. Region 12 Wales: Margam to Little Orme. Peterborough, Joint Nature Conservation Committee.
[33] Fairley, I. (2014) Wave Climate Analysis in South Pembrokeshire from 20-year Time Series of the Turbot Bank Buoy. Marine Energy Research Group. https://www.marineenergywales.co.uk/wp-content/uploads/2016/01/Turbot-Bank-Wave-Report_1014-Rev0.pdf [accessed March 2019]

Appendix A

Greenlink Cable Burial Risk Assessment

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GREENLINK INTERCONNECTOR LIMITED

Greenlink Interconnector

Cable Burial Risk Assessment

P1975J1_R4574_Rev 3 | 22 October 2019

Intertek Energy & Water Consultancy Services
Exchange House, Station Road, Liphook, Hampshire GU30 7DW, United Kingdom

DOCUMENT RELEASE FORM

Greenlink Interconnector Limited

P1975J1_R4574_Rev 3

Greenlink Interconnector

Cable Burial Risk Assessment

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Rev No	Date	Reason	Author	Checker	Authoriser
Rev 0	15/10/2018	Interim CBRA issue (pre-survey)	LDU	ATR	APA
Rev 1	23/11/2018	Interim CBRA re-issue (pre-survey) - updated with final route and based on client's comment	LDU	ATR	APA
Rev 2	25/09/2019	Revised CBRA based on Geophysical & Geotechnical Survey results	CCA/ATR	APA	APA
Rev 3	22/10/2019	Revised following received comments	CCA/ATR	APA	APA

Intertek Energy & Water Consultancy Services is the trading name of Metoc Ltd, a member of the Intertek group of companies.

SUMMARY

Greenlink Interconnector Limited, trading as 'Greenlink,' is proposing to develop an electricity interconnector linking the existing electricity grids in the UK and Ireland. The 'Greenlink' project will consist of two converter stations, one close to the existing substation at Great Island in County Wexford (Ireland) and one close to the existing substation at Pembroke in Pembrokeshire (Wales). The converter stations will be connected by underground cables (onshore) and subsea cables (offshore).

Intertek Energy & Water Consultancy Services (Intertek) has been appointed by Greenlink to conduct a Cable Burial Risk Assessment (CBRA) study for the marine sections of the Greenlink Interconnector cable route. The Interconnector will consist of two HVDC submarine power cables, likely bundled together with a fibre optic cable for control purposes.

This report (Revision 3) is the final version of the CBRA which incorporates the results of the Geophysical and Geotechnical survey campaigns completed on **03 May 2019** and comments received on Rev2 of the report **.**

The Cable Burial Risk Assessment (CBRA) has shown that the following key hazards are present along the Greenlink cable route:

- sediment mobility
- anchoring; and
- fishing.

The process to calculate the Target Depth Of Lowering (TDOL) is as follows:

1. Analysis of survey results to categorise the seabed into individual zones of similar seabed sediment type, water depth range and vessel traffic density
2. Analysis of external threats to determine depths of penetration of each external aggressor (fishing gear and various anchors sizes) in identified seabed soils in each zone of the route, according to industry research;
3. Addition of an appropriate Factor of Safety (FoS) to each of the respective maximum penetration depths;
4. Analysis of external threats (fishing gear and anchors) to calculate (where data allows) the probability of an aggressor-cable interaction in each zone of the route;
5. Determination of which threats must be protected against through burial in order to reduce risk from external aggressors down to As Low As Reasonably Practical (ALARP);
6. Determine Recommended Minimum Depth of Lowering (RMDOL) for each zone of the route by selection of the greatest penetration depth value calculated (including the FoS) for identified aggressors which must be protected against in each zone of the route in order that the overall risk to the cable over the project lifetime is reduced to ALARP;
7. Target DOL (TDOL) is then determined as what can reasonably be added to RMDOL without incurring a step change in costs and which represents a practical target for burial tools on the market

The key hazards are explained below:

Sediment Mobility

Sediment mobility in itself does not pose a threat to a submarine cable but it can lead to issues with the thermal conductivity of cables (over burial), and exposure of cables (scour); burial under excess sediment can change the thermal properties of the soil and cause hotspots along the cable, while exposure increases the risk of damage due to external aggressors such as trawling and anchoring and potentially mechanical damage from free spans.

There are a number of areas within the Greenlink 500m survey corridor where there are bedforms present which could be mobile.

The first indication of mobile bedforms can be seen between KP 5 and KP 6, just beyond an area of outcrop located in the nearshore area at Freshwater West. This area of potential mobile bedforms is located to the south of the centreline within an Annex I habitat sandbank area. The bedforms are up to 2.5m high and have a wavelength of ~250m. Smaller megaripples (height ~0.3m, wavelength ~7m) are located on the larger bedforms. These smaller megaripples extend beyond the extent of the underlying large bedforms up to KP 10 where they stop due to a change in sediment.

The next indication of mobile bedforms is at KP 26 where the centreline transects two very large sandwaves which have a height of 12m (at KP 26) and 8m at (KP 26.3) and wavelengths of 280m. Megaripples are also present on these larger features. Small isolated patches of Megaripples are then observed up to ~KP 59 (~0.3m height, ~10m wavelength).

At ~KP 59 the megaripples increase in size to ~0.5m height, ~25m wavelength and then gradually decrease in size as the route progresses to ~KP 137, likely due to a fining of sediments. There are isolated sandwaves underlying the megaripples at KP 83 (height 1.5m, wavelength 230m), KP 99 (height 5m, wavelength unknown), KP 109 (height 4m, wavelength unknown) and KP 112 (height 3.5m, wavelength unknown). At KP 89 and KP 91 there are large relic sandbank features which have an elevation shift of ~5m and ~3m respectively. These relic sandbank features might still have some mobility.

For the remainder of the route (i.e. KP 137 to KP 159) there are no further large bedforms but megaripples (height 0.5m, wavelength 10m) are present from ~KP 149 to KP 159 within a channel on the approach to the landfall in Ireland.

In addition, Intertek is also aware that beach levels in Freshwater West vary with sediment movement after storm events.

For the purposes of burial targets (RMDOL & TDOL) all depths recommended in this report are assumed to be measured against a horizontal plane which has been determined to be non-mobile and after any required mobile bedform engineering has been undertaken to flatten mobile sediments.

Fishing Risk

The review of the fishing assessment report (ref 7) for the Greenlink interconnector indicated areas of mobile and static fishing gear along the entire cable route. No fishing protection or exclusion areas from fishing activity were reported.

Moreover, as the entire route is within water depth ranges in which mobile gear fishing could take place, we recommend the cables are given sufficient protection from fishing gear interaction in all sections of the route. The Carbon Trust's guidance (ref 1) indicates that penetration of fishing gear into the seabed is limited to a maximum of 0.3 m penetration even in soft sediment based on previous literature research. Allowing for a FoS of 2 means RMDOL based on fishing risk only would result in a value of 0.60m.

In Zones 11-19 where anchor risk is not present due to water depths exceeding 100m fishing risk is the sole determinant of RMDOL. In addition, adopting a value of 0.60m to protect against fishing risk results in fishing risk being the determinant or co-determinant of RMDOL in all zones except Zone 3.

Anchoring Risk

Vessel Automatic Identification System (AIS) data has been used to determine the size and quantity of vessels which operate in the vicinity of the cable route. Vessels are grouped into size categories based on their deadweight tonnage (DWT) from Band A (0-1000 DWT) to Band G (175K-325K DWT) and an appropriate associated anchor size is assigned to each band. Analysis of this data determines the probability of anchor-cable interactions for each vessel banding and thus the size of anchor which must be protected against in order to reduce risk to the cable to ALARP.

The probabilistic assessment calculates the annual failure probability of 0.47% for the entire Greenlink route (based on anchor risk alone) if surface laid. This value equates to a return period of 214 years and a failure probability over the (40 year) lifetime of 17.08%. This is not an acceptable level of risk.

Anchoring risk is greatest in Zone 3, both in terms of vessel traffic density and also size of associated vessels. This is followed by Zone 4 and Zone 27. If the Greenlink cable is sufficiently protected within these zones from risk of anchor damage then the risk over the lifetime reduces significantly to the point where anchoring risk is only the determinant factor in Zone 3, and co-determinant in Zone 4, with all other zones having RMDOL determined by fishing risk alone. Note the key reasons why anchor risk is not the key determinant in most zones is due to both the relatively light vessel densities and also the prevalent presence of soils which prevent anchors from penetrating very deeply.

Recommended Minimum Depth of Lowering (RMDOL)

The above approach results in a RMDOL of 0.60m in all zones except Zone 3 where it is set at 0.75m. If these RMDOL values are achieved and maintained over the course of the cable lifetime then this would result in an annual failure rate of 0.02% which equates to a return period of ~6,291 years and a failure probability over the (40 year) lifetime of 0.63% - i.e. “Although they are conceivable, not expected to occur. Plausible but no known occurrences in industry.”

Target Depth of Lowering (TDOL)

TDOL is determined as what can reasonably be added to RMDOL without incurring a step change in costs and which represents a practical target for burial tools on the market. Intertek has analysed the soils and set TDOL as 1.5m where this is considered easy to achieve (Zones 1-4, 6, 12-17, 19-23, 25-28) and 1.0m where 1.5m would likely require multiple passes and/or different tools such that would not be required if only working to RMDOL. Note this approach is possible due to the relatively low RMDOL values calculated (i.e. maximum 0.75m).

The DOL specification by cable route zone are provided in **Appendix F**.

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GLOSSARY

AIS
Automatic Identification System

ALARP
As Low As Reasonably Practical

CBRA
Cable Burial Risk Assessment

CPT
Cone Penetration Test

DoL
Depth of Lowering

DoC
Depth of Cover

EU
European Union

FoS
Factor of Safety

Greenlink
Greenlink Interconnector Limited

HVAC
High-Voltage Alternating Current

HVDC
High-Voltage Direct Current

ICES
International Council for the Exploration of the Sea

IMO
International Maritime Organisation

Intertek
Intertek Energy and Water

MAIB
Marine Accident Investigation Branch

MBES
Multi-Beam Echo Sounder

MMO
Marine Management Organisation

PCI
Project of Common Interest

RMDOL
Recommended Minimum Depth of Lowering

SI
Seabed Index

SSS
Side-Scan Sonar

TDOL
Target Depth of Lowering

VC
Vibro-Core

1. INTRODUCTION

Intertek Energy & Water (Intertek) has been appointed by Greenlink Interconnector Limited (Greenlink) to conduct a Cable Burial Risk Assessment (CBRA) study for the marine sections of the Greenlink Interconnector cable route.

This report (Revision 3) is the final version of the CBRA which incorporates the results of the Geophysical and Geotechnical survey campaigns completed on **03 May 2019** and amendments based on comments received on Revision 2**.**

1.1 Project Background

Greenlink Interconnector Limited, trading as 'Greenlink,' is proposing to develop an electricity interconnector linking the existing electricity grids in the UK and Ireland. The 'Greenlink' project will consist of two converter stations, one close to the existing substation at Great Island in County Wexford (Ireland) and one close to the existing substation at Pembroke in Pembrokeshire (Wales). The converter stations will be connected by underground cables (onshore) and subsea cables (offshore). The subsea system will consist of two power cables, bundled together with a fibre optic cable for control purposes.

Greenlink will use high voltage direct current voltage (HVDC) technology to link the two power systems. Convertor stations will be located at either end of the Greenlink cable route to allow connection into the respective national grids. Greenlink will have key strategic importance providing significant additional interconnection between Ireland, the UK and onwards to mainland Europe. It will provide additional transmission network capacities, reinforcing the existing electricity grids in south-east Ireland and south Wales and contributing to each country's strategic interconnection objectives. The development and construction of Greenlink will deliver increased security of supply and fuel diversity, greater competition and ultimately provide significant benefits to consumers in Ireland, Wales and Great Britain as a whole.

Greenlink is designated as a European Union (EU) Project of Common Interest (PCI project number 1.9.1) under the provisions of European Union Regulation No. 347/2013 on guidelines for Trans-European Network for Energy (TEN-E Regulations) and has successfully applied for funding under the Connecting Europe Facility (CEF).

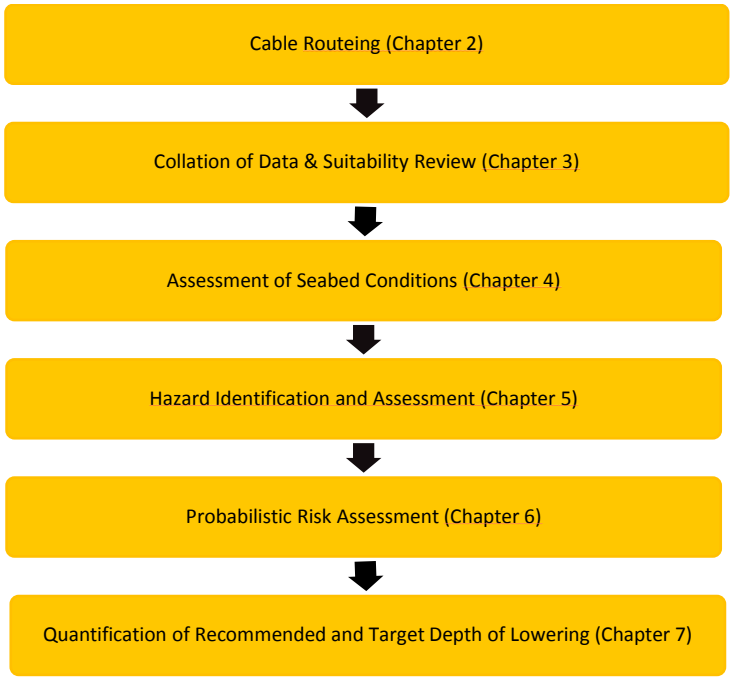
1.2 Scope of Work

The Scope of Work is as follows:

- Characterisation of the predominant hazards which could pose a risk to the cable system.
- Assessment of the risks posed to the cable system by the identified hazards.
- Assessment of the geophysical and geotechnical data along the cable route.
- Probabilistic assessment of the anchoring threat to the cable system using historical vessel AIS (Automatic Identification System) data.
- Determination of Recommended Minimum Depth of Lowering (RMDOL) and Target DOL (TDOL) along the route which if achieved would reduce risk to the submarine cable to levels acceptable to the project.

The CBRA study presented in this report has been undertaken following the Carbon Trust's proposed methodology (ref 1) and steps (see **Figure 1-1**).

Figure 1-1 Burial Risk Assessment method flowchart in line with Carbon Trust CTC835 guideline



1.3 Purpose of Report

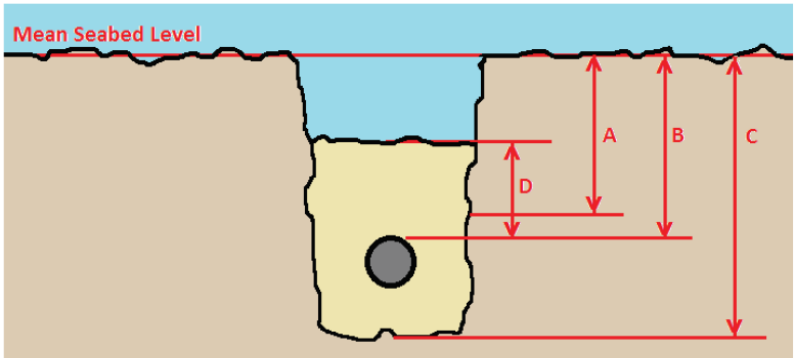
The purpose of this report is to identify any potential areas where activities, such as shipping and fishing, may pose a risk to the integrity of the installed cable. In the probabilistic risk assessment of anchoring risk, probability is measured as a ratio of the favourable cases to the whole number of cases possible. An event that would occur with certainty has a probability of 1.

Assumptions used are considered conservative and 'realistic worst case' which produces higher probabilities than would likely be the case. This enables the route and installation methods to be considered with a higher margin of safety.

1.4 Definition of Trenching Parameter

Intertek has used the Carbon Trust's definition of DOL for this study. This is illustrated in **Figure 1-2.**

Figure 1-2 Definition of Burial Terms used in Report



A Recommended Minimum Depth of Lowering
B Target Depth of Lowering
C Target Trench Depth
D Depth of Cover

Recommended Minimum Depth of Lowering (RMDOL)
This is the minimum DOL recommended for protection from the external threats. It is the direct output of the fishing risk assessment and the probabilistic anchor risk assessment and includes a factor of safety (FoS).

Target Depth of Lowering (TDOL)
This is the depth that will be specified as the target depth to the cable installation contractor. TDOL is a depth which makes best use of what is achievable by industry standard burial tools to gain additional depth beyond RMDOL without incurring a step change in costs. Target DOL is also a practical application of depth which considers the effect burial depth has on tool stability.

Target Trench Depth
This is the trench depth cable installation contractors determine is required to meet TDOL. This is driven by cable properties and the selected trenching tool and is usually the diameter of the cable plus between 0.1 m and 0.4 m beyond the TDOL.

Depth of Cover
The thickness of material on top of the cable after trenching. It is not normally required for cable protection; however, it may be required by some consenting authorities.

1.5 Relevant Data

Data obtained from the geophysical & geotechnical campaigns and other relevant data sources are presented in **Table 1-1** below.

Table 1-1 Provided Survey Data

Data Type	Name	Information
Survey Bathymetry (Ref2)	MMT_935_MERGE_2040_VORF_LAT_DTM_50cm	0.5m resolution bathymetry over a 500m survey corridor in UTM30
	Shaded_MMT_935_MERGE_2040_VORF_LAT_DTM_50cm	0.5m resolution bathymetry (Shaded Relief) over a 500m survey corridor in UTM30
	Bathymetry Contours obtained from Geophysical survey	0.5m bathymetry contours over the extent of the survey corridor
Open Source Bathymetry	EMODnet Bathymetry (Ref 3)	EMODnet Digital Terrain Model (DTM) is generated for European sea regions from selected bathy survey data sets (1975 to 2013 using SBES & MBES) and composite DTMs, while gaps with no data coverage are completed by integrating the GEBCO Digital Bathymetry. 200m Resolution
AIS Data (Ref 4)	_Intertek_Data_Extent_201708_to_201807	5-minute time series data of shipping activities in 2017 (12 months of data) +/- 30km either side of the Rev1 Greenlink route centreline provided by Oceaneering International Inc (ref 3)
Crossings (ref 5)	As found Pipeline/Cable data	As found XY locations and depth of burial for cables and pipelines along the cable route +/- 250m of the centreline
Contacts (Ref 6)	SSS contacts & Mag contacts	Seafloor Contacts and Magnetometer anomalies found within the 500m survey corridor
Seabed Features (Ref 8)	Seabed Classification & Features	Seabed surficial polygon of classified geology interpreted from SSS and correlated with MBES/SBP
Geology (Ref 9)	Shallow Geological Isopach	Shallow geological isopach interpreted from sub-bottom profiler data and correlated with side scan sonar imagery and bathymetric digital terrain model data
Geotechnical	Vibrocore, Cone Penetrometer Tests and	Geotechnical sample logs from Vibrocore (VC), Cone

Data Type	Name	Information
Samples (Ref 10)	grab sample logs	Penetration Test (CPT) and Grab Sample (GS)
Geotechnical Results report (Ref 10)	102953-GRE-MMT-SUR-REP-GEOTECRE-02102953-02, CPT-IRE-Final Plots v02, CPT-UK-Final Plots v02 and 102953 All VC 2019_04_08	Results of the Geotechnical campaign (Draft)
Geophysical Results reports (Ref 11)	102953-GRL-MMT-SUR-REP-GEOPHYRE-04	Results of the Geophysical campaign
Integrated Results report (ref 12)	102953-GRL-MMT-SUR-REP-INTEGRRE-02	Integrated Results of the Geophysical campaign
Admiralty Charts (Ref 13)	MarineFind	Navigation charts over the study area obtained from http://wmsgateway.findmaps.co.uk/wms/IntertecMetocCharts

Limitations

This document uses the information obtained from the geophysical and geotechnical campaigns carried out by MMT in 2018 and AIS data purchased from Oceaneering. This CBRA is based on MMT's survey results highlighted in **Table 1-1** and the geophysical and geotechnical reports (ref 10, 11 & 12).

2. CABLE ROUTING

2.1 Route Development Background

The Greenlink route (Greenlink_WGS84_UTM30N_09112018_Rev0) centreline has been developed by analysis of geophysical data collected throughout Q3 2018, to optimise the route from both a consenting and installability perspective. The revised centreline route originates in Freshwater West, Wales at the mean high-water mark (KP0) and ends at the mean high-water mark in Baginbun Beach, Wexford, Ireland at KP 159.267.

Four routes were originally proposed for survey on 17/08/2018 (ref: Greenlink Route Report_P1975_BN4437_rev3):

- Route A – Original base case route
- Option C – Route to different landfall (Boyce's Bay) in Ireland in case the preferred landfall, Baginbun, was not feasible
- Option D – Small additional route at the Irish nearshore to avoid outcrop; and
- Route E – Backup route in case route A was not feasible. Involves a longer route through a smaller area of potential reef.

Reconnaissance surveys along Route A and Route E were carried out in October 2018. This showed that both Route A and Route E contained large areas preliminarily identified as Annex 1 habitats that covered the full corridor widths in places. Natural Resources Wales were consulted and noted that the area of Annex I habitat lost would be too great to be considered insignificant.

On NRWs advice, a re-route was designed to avoid the Annex 1 habitats that were identified on both Route A and E. North-South Reconnaissance lines were carried out between route A and E to find the extent of outcrop associated with the Annex 1 habitat. Once the outcrop extent was highlighted, geophysical survey data was acquired within a new east-west oriented survey corridor which joined Route E to Route A.

Prior to survey, analysis of available bathymetry data within the Welsh nearshore area identified a possible sandy channel system through the extensive outcrop.

The survey data identified that the channel system deviated outside the initial survey corridor. Therefore, additional geophysical survey data was acquired showing that it was possible to follow the channel system north of the original route. A route was then developed to follow the channel avoiding the outcropping rock where possible, and survey data collected along this alignment.

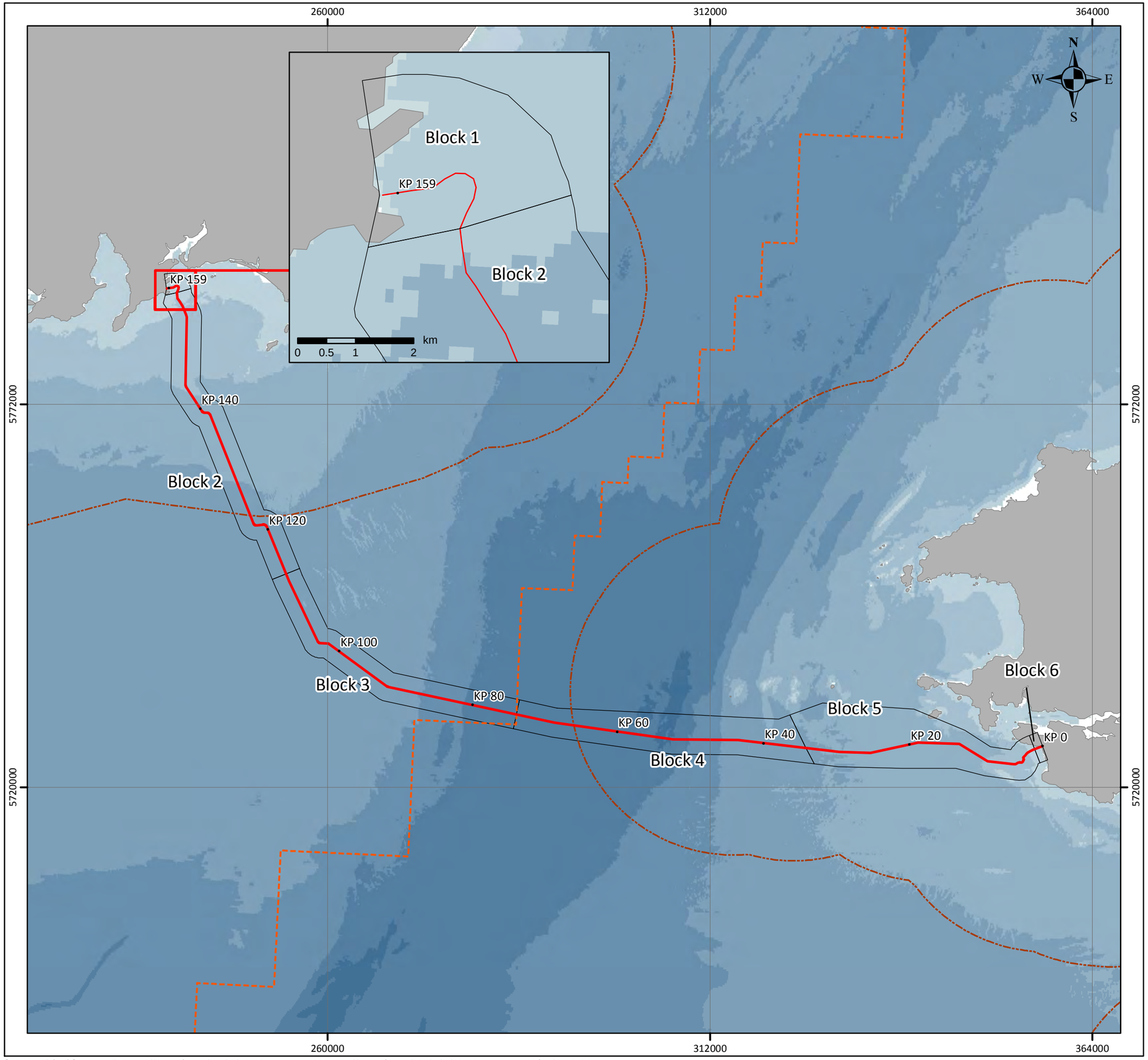
The Greenlink route has used a combination of the above to arrive at a single route centreline which is named the following:

- **Greenlink_WGS84_UTM30N_09112018_Rev0**

The survey corridor extents, associated with this route is named the following:

- **Greenlink_WGS84_UTM30N_09112018_Rev0_Survey_Corridor**

The route assessed in this report is presented in **Figure 2-1** below. The route was divided into 6 Blocks to optimise survey efficiency. The Blocks were approximately 50 km long, but the boundaries were adjusted to coincide with turns in the cable route and 10m water depth contour. Further details of the route development can be found in the routing report (Ref 14).



GREENLINK INTERCONNECTOR CABLE BURIAL RISK ASSESSMENT

Figure 2-1: Greenlink Route Overview

Legend

- Greenlink Route KP's
- Greenlink Route
- Median Line
- 12nm Territorial Sea Limit
- MMT Survey Block

Bathymetry (m below LAT)

- 0 - 20
- 20 - 40
- 40 - 60
- 60 - 80
- 80 - 100
- 100 - 120
- 120 - 150

NOTE: Not to be used for Navigation

Date	Tuesday, August 27, 2019 10:34:15
Projection	WGS_1984_UTM_Zone_30N
Spheroid	WGS_1984
Datum	D_WGS_1984
Data Source	UKHO, ESRI, DCCAE, EMODNET, CDA, MMT, Greenlink
File Reference	J:\P1975\Mxd\CBRA\ Fig_2_1_Overview.mxd
Created By	Chris Carroll
Reviewed By	Richard Marlow
Approved By	Alan Redman

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0 5 10 15 20 km

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The bathymetric metadata and Digital Terrain Model data products have been derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu. © Copyright Department of Communications, Climate Action and Environment (DCCAE). ©Esri. Contains data from UKOGD.

3. COLLATION OF DATA AND SUITABILITY REVIEW

3.1 Bathymetric Data

The seabed topography along the route is characterised by the presence of numerous mounds, areas of mobile sediments, outcrop of bedrock, boulders, linear features such as furrows or striations of coarser sediment and varying relief. The knowledge of these features is critical to any cable installation feasibility study. This section describes the existing bathymetry data in the study area and the resolution and quality of each dataset.

Sources for the bathymetry datasets can be found in Section 1.5 and is summarised below:

- EMODnet Bathymetry – 100m resolution
- MMT Survey Data – 0.5m resolution bathymetric soundings
- MMT Survey Data – 0.5m bathymetry contours

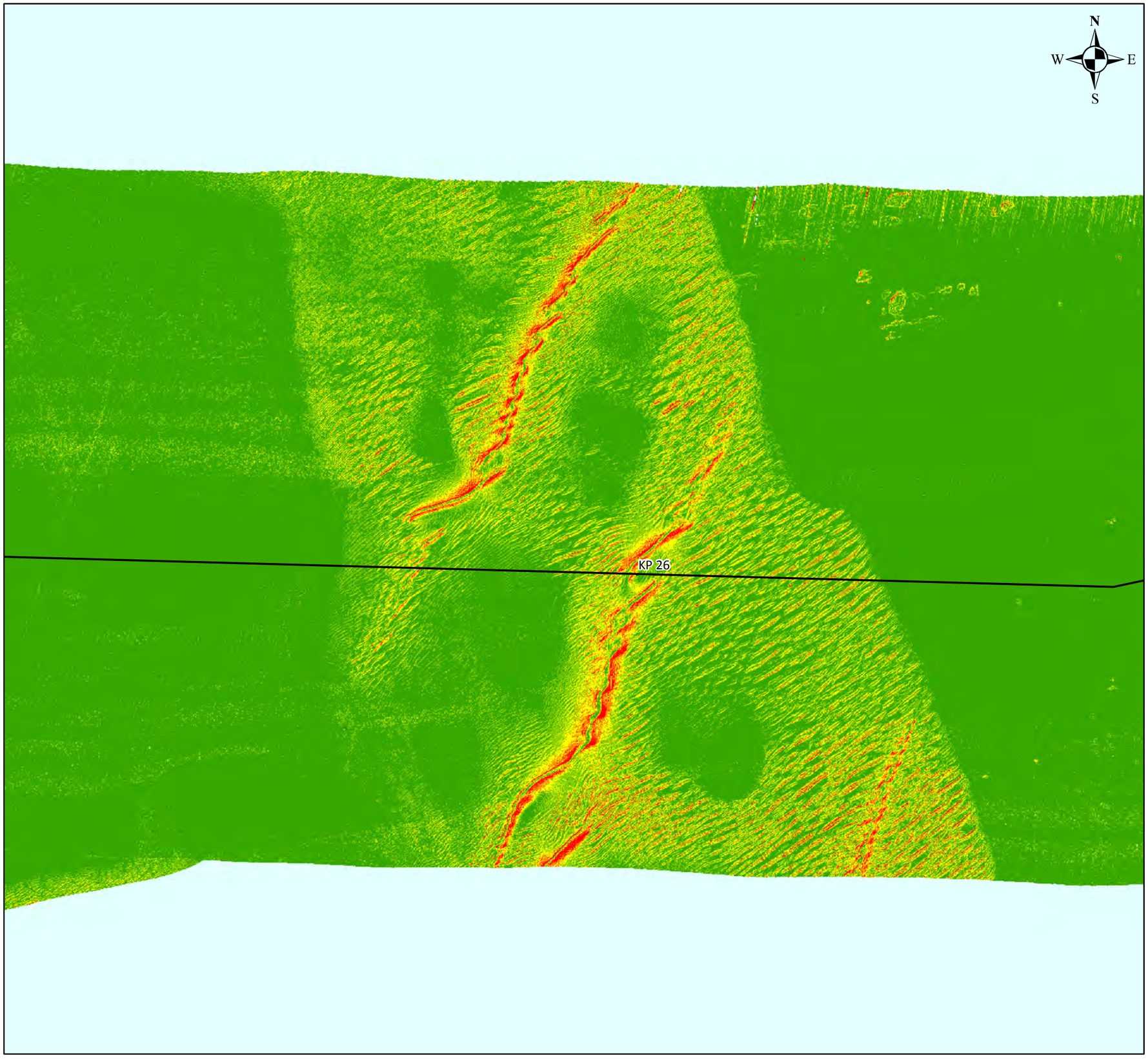
The open source data (EMODnet Bathymetry) was used to define the route centreline for survey. These sources provide a good overview of the surrounding area and highlight large features such as sandwaves. There is good overall correlation between the open source data and the acquired high resolution survey data. The open source dataset, however, does not provide the high resolution required to carry out a cable burial risk assessment. This resolution is provided by the data acquired along the route during the survey.

3.1.1 Suitability of Data

The bathymetric soundings obtained for this study is of very high quality and processed to a high resolution (0.5m). It has highlighted areas of shoaling, potential areas of sediment mobility, areas of outcrop and in some cases confirmed the presence of wrecks and obstructions.

The offshore dataset provided by EMODnet is a dataset suitable to show water depths, areas of shoaling and bathymetric lows. The low-resolution dataset confirms the presence of larger features in the study area, but its resolution is too low to determine any migration rate of mobile bedforms. The acquired bathymetric data could be used to provide this insight, if compared to a similar, but temporally different data set.

An example of the typical slopes encountered within the survey corridor has been provided by MMT and shown in **Figure 3-1**, while bathymetry of the cable route is displayed in **Figure 3-2.**



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GREENLINK INTERCONNECTOR CABLE BURIAL RISK ASSESSMENT

Figure 3-3: Seabed Slopes

Legend

- Greenlink Route KP
- Greenlink Route

Survey Bathymetry Slope (degrees)

- 0 - 5
- 5 - 10
- 10 - 15
- 15 - 20
- >20

NOTE: Not to be used for Navigation

Date	Tuesday, August 27, 2019 13:02:03
Projection	WGS_1984_UTM_Zone_30N
Spheroid	WGS_1984
Datum	D_WGS_1984
Data Source	ESRI, MMT, Greenlink
File Reference	J:\P1975\Mxd\CBRA\ Fig_3_1_Slopes.mxd
Created By	Chris Carroll
Reviewed By	Richard Marlow
Approved By	Alan Redman

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0 0.05 0.1 0.15 0.2 km

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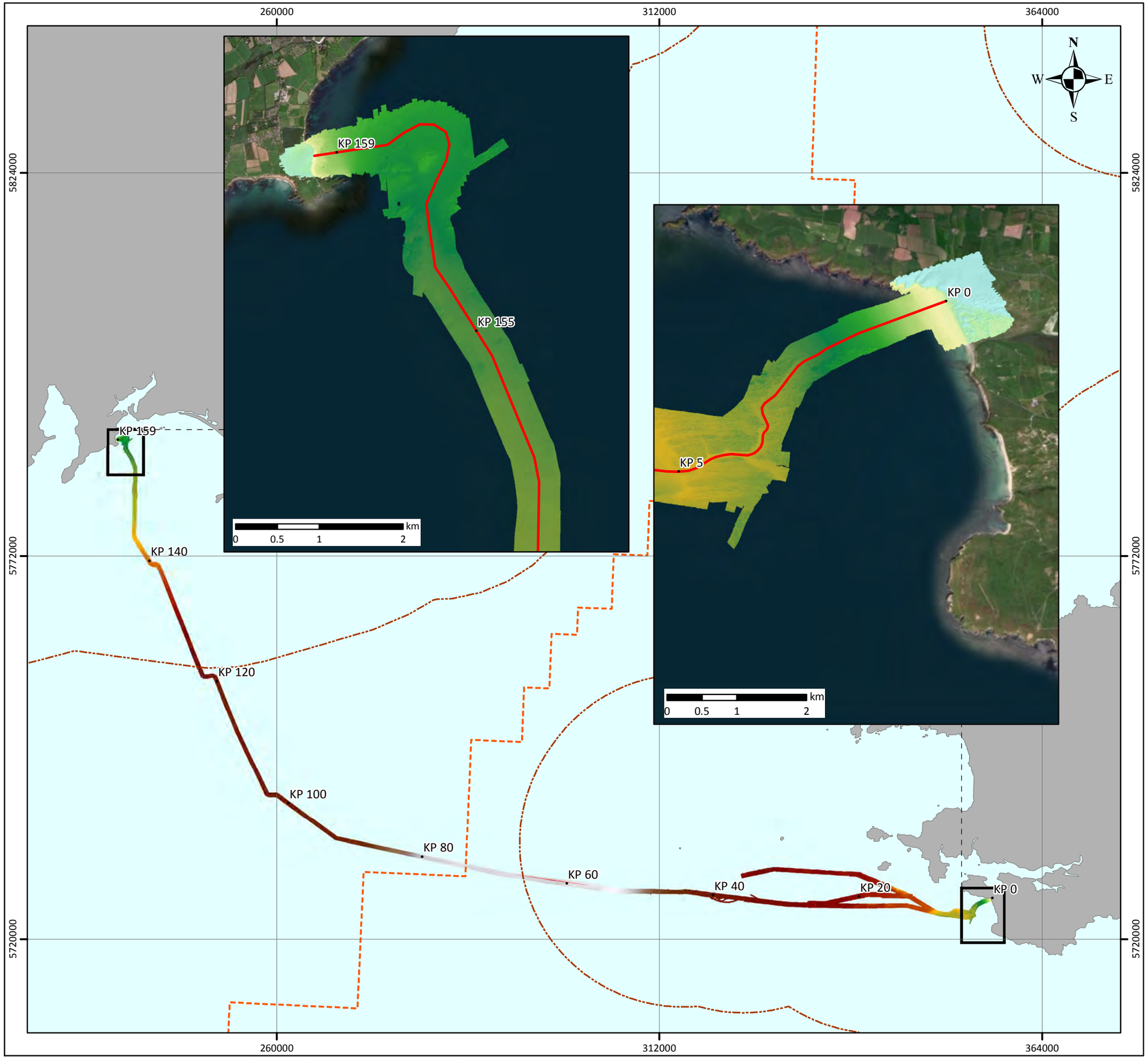

GREENLINK INTERCONNECTOR CABLE BURIAL RISK ASSESSMENT

Figure 3-2: Survey Bathymetry

Legend

- Greenlink Route KP's
- Greenlink Route
- Median Line
- 12nm Territorial Sea Limit

Survey Bathymetry (m below LAT)

130.32

-77.97

NOTE: Not to be used for Navigation

Date	Tuesday, August 27, 2019 11:42:05
Projection	WGS_1984_UTM_Zone_30N
Spheroid	WGS_1984
Datum	D_WGS_1984
Data Source	UKHO, GEBCO, ESRI, DCCAE, CDA, MMT, Greenlink
File Reference	J:\P1975\Mxd\CBRA\ Fig_3_2_Bathymetry.mxd
Created By	Chris Carroll
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Greenlink

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0 5 10 15 20 km

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3.2 Geophysical Data

Side scan sonar (SSS) data has been used for interpretation of surficial geology, identification of seabed features, and to select contacts. Sediment classes distinguished from SSS imagery are correlated with grab sample, vibrocore (VC) and cone penetration test (CPT) results. Topographical features identified from SSS records have been correlated with bathymetric digital terrain models processed from the bathymetric sounds acquired using the multibeam echo sounder (MBES). Shallow geology interpretations are based on sub-bottom profiler (SBP) data correlated with the geotechnical sampling results. SSS and MBES data is also used to corroborate the SBP data interpretation in the uppermost layers.

Magnetometer records collected during the survey are used to identify cables and ferrous objects on the seafloor within the survey corridor. A UXO survey corridor was defined within a known MOD firing range (Castlemartin) in the nearshore area of Freshwater West. A high-resolution magnetometer survey was carried out within this area to determine practicality of the primary route centreline. Note that due to line spacing, the geophysical survey outside the UXO corridor does not constitute an unexploded ordnance (UXO) survey. Full details of the geophysical and UXO campaigns can be found in ref 12 & 15 respectively.

3.2.1 Geophysical Survey (Blocks 01 to 06)

3.2.1.1 Bathymetry and Seabed Morphology

The route is generally characterised by flat or gradually changing seabed with very gentle to gentle slopes. The water depth is slowly increasing from the UK landfall towards a bathymetric trough, located approximately in the middle of the route. From there the water depth begins to decrease again, towards the Irish landfall. The maximum depth along the route is 127.8 m at KP 53.660 (UK offshore). Moderate gradients are generally associated with areas of mobile bedforms, comprising of megaripples and sandwaves, or over rocky outcrops. Mobile bedforms are frequently present throughout the corridor length. From the start of the route to KP 4.850 the route is leading through a channel between rocky outcrops. The maximum slope gradient encountered along the Rev 0 route centreline is 12.26° over a rock located on the route at KP 2.400, in the UK offshore section.

3.2.1.2 Seabed Sediments and Features

The surficial sediments vary mainly between sand and gravelly sand/sandy gravel with local areas of gravel and silt. Bedrock is found outcropping and subcropping mainly in the UK and Ireland nearshore as well as the beginning of the route, for the first 43 km, approximately. Large areas of outcropping bedrock are present within the 500m survey corridor. Areas of occasional and numerous boulders are usually present in the vicinity of outcropping and subcropping bedrock. Large areas of bedrock and clayey till are covered by a veneer of mobile sediments comprised of sand to gravel. Mobile bedforms of ripples, megaripples and occasionally sandwaves are present throughout the majority of the route. Some trawl marks were identified in the UK offshore section.

The interpretation of surficial sediment types was derived from the acoustic character of the SSS data, and the interpretations were aided by MBES bathymetric 3D surfaces and SBP data. During the review of the SSS survey data, higher intensity sonar returns (darker grey to black colours) were interpreted as relatively coarser grained sediments, and lower intensity sonar returns (lighter grey colours) were interpreted as relatively finer grained sediments. Bathymetric data was used to correct the interpretation for the effects of seabed slope on sonar returns. The correlation with the geotechnical results was initially based on the field logs and further verified with the final geotechnical results.

Seabed Sediment Classifications are as follows:

Table 3-1 Seabed Sediment Classification

Acoustic description	Interpretation
Low to medium acoustic reflectivity. Slightly grainy texture.	SILT and SAND The ratio between sand and silt can vary within this sediment type. The sediment often has a patchy appearance due to variation of the dominating sediment fraction.
Low to medium acoustic reflectivity. Slightly grainy to grainy texture with point source reflectors.	SILT Predominantly silt, may have minor fractions of clay, sand and/or gravel.
Medium acoustic reflectivity, slightly grainy texture.	SAND Predominantly sand, may have minor fractions of clay, silt and/or gravel.
Medium to high acoustic reflectivity. Slightly grainy to grainy texture, coarse texture in places.	Gravelly SAND to sandy GRAVEL The ratio between SAND and GRAVEL can vary within this sediment type.
High acoustic reflectivity. Grainy to coarse texture.	GRAVEL Predominantly gravel, may have minor fractions of clay, silt and/or sand.
Medium to high acoustic reflectivity. Exhibits relief and texture.	BEDROCK Comprises outcrops of crystalline bedrock

Seabed Feature Classifications are as follows:

Table 3-2 Seabed Feature Classification

Interpreted Seabed Feature	Criteria[1]
Ripples	Wave length <15 m, Height <1.0 m
Megaripples	Wave length 15-25 m, Height 1-3 m
Sandwaves	Wave length 25-200 m, Height >3 m
Boulder Field Occasional boulders All >0.5 m	Concentration of 10 to 20 boulders within a maximum area of 100 x 100 m
Boulder Field Numerous boulders All >0.5 m	Concentration of >20 boulders within a maximum area of 100 x 100 m
Trawl Mark Area	Concentration of numerous trawl marks
Current Lineation	Current lineation

[1] Note, there is no standard for bedform descriptions. Criteria presented in Table 3-2 are as defined by route survey contractor MMT. Alternative criteria are also common.

3.2.1.4 Contacts and Anomalies

The SSS contacts were selected according to the following criteria:

- Wreck
- Boulder
- Debris
- Other

During seabed interpretation, boulder occurrence at surface has been grouped based on the frequency and content of boulders >0.5 m per 50 x 50 m. Contacts less than 0.5 m were not picked.

Magnetic anomalies have been identified during both the geophysical survey and the UXO survey, details regarding the UXO survey and the associated UXO listings are presented in the UXO report (ref 19).

Magnetic anomalies, if identified, are classified according to the following criteria:

- Dipole, monopole or complex shape
- Single anomaly or anomalies creating a linear trend relating to possible or identified cable/pipeline crossings.

3.2.1.5 Shallow Geological Features

The shallow geology along the route is characterized by a sequence of sand, channel infills, till and bedrock (from top to bottom). A surficial sand unit is present over almost all of the route, with varying depth of some decimetres, as veneers over rock or till, to more than 10 m in some infills or mobile feature areas. The lower boundary of the sand unit is usually characterized by a gravel layer. On the Welsh platform, bedrock and till are present at shallower sediment depth, more frequently outcropping and subcropping, compared to the Irish platform. A thicker sediment cover is present in the basin extent of the St. George's Channel. Deep incisions in bedrock and till, filled by channel infill sediment (clay to gravel), are found throughout the route, although appear more extensively on the Irish platform.

The classifications of the shallow geology have been derived through a combination of analysis and interpretation of the acoustic character of the SBP data and was modified according to the geotechnical results. A comparison with available background information was made and broken down into major sediment types along the route (Table 3-3)

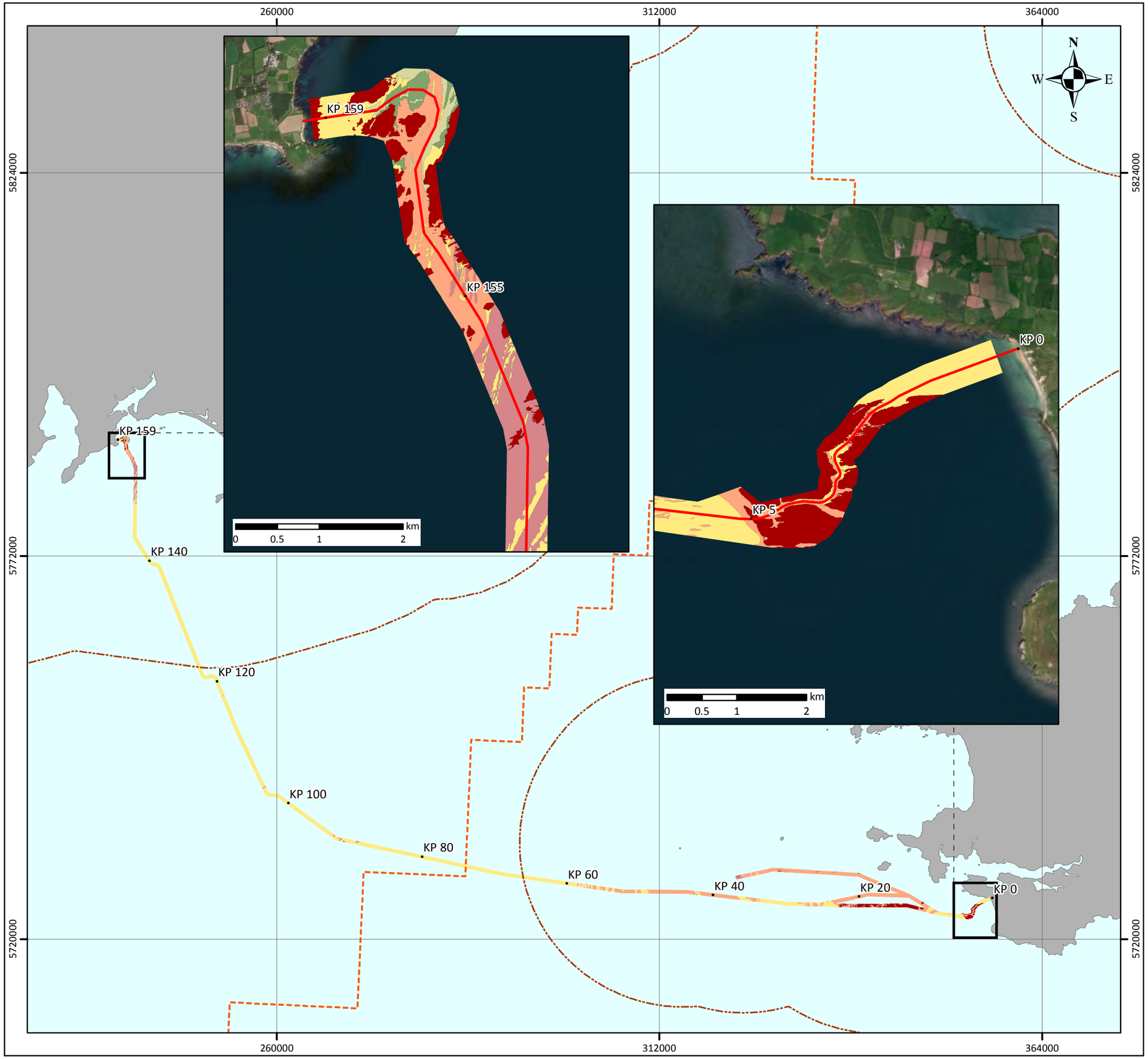
Table 3-3 Shallow Geology Soil Types and Lithology

Sediment Type	Acoustic Characters	Lithological Variation
Veneer	-	Veneer of mobile sediments not resolved in seismic data (generally <0.5 m). Gravelly SAND to GRAVEL. Occasionally SILT on Irish side. Veneer of reworked sediment by winnowing of fines often present of top of TILL and BEDROCK.
Sand	Acoustically homogeneous to layered, low to medium amplitude recent sediments present at seabed. Base often medium to high amplitude indicating presence of coarser sediment	Fine to coarse SAND. May locally contain shells, pebbles, cobbles and pockets of SILT, CLAY and GRAVEL. Commonly forming mobile sediment.
Channel Infills	Acoustically homogeneous to layered, low to medium amplitude recent sediments lying underneath surface sand layer and	Sandy to clayey sediments with layers of coarser sediment.

Sediment Type	Acoustic Characters	Lithological Variation
	filling palaeo-channels.	May locally contain pebbles, cobbles.
Till	Either heterogeneous with acoustic character indicating the presence clay with sand layers and possible coarser sediments, and boulders or Limited or no acoustic penetration.	Possible glacial deposit / till or diamicton. Unsorted sediment, soft to stiff clay with interbeds of sand, and layers/lenses of coarse sand and gravel. May contain pebbles, cobbles, and boulders.
Bedrock	High amplitude top with no acoustic penetration.	Devonian Shale and Sandstone, Cretaceous Chalk

3.2.1.6 Installation Constraints Identified During Geophysical Survey

- Bedrock outcrops/subcrops are present from KP 2 to KP 42 and KP 158 to the end of the route.
- Boulder fields with occasional to numerous boulders are present mainly in UK offshore
- Mobile sediments ranging from ripples to megaripples and occasional sandwaves, with associated local gradients, are present throughout the majority of the route
- Six cables cross the route, one in UK and five in Irish waters. All are buried and were detected during the cable crossing campaign (ref 5)
- A linear magnetometer anomaly trend at KP 6.325 might indicate a possible unknown cable
- One known wreck, Saint Jacques, was confirmed at KP 4.717, 248.6 m south of the proposed route



GREENLINK INTERCONNECTOR CABLE BURIAL RISK ASSESSMENT

Figure 3-3: Seabed Sediments

Legend

- Greenlink Route KP's
- 12nm Territorial Sea Limit
- Median Line

Seabed Sediments

- BEDROCK
- GRAVEL
- Gravelly SAND & Sandy GRAVEL
- SAND
- SILT
- SILT & SAND

NOTE: Not to be used for Navigation

Date	Tuesday, August 27, 2019 12:44:46
Projection	WGS_1984_UTM_Zone_30N
Spheroid	WGS_1984
Datum	D_WGS_1984
Data Source	UKHO, GEBCO, ESRI, DCCAE, CDA, MMT, Greenlink
File Reference	J:\P1975\Mxd\CBRA\ Fig_3_3_Seabed_Sediments.mxd
Created By	Chris Carroll
Reviewed By	Richard Marlow
Approved By	Alan Redman

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3.3 Geotechnical Data

The geotechnical survey consisted of vibrocore samples (VC) and cone penetration tests (CPT).

In total, 105 CPT locations were carried out, with 23 re-attempts required. In the UK section, there were 47 locations with 18 re-attempts required. In the Irish section there were 58 locations with only five reattempts.

For the vibrocores, a total of 105 locations were carried out with 60 re-attempts required. In the UK section, there were 47 locations, with 36 re-attempts required. In the Irish section there were 58 locations with 24 re-attempts. (ref 10).

3.3.1 Vibrocores

The vibrocores were recovered using electrically powered vibrocoring units, either a High Power vibrocore unit or the MMT owned VKG-3/6 vibrocore unit. The corers were fitted with either a 3 or 6m long core barrel and used clear PVC 100mm OD liner. A 'basket-spring type' core catcher was fitted above the cutting shoe, in the base of the vibrocore barrel, to maximise retention of the penetrated sediment during retraction from the seabed and subsequent retrieval of the unit to the vessel deck. The 6m cores were required in the Traffic Separation Zone, defined By Greenlink, at approximately KP 53 to KP 68.

During VC operations, there were instances of re-attempts being required largely due to initial poor recovery. Poor penetration and subsequent low material recovery were generally a function of dense to very dense coarse granular material or high strength cohesive material being encountered. A summary of the re-attempts is provided in the geotechnical report (ref 10).

3.3.2 Cone Penetration Testing

CPTs were carried out to a maximum depth of 6.02m using 10cm2 electric piezocones operated from a ROSON seabed CPT unit, ballasted to fourteen tonnes in air weight.

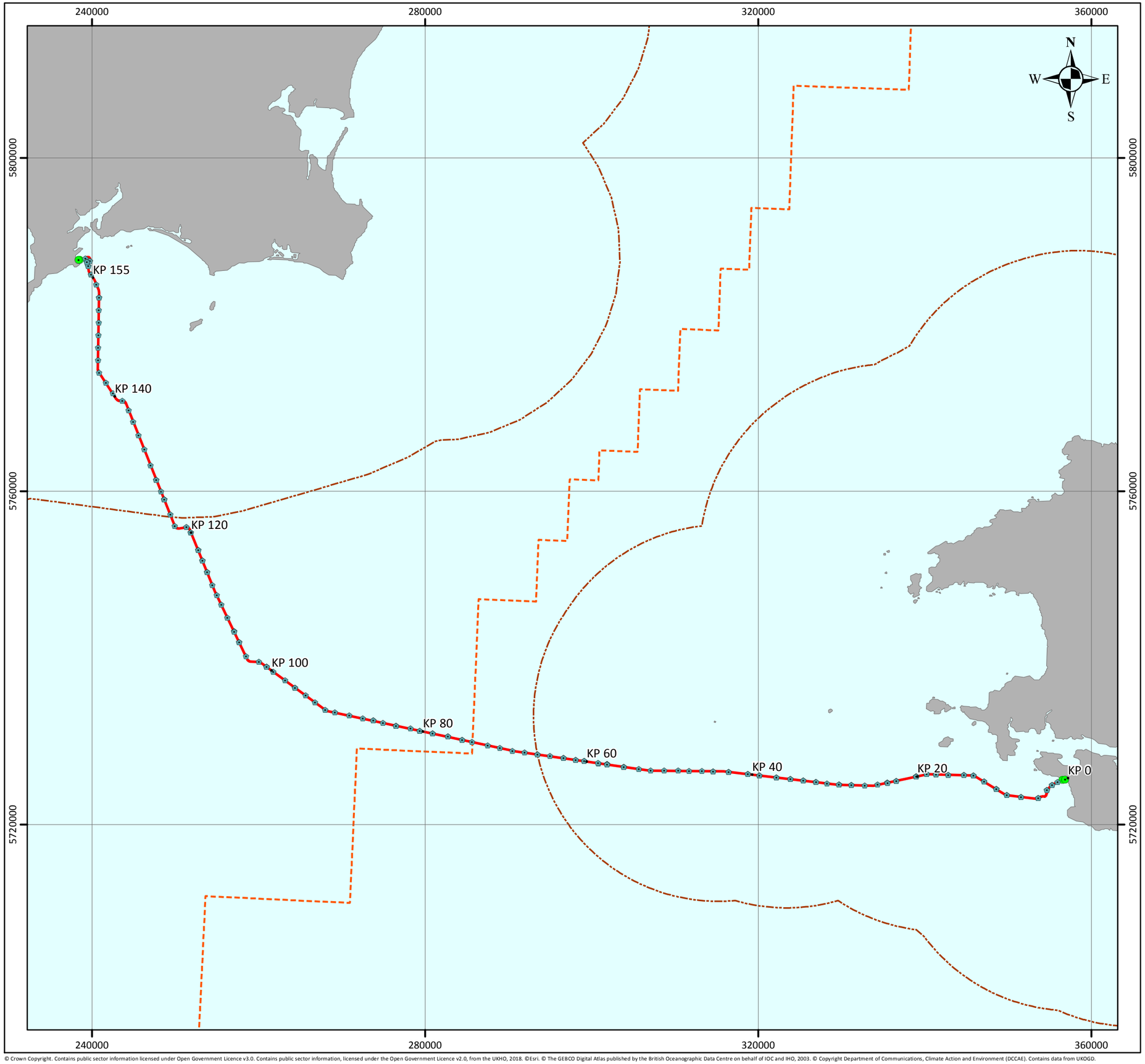
The aim at each CPT location was to reach the target penetration depth of either 3 or 6m, depending on location KP. Re-attempts were required due to either initial failure to reach the required depth, concern with the overall test application class, or due to electrical power and/or communication issues with the seabed CPT unit. The re-attempts are summarised below, with remarks when re-attempts were required due to 'system' issues. Only a single cone was lost during the operations. Again, a summary of the re-attempts is provided in the geotechnical report (ref 10).

3.3.3 Suitability of Geotechnical Data

Each VC and CPT log are clearly presented in an annex to the Geotechnical report (ref 10) and provided the relevant geological information at each location.

Within the Geotechnical report (Ref 10) a scale has been derived for the seabed conditions. The scale is called the Seabed Index (SI) and can be viewed as a semi-quantitative scale in respect of the encountered ground conditions, and to some respect, the likely difficulties for engineering activities in the investigated depth below seabed level. The Seabed Index values provided are based on the geological and geotechnical characteristics of the encountered material at a depth of 1.50m. The seabed index is not, however, a suitable categorisation for a CBRA. This is because it only provides a classification at one specific depth (i.e. 1.5m) and review of the VC and CPT show that the soil type and properties vary significantly above and below this single point. As a result, we have re-assessed the seabed classification using the CPTs and VC information directly (Section 4).

The distribution of geotechnical samples can be found in **Figure 3-4** below



GREENLINK INTERCONNECTOR CABLE BURIAL RISK ASSESSMENT

Figure 3-4: Geotechnical Overview

Legend

- Greenlink Route KP's
- Greenlink Route
- Median Line
- 12nm Territorial Sea Limit

Geotechnical Sample Location

- Vibrocore/CPT
- Borehole

NOTE: Not to be used for Navigation

Date	Tuesday, August 27, 2019 12:06:33
Projection	WGS_1984_UTM_Zone_30N
Spheroid	WGS_1984
Datum	D_WGS_1984
Data Source	UKHO, GEBCO, ESRI, CDA, DCCAE, MMT, Greenlink
File Reference	J:\P1975\Mxd\CBRA\ Fig_3_4_Geotechnical_Overview.mxd
Created By	Chris Carroll
Reviewed By	Richard Marlow
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3.4 AIS Shipping Data

AIS (Automatic Identification System) is an automatic tracking system used on ships for identifying and locating vessels by electronically exchanging data with other nearby ships and AIS base stations and satellites. The International Maritime Organisation (IMO) requires AIS to be fitted aboard international voyaging ships with gross tonnage of 300 or more tons, and all passenger ships regardless of size. This would cover almost all commercial vessels and most private vessels that would be of risk to the cable; however, some smaller fishing vessels could be missing from the AIS dataset.

Information provided by the AIS equipment usually consists of unique identification number for each vessel, vessel name, vessel type, vessel position, course and speed. Other attributes like vessel deadweight tonnage and draught may be completed by the AIS supplier.

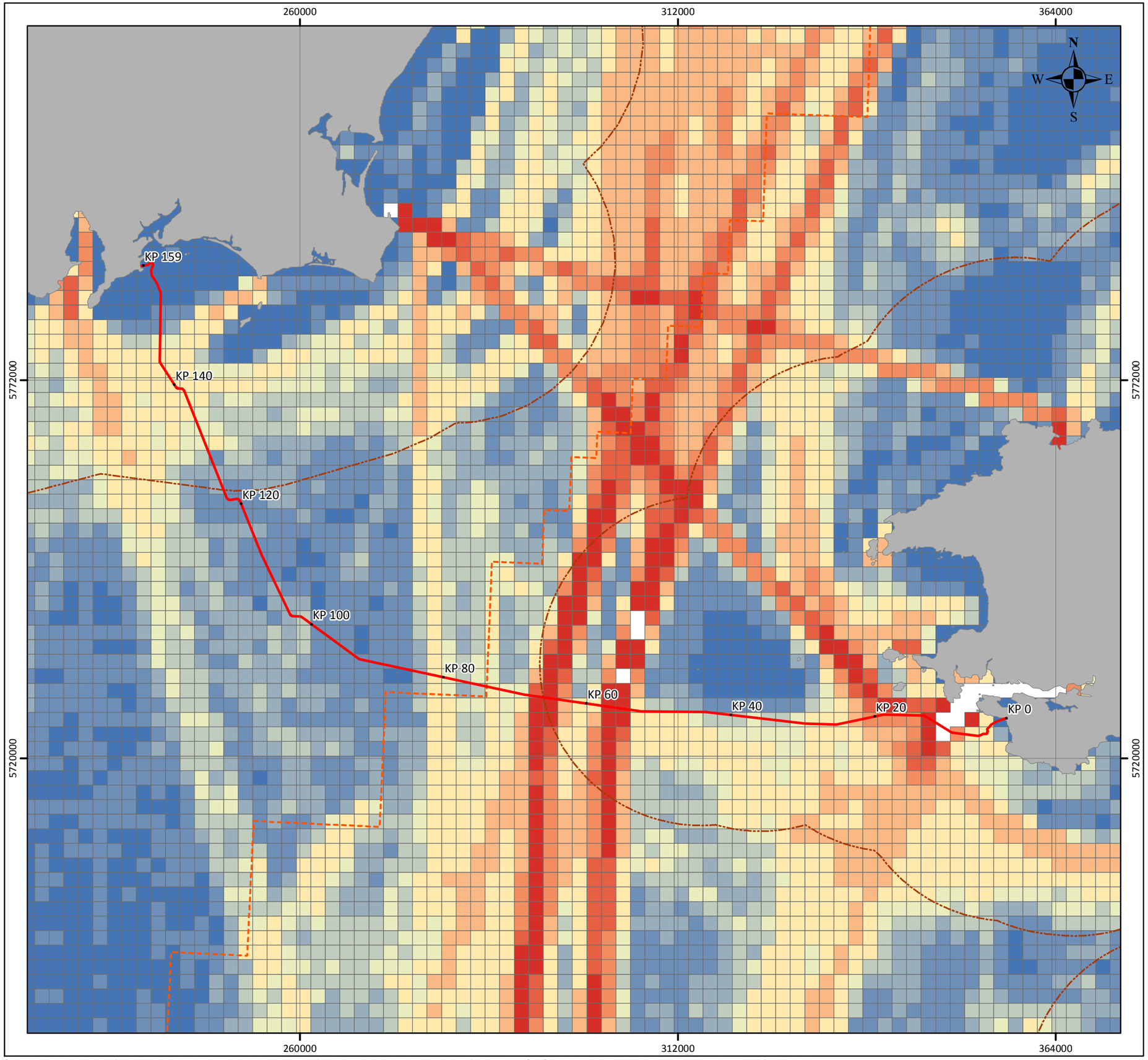
To quantify the anchoring risk to the cable, Intertek procured historical AIS data along the Greenlink cable route for the period of August 2017 to June 2018 (inclusive) (ref 4) from Oceaneering for a study area of approximatively 30km wide either side of the cable route. This wide study area allows a clear insight into vessel movements by vessel type/size in the surrounding geography.

For the purpose of evaluating changes in the key shipping routes in the region, Intertek obtained free, anonymised AIS data from the MMO (ref 16) for the year 2015. Figure 3-5 provides a visualisation of this dataset which provides an overview of vessel movement density. It should be noted that vessel DWT category can't be discerned from the anonymized data. However, it clearly shows the same area of high shipping density as apparent in the data purchased from Oceaneering.

There are two main shipping lanes along the cable route, between KP53 to KP57 and KP63 to KP67 orientated in a north-south direction. The cable crosses perpendicular to these two lanes, minimising the risks of encountering traffic during survey, installation and any operations and maintenance campaigns. The two main shipping lanes cross the cable route in water depths greater than 100m so the risk to the cable from emergency anchoring in this section of the route is considered negligible[2].

The other area of increased shipping traffic is between KP6 to 16. This area is associated with the ports of Milford Haven and Pembroke Dock. The orientation of the cable is confined by several constraints in the area and could not be engineered to cross the lane with a perpendicular orientation.

[2] In addition, as the water depths are greater than 100m under the shipping lanes, any increases in vessel traffic in these shipping lanes during the lifetime of the project will have no effect on calculated anchoring risk.



GREENLINK INTERCONNECTOR CABLE BURIAL RISK ASSESSMENT

Figure 3-5: AIS Overview

Legend

- Greenlink Route KP's
- Greenlink Route
- Median Line
- 12nm Territorial Sea Limit

AIS Yearly Average (2015)

- 0 - 50
- 50 - 100
- 100 - 150
- 150 - 200
- 200 - 250
- 250 - 500
- 500 - 1000
- 1000 - 1500
- 1500 - 2000
- > 2000

NOTE: Not to be used for Navigation

Date	Tuesday, August 27, 2019 12:10:59
Projection	WGS_1984_UTM_Zone_30N
Spheroid	WGS_1984
Datum	D_WGS_1984
Data Source	UKHO, GEBCO, CDA, ESRI, DCCAE, MMO, MMT, Greenlink
File Reference	J:\P1975\Mxd\CBRA\ Fig_3_5_AIS_Overview.mxd
Created By	Chris Carroll
Reviewed By	Richard Marlow
Approved By	Alan Redmen

Greenlink

Co-financed by the European Union
Connecting Europe Facility

intertek

0 5 10 15 20 km

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3.5 Fishing Studies

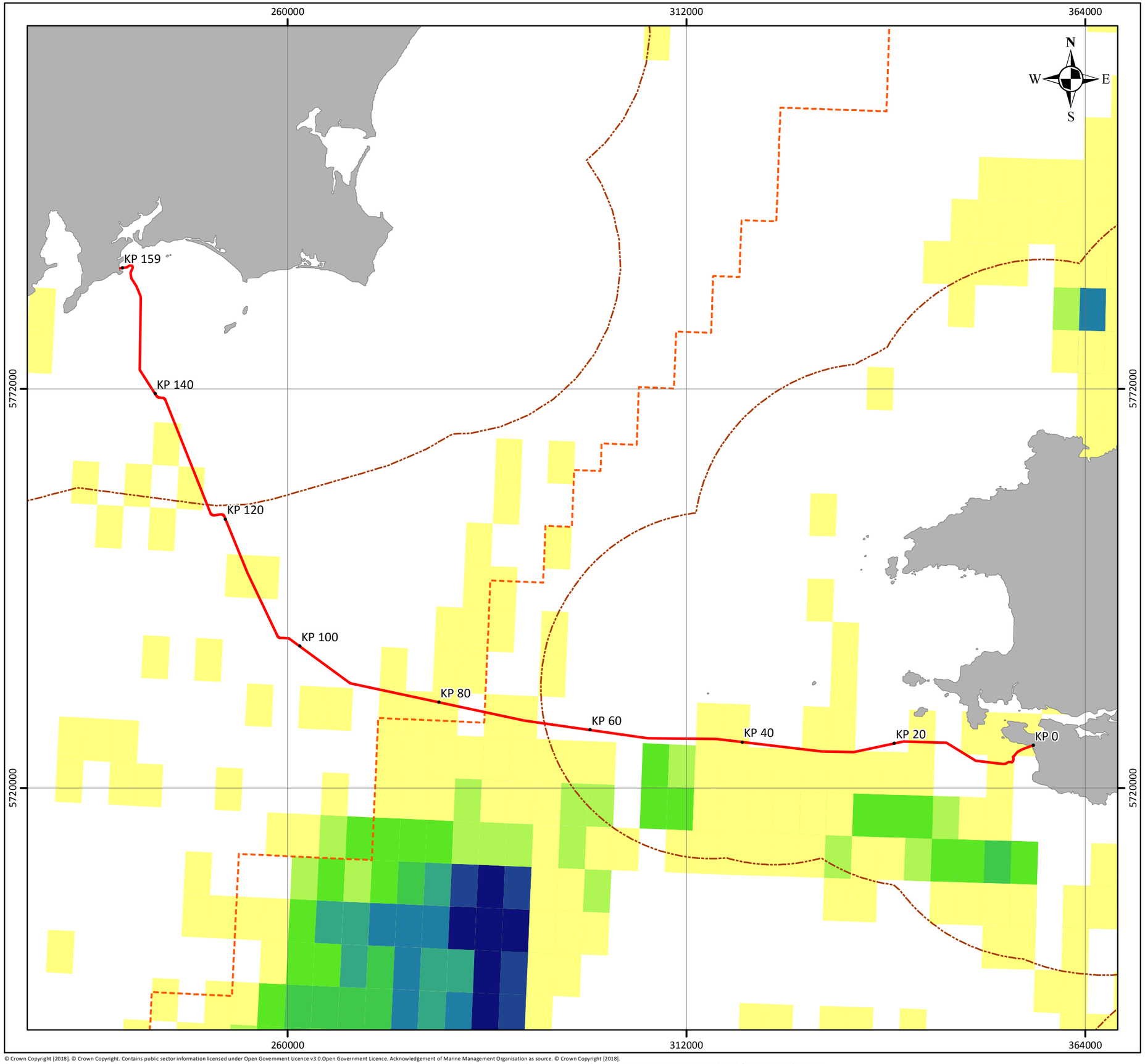
In 2018, Intertek commissioned MarineSpace Ltd to undertake a desk-based study on commercial and recreational fisheries activity near to the proposed Greenlink cable corridor (Welsh and Irish waters). The relevant sections from this study (ref 17) are summarised as follows:

- The assessment has highlighted that there is a wide spatial distribution of commercial fishing activity in the Irish and Celtic Sea, with demersal and shellfish species being the most important in terms of landings by weight and value. Key demersal target species include; cod, haddock, ling, monkfish, plaice, ray, skate and sole. Key shellfish species include; lobster, Nephrops, crabs, scallops, razor clams and whelks. Pelagic fish landings from this area are mainly of herring and mackerel, and of relatively less economic importance compared to demersal and shellfish species.
- The Welsh fisheries are particularly characterised by valuable potting grounds for crab, lobster and whelks around the Pembrokeshire coast (inside the 6nm limit), with mollusc fisheries also taking place in some estuaries and bays. Since 1995, a significant whelk fishery has developed in Carmarthen Bay and offshore of the Gower, Fishguard and Milford Haven. Since the late 1980s, the bass rod and line fishery has also proved popular amongst both commercial and recreational fishermen.
- The otter/beam trawler fleet concentrates its efforts in the Bristol Channel and Cardigan Bay and lands a mixed catch throughout the year. These trawlers (mostly <10 m) fish mainly inshore, and competition outside 6 miles from the coast can be intense, especially when the sole fishery attracts visiting beam trawlers from the south coast of Devon, Cornwall and Belgium.
- There are a large number of medium-sized ports along the south and east coast of Ireland, the largest of which is Dunmore East. The ports along the south coast receive a mix of pelagic, demersal and shellfish species (Marine Institute, 2014). The inshore pot fishery for crab, lobster, Nephrops and whelk is an important component of Irish fisheries in this region.
- The proposed Greenlink cable corridor lies within International Council for the Exploration of Sea (ICES) Rectangles 32E3, 32E4 and 33E3.
- Based on the most recent 5 years of Marine Management Organisation (MMO) data available at this time, which ranges from 2010-2016, the maximum weight and value of landings by all vessels over the period assessed were from 32E4 which covers the Welsh inshore region. Over this period, for all vessels, over 5.4 million tonnes of fish (all species) were landed with a value of over £10.5 million.
- Of this value, £6.6 million was landed by <10 m vessels with the remaining £3.9 million landed by the >10m fleet. 86.7% of the total value of landings from 32E4 were represented by shellfish. These data highlight the importance of the Welsh inshore static gear (potting) fishery in the area of the proposed cable corridor.
- For the non-UK Fleet, the key ICES Rectangle for the Irish fleet (in terms of landings) was 33E3 (Irish inshore). The key ICES Rectangles for the French fleet were 32E3 (offshore section) and 32E4 (welsh inshore) and for the Belgian fleet the key ICES Rectangle was 32E3 (offshore section).
- Although landings by weight and value varied across all ICES Rectangles (32E3, 32E4 & 33E3) between 2012-2016 generally there were no obvious trends in terms of increases or decreases in either of these values. In terms of intra-annual variation, landings for all species/vessels over the period 2012-2016 peaked in July, with a clear seasonal pattern of highest weight/value.

Areas of mobile and static fishing gear along the cable route have been identified along the cable route based on the above fisheries assessment undertaken by Marine Space Ltd and from an open government source (The MMO). While data from all vessels (UK, Spanish, Dutch, Belgian, Irish &

French) has been used to determine if fishing is present over the cable route, the UK vessel dataset was the most up to date (2016 vs 2010) and is seen to be the country of most extensive fishing. Data for non-UK vessels cannot be obtained due to licensing reasons; however, by reference to the various figures provided in the report areas of the route which show evidence of static and mobile fishing gear use have been identified.

Figure 3-6 illustrates an overview of Fishing Activities for UK Vessels and is provided as indication only.



GREENLINK INTERCONNECTOR CABLE BURIAL RISK ASSESSMENT

Fig 3-6: Fishing Activities for UK Vessels

Legend

- Greenlink Route KP's
- Greenlink Route
- Median Line
- 12nm Territorial Sea Limit

Total Minutes Fished ≥ 15m UK Vessel Landings 2015 & 2016 (Mobile Gear)

- 0.0 - 500
- 500 - 1000
- 1000 - 2000
- 2000 - 4000
- 4000 - 6000
- 6000 - 8000
- 8000 - 10000
- > 10000

Mobile gear is defined under the following fishing types: Boat dredges, mechanized dredges, hand lines and pole-lines (hand-operated), long lines (not specified), set long lines, hooks and lines (not specified), otter trawls (not specified), otter trawls – bottom, otter trawls – midwater, otter twin trawls, with purse lines (purse seines), pair trawls – bottom, pair trawls – midwater, Danish seines, pair seines, Scottish seines, seine nets not elsewhere specified, beam trawls, nephrops trawls, midwater trawls not elsewhere specified, shrimp trawls – midwater, other trawls not specified.

NOTE: Not to be used for Navigation

Date	Tuesday, August 27, 2019 14:08:57
Projection	WGS_1984_UTM_Zone_30N
Spheroid	WGS_1984
Datum	D_WGS_1984
Data Source	UKHO, GEBCO, ESRI, DCCAE, CDA, MMO, Greenlink
File Reference	J:\P1975\Mxd\CBRA\ Fig_3_6_Fishing_Activities_UK_Vessels.mxd
Created By	Chris Carroll
Reviewed By	Richard Marlow
Approved By	Alan Redman

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0 5 10 15 20 km

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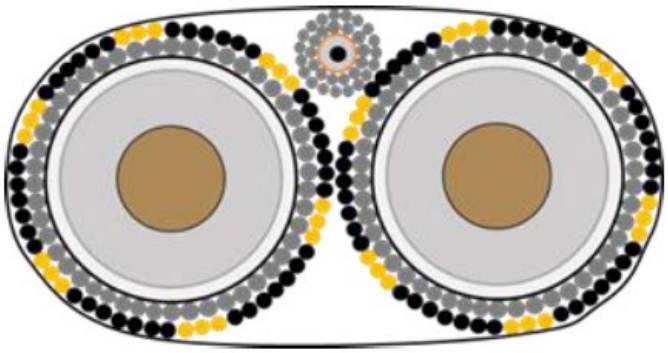
3.6 Cable Dimensions

Greenlink will be a submarine cable system composed of two power cables and a fibre optic. This system transmits power via a closed circuit of two HVDC submarine cables laid alongside each other. It is likely that cables will be bundled together as a pair with no separation between the cables (Figure 3-7). A fibre optic cable will also be laid for control and communication purposes.

The cable's dimension will be used to define the trenching requirements and the selection of trenching tools. However, the cable's dimensions do not impact the specification of the RMDOL and TDOL (as these values are defined as depth between Mean Seabed Level (MSBL) and the top of the product (ToP).

Figure 3-7 Typical Cable Bundle Arrangement



3.7 Vessel Incident Data

For this study, Intertek has reviewed the Annual Report (2017) from the Marine Accident Investigation Branch (MAIB) available on www.gov.uk/maib (ref 18). No investigations or accidents were reported in 2017 near the Greenlink cable corridor.

4. ASSESSMENT OF SEABED CONDITIONS

This section presents the breakdown of the Greenlink cable route based on distinct seabed conditions based on our review of the available geotechnical and regional geological data.

In the MMT geotechnical report (ref 10), complete descriptions of CPT and VC samples at each location are provided. A further level of description is provided by applying a "Seabed Index" classification to each complete sample, reproduced from the MMT report in **Table 4-1** below. This classification is applied at 1.50m depth.

As discussed in Section 3.3.3, the seabed index is not a suitable categorisation for a CBRA because it only provides a classification at one specific depth (i.e. 1.50m) and review of the VC and CPT show that the soil type and properties vary significantly above and below this single point. As a result, we have re-assessed the seabed classification using the CPTs and VC information directly. The results of this analysis are provided in **Appendix A.**

Table 4-1 Summary of the Seabed Index (SI) Scale

SI	Typical Seabed Sediment
1	Shallow Bedrock (<1.00m)
2	Bedrock / Obstruction (>1.00m)
3	Very dense granular, very to extremely high strength cohesive
4	Medium to high strength cohesive
5	Dense granular
6	Medium dense granular
7	Loose granular, low to medium strength cohesive
8	Very loose granular, low strength cohesive
9	Very low strength sandy cohesive
10	Extremely low strength cohesive

Table 4-2 Interpreted Undrained Shear Strength Parameter and Classification

Descriptive term	Shear Strength Range (kPa)
extremely low	<10
very low	10 to 20
low	20 to 40
medium	40 to 75
high	75 to 150
very high	150 to 300

Table 4-3 Interpreted Relative Density Parameter and Classification

Descriptive Term (Relative Density)	Cone Resistance Range (MPa)
very loose	<2.5
loose	2.5 to 5
medium dense	5 to 10
dense	10 to 20
very dense	>20

5. RISK IDENTIFICATION AND ASSESSMENT

To specify an appropriate DOL for the Greenlink cable, Intertek conducted a risk identification and assessment considering both the likelihood and severity of all external threats to the cable.

Risks that pose a threat to installed marine cables can be classified as either natural or anthropogenic risks. The following sections describe the most common risks affecting marine cables.

The completed Risk Register is provided in **Appendix B.**

5.1 Natural Hazards

5.1.1 Sediment Mobility

Sediment mobility in itself does not pose a threat to a submarine cable but it can lead to issues with the thermal conductivity of cables (over burial), and exposure of cables (scour); burial under excess sediment can change the thermal properties of the soil and cause hotspots along the cable, while exposure increases the risk of damage due to external aggressors such as trawling and anchoring and potentially mechanical damage from free spans.

There are several areas within the Greenlink 500m corridor where there are bedforms present which could be mobile.

The first indication of mobile bedforms can be seen between KP 5 and KP 6, just beyond an area of outcrop located in the nearshore area at Freshwater West. This area of potential mobile bedforms is located to the south of the centreline within an Annex I habitat sandbank area. The bedforms are up to 2.5m high and have a wavelength of ~250m. Smaller megaripples (height ~0.3m, wavelength ~7m) are located on the larger bedforms. These smaller megaripples extend beyond the extent of the underlying large bedforms up to KP 10 where they stop due to a change in sediment.

The next indication of mobile bedforms is at KP 26 where the centreline transects two very large sandwaves which have a height of 12m (at KP 26) and 8m at (KP 26.3) and wavelengths of 280m. Megaripples are also present on these larger features. Small isolated patches of Megaripples are then observed up to ~KP 59 (~0.3m height, ~10m wavelength).

At ~KP 59 the megaripples increase in size to ~0.5m height, ~25m wavelength and then gradually decrease in size as the route progresses to ~KP 137, likely due to a fining of sediments. There are isolated sandwaves underlying the megaripples at KP 83 (height 1.5m, wavelength 230m), KP 99 (height 5m, wavelength unknown), KP 109 (height 4m, wavelength unknown) and KP 112 (height 3.5m, wavelength unknown). At KP 89 and KP 91 there are large relic sandbank features which have an elevation shift of ~5m and ~3m respectively. These relic sandbank features might still have some mobility.

For the remainder of the route (i.e. KP 137 to KP 159) there are no further large bedforms but megaripples (height 0.5m, wavelength 10m) are present from ~KP 149 to KP 159 within a channel on the approach to the landfall in Ireland.

In addition, Intertek is also aware that beach levels in Freshwater West vary with sediment movement after storm events.

For further details of mobile features interpreted along the Greenlink corridor please see MMT's Geophysical Report (Ref 12).

For the purposes of burial targets (RMDOL & TDOL) all depths recommended in this report are assumed to be measured against a horizontal plane which has been determined to be non-mobile and after any required mobile bedform engineering has been undertaken to flatten mobile sediments.

5.1.2 Other Geohazards

Earthquakes, volcanic eruptions, landslides, slumps and turbidity flows, could have a devastating effect on a subsea cable within its operational lifespan. Generally, these hazards are associated with areas that are tectonically active or are located on or near a continental slope or rise. The Greenlink Cable route resides in an area that is tectonically stable and away from a continental shelf/plate boundary; therefore, is it not expected that any significant hazards of this nature present on the route. No areas of unstable sediment have been encountered along the Greenlink route.

5.1.3 Outcropping Bedrock

Bedrock and hard sediment are considered an issue when the seabed proves to have properties that affect, and effectively inhibit, the use of the common trenching methods.

Bedrock and hard sediment may cause problems with reaching the required burial depth. In addition, topographical irregularities in bedrock or hard sediment may cause freespan, point load, and abrasion. Methods to avoid problems with bedrock or hard sediment include appropriate micro-routing, deployment of heavier trenching machines, or the installation of additional cable protection.

MMT's Geophysical results report (Ref 12) details in full the exact locations of hard ground. There are several areas of outcrop within the Greenlink route corridor. There is a large outcrop extent at the Nearshore area in Wales from approx. KP 2 to KP 5, however the route has been engineered to avoid the nearshore outcrop by routeing through a palaeochannel, infilled with sand.

Table 5-1 list areas of outcropping bedrock, in which the Greenlink cable could possibly be engineered to avoid.

Table 5-1 Outcropping Bedrock along the Greenlink Route (ref 10)

Feature	KP Start	KP End
Bedrock	2.216	2.236
Bedrock	2.380	2.403
Bedrock	2.778	2.788
Bedrock	4.874	4.997
Bedrock	11.041	1.137
Bedrock	24.178	24.202
Bedrock	42.066	42.104
Bedrock	158.387	158.395
Bedrock	158.425	158.490
Bedrock	159.071	159.078
Bedrock	159.089	159.172

5.1.4 Waves and Currents

Waves and currents may cause abrasion and stress to an exposed cable where it crosses over rock or rough terrain. Sufficient burial and protection of a subsea cable will reduce the risk of waves and currents to a negligible level.

5.1.5 Extreme Weather

Extreme weather is unexpected, unusual, unpredictable, severe or unseasonal weather and involves weather at the extremes of the historical distribution. While the Greenlink cable is geographically in a relatively weather-stable area, sufficient depth of lowering and protection will be required to deal with the effects of extreme weather such as excessive scour and extensive movement of mobile sediments. For the purposes of burial targets (RMDOL & TDOL) all depths recommended in this report are assumed to be measured against a horizontal plane which has been determined to be non-mobile and after any required mobile bedform engineering has been undertaken to flatten mobile sediments.

5.2 Anthropogenic Hazards

5.2.1 Shipping

Shipping represents an anchoring hazard to a cable on or in the seabed. Vessels that drop their anchors have the potential to interact with the cables if the anchor is dragged along the cable route or dropped directly on the cable. Ships in transit do not typically anchor under normal conditions and planned anchoring normally takes place within a designated area. Contact with an anchor is often catastrophic for the cable as the forces applied by a moving anchor can be extremely large. The anchoring hazard may result from:

- Insufficient protection
- Emergency anchoring (where an anchor is deployed to prevent collision or grounding)
- Accidental anchoring (where an anchor falls unexpectedly from a vessel due to equipment impact or operator error). Accidental anchoring is accentuated by proximity to a port where, for navigational reasons such as the traffic density, proximity of obstructions, shallow waters and other vessels, anchors are more likely to be readied for deployment.
- A vessel being anchored inadequately (where an anchor is deployed but drags along the seabed prior to embedment)

All charted anchorage areas were identified and avoided as part of the routing study hence accidental anchoring and inadequate anchoring are not relevant to this study.

5.2.2 Fishing gear Interaction

Noting that vessels of less than 300 gross tonnes are not presently required to carry AIS transponders, fishing data obtained from the Marine Management Organisation (MMO) has been analysed to determine areas fished using mobile methods (dredging, trawling, netting etc). It is difficult to determine the specific type of gear used so the depth of lowering and protection methods are derived from the maximum depth of penetration from fishing.

5.2.3 Dredging/Aggregate Extraction/Subsea Mining/Dumping

Within UK and Irish waters all active and historical dredging areas are known and have detailed surveys undertaken to ascertain sediment levels. All disposal and dumping sites are also known and are contaminated with material such as heavy metals and in some extreme cases radioactive waste. Aggregation extraction areas have also been avoided. These areas have been avoided. Further information can be found in the routeing report (ref 14).

5.2.4 Other Cables

The Greenlink interconnector will cross 6 existing fibre optic cables, 1 of which is out of service, leaving 5 cables that will require third party crossing agreements and designs. Before and after each crossing location, the cable will be graded from the seabed to cross the cable. The point at which the cable starts grading to the surface will need to be carefully planned and analysed to ascertain the protection levels in these areas. Crossing design requirements are outside the scope of this CBRA.

MMT surveyed 5 known in-service assets and 1 out of service asset. Details of this survey can be found in MMT's crossing survey report (Ref 5).

5.3 Risk Assessment and Evaluation Criteria

In this section, the risk acceptance criteria are discussed to allow implementation of the results of the probability of failure and consequence of failure assessment. The key output of this risk register being a probabilistic assessment of the risk to the cable after burial options are completed to a specified depth.

Figure 5-1 shows the risk matrix that we developed for the purpose of this project. The generic meaning of the colour code is indicated in the legend below the Figure. The principle works as follows: an event, such as a cable failure, has a probability of happening, and has a severity. The combination gives a location in the risk matrix and from that follows required next steps.

Figure 5-1 Risk Matrix

		Likelihood				
		Rare (1)	Unlikely (2)	Possible (3)	Likely (4)	Almost certain (5)
Severity	Insignificant (1)	1	2	3	4	5
	Minor (2)	2	4	6	8	10
	Moderate (3)	3	6	9	12	15
	Major (4)	4	8	12	16	20
	Severe (5)	5	10	15	20	25

	Broadly acceptable
	ALARP low
	ALARP medium
	ALARP high
	Intolerable

The severities are defined for two different categories, cost and performance, as shown in Error! Reference source not found., while the definition of the likelihood is shown in **Figure 5-3**.

Figure 5-2 Severity Definition

			Severity				
			Insignificant (1)	Minor (2)	Moderate (3)	Major (4)	Severe (5)
Category	Cost		Less than £50K	£50K - £500K	£500K - £10M	£10M - £200M	10% CAPEX (>£200M)
	Performance	Availibility	Increased surveillance	Increased maintenance Occasional duration limits (days) at peak capacity	One substantial outage + major intervention Regular duration limits (hours) at peak capacity	Between one and eight 6-month outages. Between 1 and 10% capacity loss	10% availability drop through project lifetime (eg > eight 6 month outages in 40 years) > 10% max capacity loss
		Derating	Rare minor derating in a short period of time.	Routine minor derating for short period of time.	Minor derating for extended period.	Substantial derating for significant period of time.	Significant permanent derating.

Figure 5-3 Likelihood Definition

	Description	Probability of event in the lifetime (40 Years)	Probability of event per year range
Rare (1)	Although they are conceivable, not expected to occur. "Plausible but no known occurrences in industry."	0% - 2%	0.00% - 0.05%
Unlikely (2)	Incidents of this nature are uncommon but there is a chance that they may occur.	2% - 10%	0.05% - 0.26%
Possible (3)	This may happen.	10% - 25%	0.26% - 0.72%
Likely (4)	Likely to experience in the near-future.	25% - 75%	0.72% - 3.41%
Almost certain (5)	Will occur or is already occurring. "Probably within the life time of the project (i.e. several known occurrences per year)."	75% - 100%	3.41% - 100.00%

5.4 Risk Mitigation

There are several remedial methods of protection that can be considered to reduce the risk to the cable. The principal method of protection for most modern cable systems is burial into the seabed. In general, an activity must penetrate through the material above the burial to interact with the cable.

It may be noted that there are instances in which utility crossings, joints, HDD exits or extremely hard soil conditions (e.g., bedrock) preclude burial or reduce the depth achievable. In such instances, there are three primary means of remedial protection which can be used:

- Concrete mattresses
- Rock placement
- Articulated shell

5.5 Final Route Segmentation

The final route segmentation used for the probabilistic assessment was segmented according to changes in risk profile resulting from changes to:

- Seabed geology
- External risk factors (e.g. Anchoring risk variation by location and water depth)

Bathymetric profile for the cable route is illustrated in **Figure 5-4** and the final cable segmentation for the Greenlink cable route is presented in the Cable Burial Risk Assessment (CBRA) Summary Table (**Section 7**).

Figure 5-4 Greenlink Route Profile (East to West)

Baginbun Beach Landfall
(KP159.27)

Freshwater West Landfall
(KP0)

6. PROBABILISTIC RISK ASSESSMENT

This section describes the methodology and results used to assess the fishing and anchoring risk the Greenlink cable system.

All relevant factors are assessed for a cable route on a section by section basis.

6.1 Fishing Risk Assessment Methodology

The review of the fishing assessment report indicated presence of mobile and static fishing areas present along the entire cable route. No fishing protection or exclusions areas from fishing activity was reported.

Moreover, as the entire route is within water depth range in which mobile gear fishing could take place, we recommend the cable is given sufficient protection from potential fishing gear interaction along the entire route.

The Carbon Trust' guidance (ref 1) indicates that penetration of fishing gear into the seabed is limited to a maximum of 0.3 m penetration even in soft sediment based on previous literature research.

Adding a FoS of 2 to account for measurement errors and deformation of soil beneath fishing gear gives a RMDOL of 0.60m for fishing risk alone.

In Zones 11-19 where anchor risk is not present due to water depths exceeding 100m fishing risk is the sole determinant of RMDOL. In addition, adopting a value of 0.60m to protect against fishing risk results in fishing risk being the determinant or co-determinant of RMDOL in all zones except Zone 3.

6.2 Vessel and Anchors Bands

To facilitate easier analysis of the vessel traffic the vessels were grouped into seven deadweight tonnage bands. This allowed a set range of anchor sizes to be used to characterise those carried by shipping fleets in the tonnage bands. This is shown below in **Table 6-1.**

The vessels' DWT were calculated from the vessel length data supplied in the AIS data. The methodology to calculate the vessels' DWT is as follows:

1. Create a list of all unique vessels present in the AIS data set
2. For each vessel category (Cargo, Tanker, Passenger, etc) research the DWT information online (https://www.marinetraffic.com/, ref 19) using vessel MMSI number for a sufficient set of vessels per category (30 to 50 vessels' DWT were researched online per category).
3. For each vessel category, plot the DWT vs Length and derive a conservative power trendline that fits the distribution of data points.

Based on the above process, the following empirical formulas were derived by Intertek and used to calculate the vessels' DWT:

$$DWT_{cargo} = 0.0017 \times L^{3.2551}$$

$$DWT_{Tanker} = 0.0025 \times L^{3.175}$$

$$DWT_{Passenger}{}^{3} = 0.0583 \times L^{2.1278}$$

$$DWT_{Vessel<70m} = 0.0009 \times L^{3.3717}$$

Where:

DWT = Vessel deadweight tonnage (tonnes)

L = Vessel length (m)

The plots from which the above empirical formulas have been derived are provided in **Appendix D.**

Once the vessel deadweight tonnage is known, the theoretical anchor mass can be calculated by the following empirical formula proposed by Luger as referenced in the Submarine Power Cables book by Worzyk, (Ref 24) (this is recognised as an acceptable approach by the Carbon Trust's CTC-835):

$$y = 7 \times 10^{-13}x^3 - 6 \times 10^{-7}x^2 + 0.1635x + 2162.2$$

Where:

y = Anchor mass (kg)

x = Vessel deadweight tonnage (upper DWT boundary of each band) (tonnes)

The Carbon Trust's guidance (ref. 1) shows the Luger formula to be a good fit with the International Association of Classification Societies (IACS) rules for vessel DWT between 10,000 and at least up to 100,000. Thus, for the vessel Band with a DWT up to 10,000 (Bands A & B), Intertek has used the estimated anchor size from Table 9 of ref.1, for Bands C-E we have used Luger's formula and for Bands F-G we have used a chart from a presentation given by Luger (Ref 25).

We then used an anchor catalogue (Ref 20) to select realistic stockless anchor dimensions based on the theoretical anchor mass calculated. The "Hall" pattern anchor is used for Bands A-E and "Spek" is used for Bands F and G as these are typical stockless anchors in common use, especially on older vessels. These types of anchors have a relatively long fluke length for its unit mass and a large opening angle, which equates to more penetration for a given fluke length.

[3] The relationship between DWT and vessel length would normally be expected to be closer to the cube of the length than the square. However, as demonstrated in the **Appendix D**, the formula is a good fit to the data set obtained from research.

Table 6-1 Vessel and Anchor Size Bands

Band Name	Vessel DWT [Tonnes]	Calculated Theoretical Anchor Mass [kg]	Selected Anchor Mass [kg]
Band A	0 – 1,000	524*	570
Band B	1,000 - 3,500	1,302	1,290
Band C	3,500 - 20,000	5,198	5,000
Band D	20,000 – 40,000	7,787	7,800
Band E	40,000 – 80,000	11,761	11,100
Band F	80,000 – 175,000	17,761	17,800
Band G	175,000 – 325,000	22,167	20,000

* Within this band there are a significant number of vessels present that are too small to carry an anchor of this mass. As such, the selected anchor mass represents a conservative approach.

6.3 Probabilistic Model

Intertek have developed a robust probabilistic assessment to determine the probability of interaction between an anchor and an installed cable based on local data for shipping traffic intensities, derived from historical AIS data. The model predicts the probability of a buried cable being struck because of anchoring. The probability of cable-anchor interaction decreases as DoL is increased beyond the maximum penetration depth of each anchor size.

The method takes account of:

- shipping traffic intensity by vessel size;
- probability of engine failure;
- probability of an emergency anchor deployment;
- dragging distance of an anchor; and
- protection factor provided by soils.

The assessment provides the annual probability of a failure, which can in turn be used to calculate the mean time to failure (MTTF) for anchoring. It should be recognised that it does not predict a failure time and that failure in year 1 is equally as likely as in any subsequent year.

The probabilities are calculated for a range of vessel and anchor sizes. The anchor size for the upper end of the vessel tonnage band is used, as indicated in Table 6-1.

The probability of failure of the cable because of damage caused by emergency anchoring is calculated using the following equation:

$$P_{anchor\ damage\ per\ km} = K \times P_{loss} \times P_{deploy} \times P_{fa}$$

Where:

$P_{anchor\ damage\ per\ km}$ = probability of anchor damage on cable (-/year.km^{-1})

K = total number of ship hours in sample box (hr/year.km^{-2})

P_{loss} = probability of engine failure (-/engine hour)

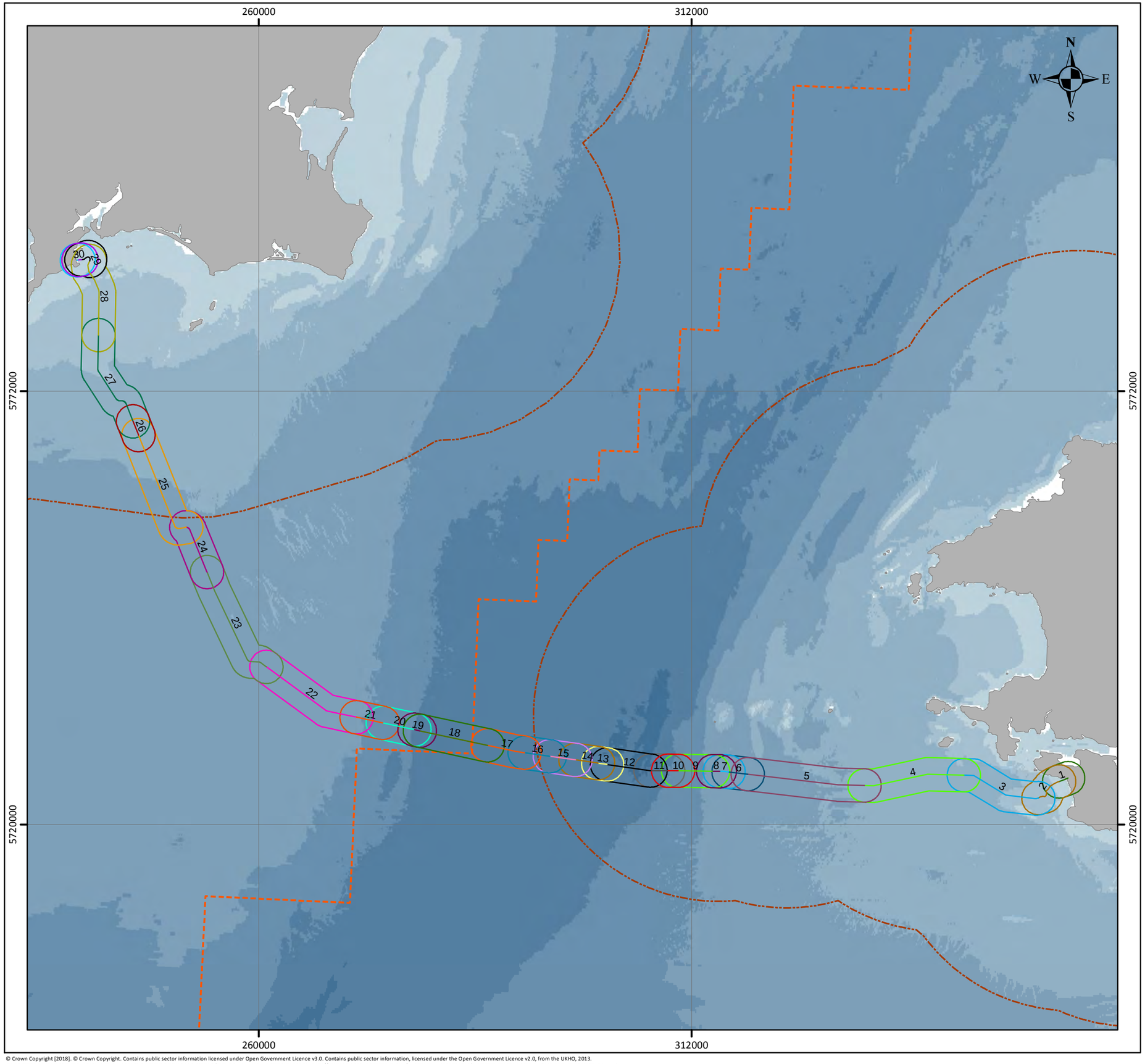
P_{deploy} = probability of anchor operation (-)

P_{fa} = protection factor (-)

Zones of Interest

A vessel does not immediately drop an anchor when it encounters engine problems. It drifts for a period while trying to recover from the engine problem. If unrecoverable, it slows down to below approximately 1 knot before dropping an anchor. Anchoring at speeds above 1 knot will most likely lead to vessel structural damage. Defining a Zone of Interest which is greater than just directly adjacent to the cable route allows for a potential period spent drifting while trying to recover the engine and/or slow down sufficiently to allow anchoring to take place. This means that the Greenlink cables will not just be affected by vessels that are directly above it.

The Zones of Interest for the cable routes for each individual cable segments are defined as a 2km buffer around each segment. **Figure 6-1** shows the cable route segments and associated Zones of Interest used.



GREENLINK INTERCONNECTOR CABLE BURIAL RISK ASSESSMENT

Figure 6-1: Current Route Zone Overview

Legend

- Median Line
- 12nm Territorial Sea Limit

Bathymetry (m below LAT)

- 0 - 20
- 20 - 40
- 40 - 60
- 60 - 80
- 80 - 100
- 100 - 120
- 120 - 150

Greenlink Zone & Buffer (2km)

1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31

NOTE: Not to be used for Navigation

Date	Tuesday, August 27, 2019 15:42:21
Projection	WGS_1984_UTM_Zone_30N
Spheroid	WGS_1984
Datum	D_WGS_1984
Data Source	UKHO, GEBCO, EMODNE, ESRI, DCCAE, CDA, Greenlink
File Reference	J:\P1975\Mxd\CBRA\ Fig_6_1_Greenlink_Route_Zones.mxd
Created By	Chris Goode
Reviewed By	Chris Carroll
Approved By	Alan Redman

Co-financed by the European Union
Connecting Europe Facility

0 5 10 15 20 km

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The bathymetric metadata and Digital Terrain Model data products have been derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu. © Copyright Department of Communications, Climate Action and Environment (DCCAE).

K - Total number of ship hours in sample box

This can be obtained by interrogating the historical AIS data. The AIS data has readings every 5 minutes.

Each Zone of Interest is split into a grid of 1km square boxes and the vessel intensities for each vessel class is calculated for each 1km square box from the AIS data.

The cable route length is then divided into sample boxes. A sample box is defined as a 1 km long box, parallel with the route of width equal to the anchor drag distance.

The vessel intensities used for each sample box are defined as the P90 vessel intensity for each vessel/anchor bands from the Zone of Interest (i.e. the vessel intensities for which 90% of the 1km square boxes have lower intensity per band) multiplied by the drag distance(m)/1000m.

Vessel density numbers are provided in **Appendix E**.

P_{loss} - Probability of engine failure

This is taken from a report compiled by DNV (Det Norske Veritas) for the Marine & Coastguard Agency (ref 21) for coastal waters around the UK. The value used in the calculations is 0.00015 / hr (equivalent to an average of 1.3 / yr of continuous vessel operation). In general, this figure is probably somewhat conservative.

P_{deploy} - Probability of anchor operation:

The anchor will not be dropped in every emergency situation. This depends on the local geography, local bathymetry and the Vessel Master's knowledge.

Table 6-2 provides the P_{deploy} factors which have been applied in this CBRA.

Table 6-2 P_{deploy} values by Vessel Band and Water Depth

Water Depth (m)	P_{deploy}						
	Band A	Band B	Band C	Band D	Band E	Band F	Band G
0-50	0.5	0.5	0.5	0.5	0.5	0.5	0.5
50-75	0.05	0.05	0.1	0.1	0.1	0.1	0.1
75-100	0	0	0.05	0.05	0.05	0.05	0.05
>100	0	0	0	0	0	0	0

P_{fa} - Protection factor:

This considers the protection offered by soil cover. P_{fa} is a combination between the anchor penetration depth in different soil condition and the actual cable DOL and is either 0 or 1. If the cable DoL is greater than the maximum anchor penetration depth (including FoS) for a given anchor size then P_{fa} equals to 0 for that anchor size. Conversely, if cable DoL is less than or equals to the anchor penetration depth (including FoS) for a given anchor size then P_{fa} equals to 1 for that anchor size.

Anchor penetration depths for SANDS and CLAYS (or SAND/CLAY mixes) are typically calculated by taking the sine of the fluke opening angle and multiplying by the fluke length (for Hall anchors this is 45°). This is due to observations that anchor shanks are typically supported by the soil as they are dragged over it. However, EXTREMELY LOW STRENGTH SILTS and CLAYS (i.e. with shear strength <10kPa) are unable to support the shank and as such penetration can be significantly deeper – 3 times the sine 45° of fluke length is typically used in the industry (note these soils are not present on the Greenlink route). In addition, industry understanding is that HIGH STRENGTH CLAYS (≥100kPa) prevent flukes penetrating at all and where soils with shear strength of this level or above are

present on the Greenlink route in underlying layers we have designated the depth they are at as the maximum depth any anchor will penetrate to.

As above, the industry typically applies Sin 45° of fluke length to calculate anchor penetration in SANDS. However, trials in the German Bight in 2013 (ref 22) suggest that in SANDS anchor penetration are less than previously thought. This report concluded that a 11.5t Hall anchor would have a maximum depth of penetration of 1m in VERY LOOSE SAND, 0.79m in LOOSE SAND and 0.40m in a MEDIUM DENSE SAND which are less than the theoretical value of 1.17m calculated by Sin 45° of fluke length. In addition, the report indicates extrapolation of results to anchors of different size using a scaling factor is valid.

Thus, for each anchor size defined in **Table 6-1**, Intertek calculated the theoretical anchor penetration depth and used the results outlined in the German Bight Anchor Penetration Trials report (ref 22) to scale these anchor penetration depths to more realistic values for areas of SAND sediment type. Areas of SAND sediment type which were dense or very dense were considered as medium dense for the purposes of calculating anchor penetration depths.

A Factor of Safety of 1.5 has been applied on the anchor penetration depths to consider:

- uncertainty in anchor sizing;
- uncertainty of soil type; and
- deformation of the soil beneath the maximum penetration depth.

In addition, all final maximum penetration depths have been rounded up to the closet 5cm to avoid implying a level of accuracy which is not justified. Results of anchor penetration calculations by soil category, without and with the Factor of Safety are provided in Table 6-3 and 6-4 respectively.

In addition (and as can be expected), there are a number of zones in which there is a surficial sediment layer which has soil properties which vary significantly from the underlying layers. To account for this, we have defined all layers which are present within the soils depths which are relevant to the burial of the cable. Anchor penetration has then been first calculated for the top layer (Layer 1) and if the anchor penetrates through this layer into the underlying layer then a second calculation has been undertaken to determine penetration depth in Layer 2. The method for calculating Layer 2 penetration is as follows:

- calculate the remaining anchor penetration potential (in percentage terms) for each anchor size after it has penetrated Layer 1 (e.g. in LOOSE SAND a Band C anchor will penetrate 0.75m, if the top layer is 0.50m then the anchor has ~33% of its penetrating potential remaining after penetrating through Layer 1)
- multiply the remaining anchor penetration by the maximum anchor penetration in Layer 2 to derive the Layer 2 penetration depth (e.g. in MEDIUM DENSE SAND a Band C anchor will penetrate 0.40m. If only ~33% of its penetrating potential remains after penetrating through Layer 1 then this equates to ~0.13cm penetration into Layer 2)

Thus, total penetration is calculated by adding the penetration thicknesses for Layer 1 and (where applicable) Layer 2 together.

Table 6-3 Anchor Sizes and Anchor Penetration Depth by Soil Category

Band Name	Selected Anchor Mass [kg]	Theoretical anchor penetration value [m]	Scaled anchor penetration by soil category [m]			
			Very Loose sand	Loose sand	Medium dense	SAND and CLAY (≥10 to <100 kPa) & CLAY (≥10 to <100 kPa)
Band A	570	0.44	0.38	0.30	0.15	0.44
Band B	1,290	0.57	0.49	0.39	0.20	0.57
Band C	5,000	0.89	0.76	0.60	0.30	0.89
Band D	7,800	1.05	0.89	0.71	0.36	1.05
Band E	11,100	1.17	1.00	0.79	0.40	1.17
Band F	17,800	1.25	1.06	0.84	0.43	1.25
Band G	20,000	1.28	1.09	0.86	0.44	1.28

Table 6-4 Anchor sizes and anchor penetration depth by soil category including a Factor of Safety of 1.5

Band Name	Selected Anchor Mass [kg]	Theoretical anchor penetration value [m]	Scaled anchor penetration by soil category (incl. FoS of 1.5 & rounded up to nearest 0.05m) [m]			
			Very Loose sand	Loose sand	Medium dense	SAND and CLAY (≥10 to <100 kPa) & CLAY (≥10 to <100 kPa)
Band A	570	0.44	0.60	0.45	0.25	0.70
Band B	1,290	0.57	0.75	0.60	0.30	0.90
Band C	5,000	0.89	1.15	0.95	0.50	1.35
Band D	7,800	1.05	1.35	1.10	0.55	1.60
Band E	11,100	1.17	1.50	1.20	0.60	1.80
Band F	17,800	1.25	1.60	1.30	0.65	1.90
Band G	20,000	1.28	1.65	1.30	0.70	1.95

6.4 Identification of the Acceptable Risk

The calculation for probability of a cable strike for the entire cable system is given by:

$$P_{anchor\ damage,total\ system} = \sum P_{anchor\ damage\ per\ km}$$

Where:

$P_{anchor\ damage,total\ system}$ = probability of anchor damage for the entire cable route (-/year)

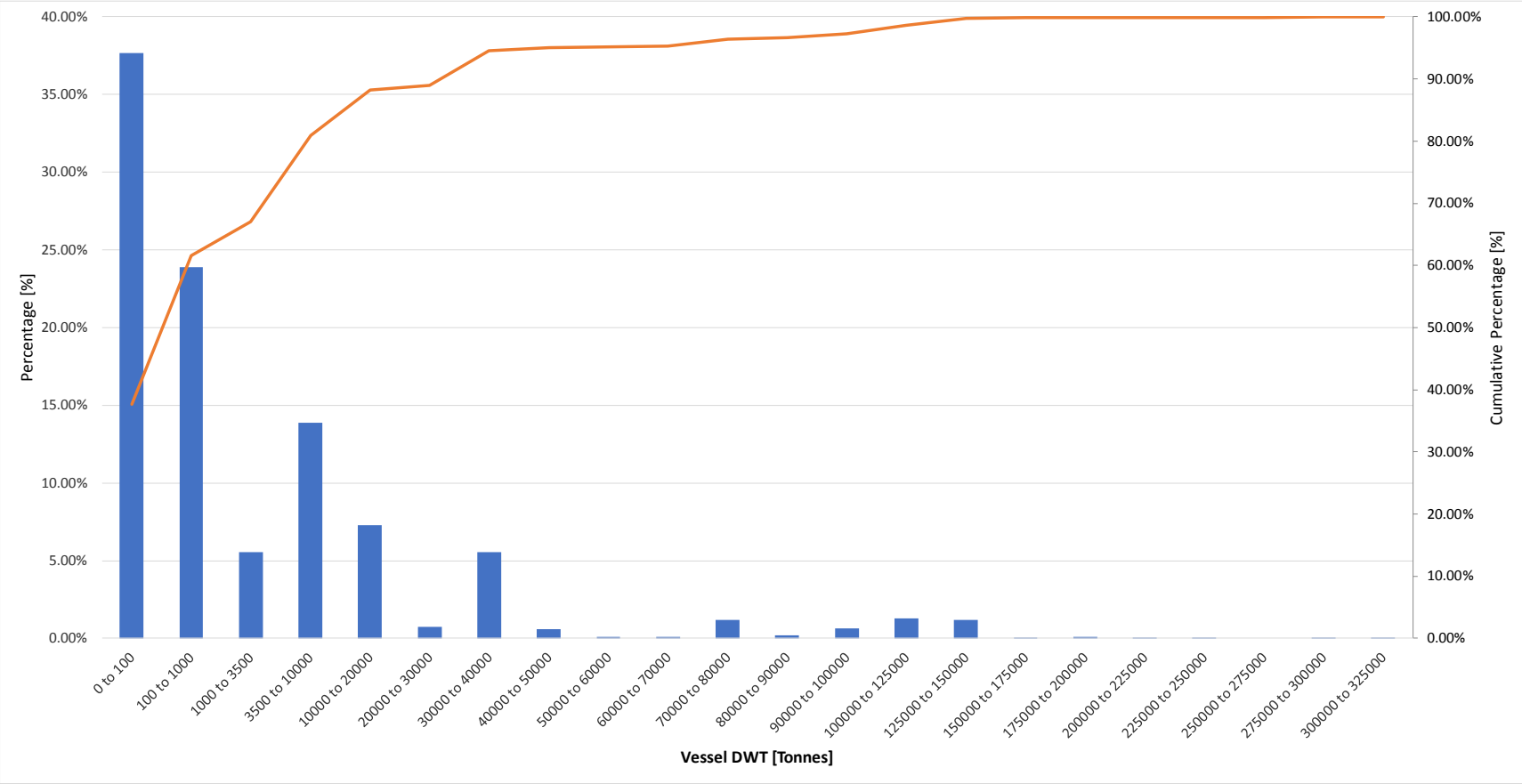
As recommended by the Carbon Trust's guideline (ref 1), Intertek used an iterative approach to identify a burial depth which results in a "target" residual risk to overall cable system.

The iterative step can be described as follows:

4. Calculate the value of $P_{anchor\ damage,total\ system}$ for all vessels with a surface-laid cable
5. Identify the value of $P_{anchor\ damage,total\ system}$ that would be acceptable to the stakeholders
6. Goal-seek RMDOL which achieves this tolerable level
7. If the RMDOL is considered impractical the acceptable level of risk should be re-considered.

The probabilistic assessment calculates the annual failure probability of 0.47% for the entire Greenlink route (based on anchor risk alone) if surface laid. This value equates to a return period of 214 years and a failure probability over the (40 year) lifetime of 17.08%. This is not an acceptable level of risk. **Figure 6-2** shows vessel size distribution by DWT. Naturally, vessel densities are overwhelmingly composed of smaller vessels, so risk reduces significantly as DOL increases over and above the penetration depths of anchor sizes associated with smaller vessels.

Figure 6-2 Overview of Vessel Size Distribution



6.5 Probabilistic risk assessment results

6.5.1 Results for Recommended Minimum DOL

A RMDOL was derived on a zone basis to remove the risk from anchoring from the selected vessel band in order to achieve an overall acceptable risk. The tables below present the RMDOL and associated annual failure probability for the following 7 scenarios:

8. Scenario 1: Protection against vessels in Band A
9. Scenario 2: Protection against vessels in Bands A to B
10. Scenario 3: Protection against vessels in Bands A to C
11. Scenario 4: Protection against vessels in Bands A to D
12. Scenario 5: Protection against vessels in Bands A to E
13. Scenario 6: Protection against vessels in Bands A to F
14. Scenario 7: Protection against vessels in Bands A to G
15. Scenario 8: Selected protection section by section

As can be seen in the provided scenarios, anchoring risk is concentrated in Zone 3, both in terms of vessel traffic density and also size of associated vessels. This is followed by Zone 4 and Zone 27. If the Greenlink cable is sufficiently protected within these zones from risk of anchor damage then the risk over the lifetime reduces significantly to the point where anchoring risk is only the determinant in Zone 3, and co-determinant in Zones 4, with all other zones having RMDOL determined by fishing risk alone. Note, the key reasons why anchor risk is not the key determinant in most zones is due to both the relatively light vessel densities and also the prevalent presence of soils which prevent anchors from penetrating very deeply.

The above approach results in a RMDOL of 0.60m in all zones except Zone 3 where it is set at 0.75m. If these RMDOL values are achieved and maintained over the course of the cable lifetime then this would result in an annual failure rate of 0.02% which equates to a return period of ~6,291 years and a failure probability over the (40 year) lifetime of 0.63% - i.e. “Although they are conceivable, not expected to occur. Plausible but no known occurrences in industry.”.

6.5.2 Results for Target DoL

TDOL is determined as what can reasonably be added to RMDOL without incurring a step change in costs and which represents a practical target for burial tools on the market. Intertek has analysed the soils and set TDOL as 1.5m where this is considered easy to achieve (Zones 1-4, 6, 12-17, 19-23, 25-28) and 1.0m where 1.5m would likely require multiple passes and/or different tools such that would not be required if only working to RMDOL. Note this approach is possible due to the relatively low RMDOL values calculated (i.e. maximum 0.75m)

The DOL specification by cable route zone are provided in **Appendix F**.

7. CBRA ASSESSMENT

Zones						Water Depth (m below LAT)			Known Co-Located Infrastructure/ Obstacles	Geophysical/Geotechnical Data						Shipping Data (Anchoring Assessment)				Fishing Data		Recommended Minimum Depth of Lowering (m)	Target Depth of Lowering (m)
FID	Geo Zone	Zone ID	Start KP	End KP	Length (km)	MAX	MIN	Mean		Survey Block	Dominant Sediment Type (within Anchor Penetration Depths)	Predominant Density (0-2m where applicable)	Predominant Shear Strength (0-2m where applicable)	Mobile Features (where applicable)	Categorisation for Anchor Penetration Calculation	Risk from Anchoring?	Shipping Buffer Size (m)	Water Depth Range (m)	Recommended DoL for Protection against Anchor Strike (including Factor of Safety of 1.5 & rounded up to nearest 0.05m) (m)	Presence of Fishing	Recommended DoL for Protection against Fishing Gear (including Factor of Safety of 2) (m)		
1	1	1A	**0.000**	**1.149**	1.149	10.009	-8.290	1.780		6	Medium Dense Sand with Loose Sand Veneer (0.5m)	Medium Dense	-	-	MEDIUM DENSE SAND	Yes	2,000	0 to 10	0.45	Mobile & Static	0.60	0.60	1.50
2	1	1B	**1.149**	**4.737**	3.588	34.998	10.009	25.969		5	Medium Dense Sand with Loose Sand Veneer (0.5m)	Medium Dense	-	-	MEDIUM DENSE SAND	Yes	2,000	10 to 30	0.45	Mobile & Static	0.60	0.60	1.50
3	2	2	**4.737**	**14.382**	9.645	50.930	29.855	41.068		5	Medium Dense Sand with Very Loose Sand Veneer (0.3m)	Medium Dense	-	Ripples & Sandwaves	MEDIUM DENSE SAND	Yes	2,000	30 to 50	0.75	Mobile & Static	0.60	0.75	1.50
4	3	3	**14.382**	**26.451**	12.069	59.550	50.870	55.814		5	Medium Dense Sand with Very Loose Sand Veneer (0.15m)	Medium Dense	(KP 23.675 Sample 12, High kPa at 1m depth (>100kPa), KP 28.032 kPa > 150 at 0.5m)	Sandwaves	MEDIUM DENSE SAND	Yes	2,000	50 to 75	0.60	Mobile & Static	0.60	0.60	1.50
5	4	4	**26.451**	**40.555**	14.104	68.321	57.710	61.906		4 to 5	Medium Dense Sand with Very Loose Sand Veneer (0.2m)	Medium Dense	(Samples 015 & 016 around KP 26 to 31 have >100 kPa at depths from 0.4m, then no shear strengths values within 2m. High kPa values below 2m at KP 35.400 with sample 095. KP 37.100 Sample 096 has kPA > 120)	Ripples	MEDIUM DENSE SAND	Yes	2,000	50 to 75	0.40	Mobile & Static	0.60	0.60	1.00
6	5	5	**40.555**	**42.871**	2.316	69.879	66.486	67.462		4	Medium Dense Sand with Loose Sand Veneer (0.2m) (Termination depth of CPT 0.52m)	Medium Dense	-	Ripples	MEDIUM DENSE SAND	Yes	2,000	50 to 75	0.35	Mobile & Static	0.60	0.60	1.50
7	6	6A	**42.871**	**43.941**	1.070	75.000	69.783	72.574		4	Medium Dense Sand with Loose Sand Veneer (0.2m)	Medium Dense	(No values provided but limited CPT penetration)	-	MEDIUM DENSE SAND	Yes	2,000	50 to 75	0.35	Mobile & Static	0.60	0.60	1.00
8	6	6B	**43.941**	**44.735**	0.794	76.870	74.750	75.882		4	Medium Dense Sand with Loose Sand Veneer (0.2m)	Medium Dense	-	-	MEDIUM DENSE SAND	Yes	2,000	75 to 100	0.00	Mobile & Static	0.60	0.60	1.00
9	7	7	**44.735**	**48.947**	4.212	91.484	76.477	83.101		4	Medium Strength CLAY/Loose SAND with Very Loose SAND Veneer (0.3m) (Max 1m anchor penetration)	Loose	(Top 0.5m up to 80 kPa From 1.4m > 110 kPA)	-	SAND and CLAY (≥10 to <100 kPa) & CLAY (≥10 to <100 kPa)	Yes	2,000	75 to 100	0.00	Mobile & Static	0.60	0.60	1.00
10	8	8A	**48.947**	**50.133**	1.187	99.959	90.690	95.274		4	Medium Dense Sand with Very Loose Sand Veneer (0.5m)	Medium Dense	(From 1.3m depth Clays > 100kPA)	Ripples	MEDIUM DENSE SAND	Yes	2,000	75 to 100	0.00	Mobile & Static	0.60	0.60	1.00
11	8	8B	**50.133**	**52.257**	2.123	118.589	99.959	109.216		4	Medium Dense Sand with Very Loose Sand Veneer (0.5m)	Medium Dense	(80 to 90 kPa from 1.4m depth at KP 52.260, Rest is <40 kPa)	-	MEDIUM DENSE SAND	Yes	2,000	>100	-	Mobile & Static	0.60	0.60	1.00
12	9	9	**52.257**	**57.523**	5.266	127.857	114.072	119.046		4	Medium Dense Sand with Very Loose Sand Veneer (0.3m)	Medium Dense	(80 to 90 kPa from 1.4m depth at KP 52.260 Rest is <50 kPa along section)	-	MEDIUM DENSE SAND	Yes	2,000	>100	-	Mobile & Static	0.60	0.60	1.50
13	10	10	**57.523**	**58.608**	1.085	116.680	113.730	115.236		4	Very Loose Sand with Medium Dense Sand Veneer (0.3m)	Medium Dense	-	Ripples	MEDIUM DENSE SAND	Yes	2,000	>100	-	Mobile & Static	0.60	0.60	1.50
14	11	11	**58.608**	**61.366**	2.758	116.720	110.220	113.162	Pan European Crossing 2 Cable [KP 59.790]	4	Medium Dense Sand with Very Loose Sand Veneer (0.1m)	Medium Dense	-	Ripples	MEDIUM DENSE SAND	Yes	2,000	>100	-	Mobile & Static	0.60	0.60	1.50
15	12	12	**61.366**	**64.472**	3.106	113.600	110.657	111.821		4	Loose Sand	Loose	-	Ripples	LOOSE SAND	Yes	2,000	>100	-	Mobile & Static	0.60	0.60	1.50
16	13	13	**64.472**	**67.531**	3.059	116.246	110.540	114.007		4	Low Strength CLAY with Loose Sand Veneer (0.3m)	-	Low Strength	Ripples & Sandwaves	SAND and CLAY (≥10 to <100 kPa) & CLAY (≥10 to <100 kPa)	Yes	2,000	>100	-	Mobile & Static	0.60	0.60	1.50
17	14	14	**67.531**	**72.063**	4.532	115.900	111.730	113.843		4	Loose Sand with Very Loose Sand Veneer (0.2m)	Loose	-	Ripples	LOOSE SAND	Yes	2,000	>100	-	Mobile & Static	0.60	0.60	1.50
18	15	15	**72.063**	**80.380**	8.317	115.920	103.660	112.699		3 to 4	Medium Strength CLAY with Loose Sand Veneer (0.3m)	-	Medium Strength	Ripples	SAND and CLAY (≥10 to <100 kPa) & CLAY (≥10 to <100 kPa)	Yes	2,000	>100	-	Mobile & Static	0.60	0.60	1.00
19	16	16A	**80.380**	**81.043**	0.663	104.349	99.940	102.435		3	Medium Dense Sand with Loose Sand Veneer (0.3m)	Medium Dense	-	Ripples	MEDIUM DENSE SAND	Yes	2,000	>100	-	Mobile & Static	0.60	0.60	1.50
20	16	16B	**81.043**	**84.937**	3.894	100.035	88.069	92.368		3	Medium Dense Sand with Loose Sand Veneer (0.3m)	Medium Dense	-	Ripples	MEDIUM DENSE SAND	Yes	2,000	75 to 100	0.00	Mobile & Static	0.60	0.60	1.50
21	17	17A	**84.937**	**88.154**	3.217	88.153	74.930	82.771	Hybernia Atlantic Cable [KP 86.7]	3	Medium Dense Sand with Very Loose Sand Veneer (0.25m)	Medium Dense	-	Ripples	MEDIUM DENSE SAND	Yes	2,000	75 to 100	0.00	Mobile & Static	0.60	0.60	1.50
22	17	17B	**88.154**	**100.786**	12.632	75.000	65.700	70.211	Pan European Crossing 1 Cable [KP 95.933]	2 to 3	Medium Dense Sand with Very Loose Sand Veneer (0.25m)	Medium Dense	-	Ripples & Sandwaves	MEDIUM DENSE SAND	Yes	2,000	50 to 75	0.40	Mobile & Static	0.60	0.60	1.50
23	18	18	**100.786**	**114.905**	14.119	68.680	63.980	67.289	ESAT1 Cable [KP 102.512]	2	Medium Dense Sand with Loose Sand Veneer (0.3m)	Medium Dense	-	Ripples & Sandwaves	MEDIUM DENSE SAND	Yes	2,000	50 to 75	0.40	Mobile & Static	0.60	0.60	1.50
24	19	19	**114.905**	**120.941**	6.036	72.520	66.790	69.504		2	Medium Dense Sand with Very Loose Sand Veneer (0.2m)	Medium Dense	-	Ripples	MEDIUM DENSE SAND	Yes	2,000	50 to 75	0.40	Mobile & Static	0.60	0.60	1.00
25	20	20	**120.941**	**134.199**	13.258	67.080	52.639	60.109	Solas Cable [KP 121.534]	2	Medium Dense Sand with Loose Sand Veneer (0.2m)	Medium Dense	-	Ripples	MEDIUM DENSE SAND	Yes	2,000	50 to 75	0.35	Mobile & Static	0.60	0.60	1.50
26	21	21A	**134.199**	**135.969**	1.770	53.100	49.970	52.002		2	Medium Dense Sand	Medium Dense	-	Ripples	MEDIUM DENSE SAND	Yes	2,000	50 to 75	0.25	Mobile & Static	0.60	0.60	1.50
27	21	21B	**135.969**	**147.952**	11.983	49.990	31.230	40.092	Out of Service Celtic Cable [139.097]	2	Medium Dense Sand	Medium Dense	-	Ripples	MEDIUM DENSE SAND	Yes	2,000	30 to 50	0.25	No fishing present from data or fisheries assessment, however - static fishing gear is known in this area from liaison with fishermen	0.60	0.60	1.50
28	22	22	**147.952**	**157.212**	9.260	31.610	14.030	24.941		1 to 2	Medium Dense Sand with Loose Sand Veneer (0.3m)	Medium Dense	-	Ripples	MEDIUM DENSE SAND	Yes	2,000	30 to 50	0.40		0.60	0.60	1.50
29	23	23A	**157.212**	**158.713**	1.501	14.180	10.021	13.148		1	Medium Dense Sand with Low Strength Clay Veneer (0.3m)	Medium Dense	-	Ripples	MEDIUM DENSE SAND	Yes	2,000	10 to 30	0.45		0.60	0.60	1.00
30	23	23B	**158.713**	**159.060**	0.347	10.021	3.874	7.183		1	Medium Dense Sand with Low Strength Clay Veneer (0.3m)	Medium Dense	-	-	MEDIUM DENSE SAND	Yes	2,000	10 to 30	0.45		0.60	0.60	1.00
31	24	24	**159.060**	**159.267**	0.207	3.877	-4.468	1.407	Rock Outcrop	1	Weathered Mudstone	ROCK	-	-	ROCK	Yes	2,000	0 to 10	Mechanical Protection		0.60	0.60 (or mechnical protection)	0.60 (or equivalent mechanical protection)

8. CONCLUSION AND RECOMMENDATIONS

The cable burial risk assessment has shown that the following hazards are present along the Greenlink cable route. The main areas of concern are explained below:

Sediment Mobility

Sediment mobility in itself does not pose a threat to a submarine cable but it can lead to issues with the thermal conductivity of cables (over burial), and exposure of cables (scour); burial under excess sand can change the thermal properties of the soil and cause hotspots along the cable, while exposure increases the risk of damage due to external aggressors such as trawling and anchoring and potentially mechanical damage from free spans.

There are a number of areas within the Greenlink 500m corridor where there are bedforms present which could be mobile.

The first indication of mobile bedforms can be seen between KP 5 and KP 6, just beyond an area of outcrop located in the nearshore area at Freshwater West. This area of potential mobile bedforms is located to the south of the centreline within a protected sandbank area. The bedforms are up to 2.5m high and have a wavelength of ~250m. Smaller megaripples (height ~0.3m, wavelength ~7m) are located on the larger bedforms. These smaller megaripples extend beyond the extent of the underlying large bedforms up to KP 10 where they stop due to a change in sediment.

The next indication of mobile bedforms is at KP 26 where the centreline transects two very large sandwaves which have a height of 12m (at KP 26) and 8m at (KP 26.3) and wavelengths of 280m. Megaripples are also present on these larger features. Small isolated patches of Megaripples are then observed up to ~KP 59 (~0.3m height, ~10m wavelength).

At ~KP 59 the megaripples increase in size to ~0.5m height, ~25m wavelength and then gradually decrease in size as the route progresses to ~KP 137, likely due to a fining of sediments. There are isolated sandwaves underlying the megaripples at KP 83 (height 1.5m, wavelength 230m), KP 99 (height 5m, wavelength unknown), KP 109 (height 4m, wavelength unknown) and KP 112 (height 3.5m, wavelength unknown). At KP 89 and KP 91 there are large relic sandbank features which have an elevation shift of ~5m and ~3m respectively. These relic sandbank features might still have some mobility.

For the remainder of the route (i.e. KP 137 to KP 159) there are no further large bedforms but megaripples (height 0.5m, wavelength 10m) are present from ~KP 149 to KP 159 within a channel on the approach to the landfall in Ireland.

In addition, Intertek is also aware that beach levels in Freshwater West vary with sediment movement after storm events.

For the purposes of burial targets (RMDOL & TDOL) all depths recommended in this report are assumed to be measured against a horizontal plane which has been determined to be non-mobile and after any required route engineering has been undertaken to flatten mobile sediments.

Fishing Risk

The review of the fishing assessment report (ref 7) for the Greenlink interconnector indicated areas of mobile and static fishing gear along the entire cable route. No fishing protection or exclusion areas from fishing activity were reported.

Moreover, as the entire route is within water depth ranges in which mobile gear fishing could take place, we recommend the cables are given sufficient protection from fishing gear interaction in all sections of the route. The Carbon Trust's guidance (ref 1) indicates that penetration of fishing gear into the seabed is limited to a maximum of 0.3 m penetration even in soft sediment based on

previous literature research. Allowing for a FoS of 2 means RMDOL based on fishing risk only would result in a value of 0.60m.

In Zones 11-19 where anchor risk is not present due to water depths exceeding 100m fishing risk is the sole determinant of RMDOL. In addition, adopting a value of 0.60m to protect against fishing risk results in fishing risk being the determinant or co-determinant of RMDOL in all zones except Zone 3.

Anchoring Risk

Vessel Automatic Identification System (AIS) data has been used to determine the size and quantity of vessels which operate in the vicinity of the cable route. Vessels are grouped into size categories based on their deadweight tonnage (DWT) from Band A (0-1000 DWT) to Band G (175K-325K DWT) and an appropriate associated anchor size is assigned to each band. Analysis of this data determines the probability of anchor-cable interactions for each vessel banding and thus the size of anchor which must be protected against in order to reduce risk to the cable to ALARP.

The probabilistic assessment calculates the annual failure probability of 0.47% for the entire Greenlink route (based on anchor risk alone) if surface laid. This value equates to a return period of 214 years and a failure probability over the (40 year) lifetime of 17.08%. This is not an acceptable level of risk.

Anchoring risk is concentrated in Zone 3, both in terms of vessel traffic density and also size of associated vessels. This is followed by Zone 4 and Zone 27. If the Greenlink cable is sufficiently protected within these zones from risk of anchor damage then the risk over the lifetime reduces significantly to the point where anchoring risk is only the determinant in Zone 3, and co-determinant in Zones 4, with all other zones having RMDOL determined by fishing risk alone. Note, the key reasons why anchor risk is not the key determinant in most zones is due to both the relatively light vessel densities and also the prevalent presence of soils which prevent anchors from penetrating very deeply.

Recommended Minimum Depth of Lowering (RMDOL)

The above approach results in a RMDOL of 0.60m in all zones except Zone 3 where it is set at 0.75m. If these RMDOL values are achieved and maintained over the course of the cable lifetime then this would result in an annual failure rate of 0.02% which equates to a return period of ~6,291 years and a failure probability over the (40 year) lifetime of 0.63% - i.e. “Although they are conceivable, not expected to occur. Plausible but no known occurrences in industry.”

Target Depth of Lowering (TDOL)

TDOL is determined as what can reasonably be added to RMDOL without incurring a step change in costs and which represents a practical target for burial tools on the market. Intertek has analysed the soils and set TDOL as 1.5m where this is considered easy to achieve (Zones 1-4, 6, 12-17, 19-23, 25-28) and 1.0m where 1.5m would likely require multiple passes and/or different tools such that would not be required if only working to RMDOL. Note this approach is possible due to the relatively low RMDOL values calculated (i.e. maximum 0.75m)

The DOL specification by cable route zone are provided in **Appendix F**

REFERENCES

1 Guidance for the Preparation of Cable Burial Depth of Lowering Specification, *Carbon Trust CTC835*

2 MMT Survey Data: Bathymetry

3 EMODNet (200m resolution), *http://portal.emodnetbathymetry.eu/*

4 AIS data. Oceaneering

5 MMT Crossing Survey report, *102953-GRL-MMT-SUR-REP-CABLECRE-03*

6 MMT Survey Data: Contacts

7 MMT Survey Data: Seabed Features

8 MMT Survey Data: Geology

9 MMT Geotechnical Sample Locations

10 MMT Geotechnical Report and VC & CPT logs, *102953-GRE-MMT-SUR-REP-GEOTECRE-02102953-02, CPT-IRE-Final Plots v02, 102953-CPT-UK-Final Plots v02, 102953 All VC 2019_04_08*

11 MMT Geophysical Report and Survey Results, 102553-NEU-MMT-SUR-REP-OPERFR-02

12 MMT Integrated Results report, 102953-GRL-MMT-SUR-REP-INTEGRRE-02

13 Admiralty charts, *http://wmsgateway.findmaps.co.uk/wms/IntertecMetocCharts?*

14 Greenlink Cable Route Report, P1975_BN4437_Rev3

15 MMT UXO Report, *102953-GRL-MMT-SUR-REP-UXOREP-03*

16 Anonymised AIS data for 2015, https://www.gov.uk/

17 Greenlink Interconnector Commercial Fisheries Assessment 2018, MarineSpace

18 GMarine Incident Report, www.gov.uk/maib

19 Vessel DWT, *https://www.marinetraffic.com/*

20 Anchor Catalogue, http://www.sotra.net/catalogue/2016/index.html)

21 Risk assessment of pipeline protection, *DNV_RP_F107*

22 Anchor Tests German Bight, Deltares

23 Marine & Coastguard Agency, DNV 2005

24 Submarine Power Cables - Design, Installation, Repair, Environmental Aspects, Worzyk, T, 2009

25 Developments in anchor technology and anchor penetration in the seabed, Dirk Luger, GeoDelft Presentation, Bremen, DK, 23 March 2006

APPENDIX A

Geotechnical Boundaries

Zone	Comments/Assumptions	Route KP	Location	Type	Top Layer				Layer 2				Layer 3			
					Top Layer Thickness (m)	Top Layer Description	Top Lay Relative density Description	Top Layer Shear Strength Description	Layer 2 Thickness (m)	Layer 2 Description	Layer 2 relative density Description	Layer 2 Shear Strength Description	Layer 3 Thickness (m)	Layer 3 Description	Layer 3 relative density Description	Layer 3 Shear Strength Description
1	Medium Dense SAND with 0.5m Veneer of Loose SAND	0.4	BH_04A_FW	BH	6.8	Silty SAND	-	-								
1	Medium Dense SAND with 0.5m Veneer of Loose SAND	0.69	BH_05A_FW	BH	4.95	Silty SAND	-	-								
1	Medium Dense SAND with 0.5m Veneer of Loose SAND	1.374	953_VC_094	VC	1.09	Silty SAND	-	-	0.24	GRAVEL	-	-	1.42	Clayey SILT	-	-
1	Medium Dense SAND with 0.5m Veneer of Loose SAND	1.374	953_CPT_094	CPT	0.34	Silty SAND	Loose to Medium Dense	-	1	Slightly Silty SAND	Medium Dense to Dense	-	0.28	GRAVEL	Dense to Very Dense	-
1	Medium Dense SAND with 0.5m Veneer of Loose SAND	2.096	953_VC_001A	VC	1.22	Silty SAND	-	-	0.4	Silty SAND	-	-	0.3	Silty GRAVEL	-	-
1	Medium Dense SAND with 0.5m Veneer of Loose SAND	2.097	953_CPT_001	CPT	0.44	Silty SAND	Loose to Medium Dense	-	0.96	Slightly Silty SAND	Medium Dense to Dense	-	0.74	Silty SAND	Medium Dense to Dense	-
1	Medium Dense SAND with 0.5m Veneer of Loose SAND	3.016	953_VC_093A	VC	1.89	Intermittent Layers of SAND & GRAVEL	-	-								
1	Medium Dense SAND with 0.5m Veneer of Loose SAND	3.015	953_CPT_093	CPT	0.82	Silty SAND	Loose to Medium Dense	-	0.94	Silty SAND & GRAVEL	Medium Dense to Dense	-	0.36	Silty SAND	Medium Dense	-
1	Medium Dense SAND with 0.5m Veneer of Loose SAND	4.738	953_VC_092A	VC	2.42	SAND	-	-								
1	Medium Dense SAND with 0.5m Veneer of Loose SAND	4.737	953_CPT_092	CPT	0.48	Silty SAND	Loose to Very Dense	-	2.6	Slightly Silty SAND	Medium Dense	-				
2	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	6.848	953_VC_002A	VC	0.38	Sandy GRAVEL	-	-								
2	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	6.849	953_CPT_002	CPT	0.1	Sandy GRAVEL	Very Loose to Loose	-	0.4	Sandy GRAVEL	Medium Dense to Dense	-	1.04	Silty SAND	Dense	-
2	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	6.852	953_CPT_002A	CPT	0.1	Sandy GRAVEL	Very Loose to Loose	-	0.44	Sandy GRAVEL	Medium Dense to Dense		2.28	Silty SAND	Dense	-
2	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	8.577	953_VC_106A	VC	2.1	SAND	-	-								
2	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	8.567	953_CPT_106	CPT	0.2	Silty SAND	Very Loose to Loose	-	3.22	Slightly Silty SAND	Medium Dense to Dense	-				
2	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	10.036	953_VC_003B	VC	0.13	Silty SAND	-	-	0.11	Clayey Gravel	-	-				
2	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	10.034	953_CPT_003	CPT	0.1	Silty SAND	Very Loose to Loose	-	0.28	Silty SAND	Medium Dense to Dense		0.08	Silty GRAVEL	Very Dense	-
2	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	10.034	953_CPT_003A	CPT	0.16	Silty SAND	Very Loose to Loose	-	0.22	Clayey Gravel	Very Dense	-				
2	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	11.758	953_VC_004	VC	0.3	SAND	-	-	0.44	Weathered MUSDTONE	-	-				
2	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	11.754	953_CPT_004A	CPT	0.1	Silty SAND	Very Loose to Loose	-	0.62	Silty SAND & GRAVEL	Medium Dense to Very Dense	-	1.36	Weathered MUSDTONE	Very Dense	-
2	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	11.758	953_CPT_004	CPT	0.1	Silty SAND	Very Loose to Loose	-	0.26	Silty SAND & GRAVEL	Medium Dense to Very Dense	-	0.6	Weathered MUSDTONE	Very Dense	-
2	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	13.239	953_VC_005A	VC	0.28	Silty SAND	-	-	1.68	Silty GRAVEL	-	-				
2	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	13.238	953_CPT_005	CPT	0.2	Silty SAND	Very Loose to Loose	-	0.68	Silty SAND	Medium Dense to Dense	-	2.02	Silty GRAVEL	Dense to Very Dense	-
2	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	14.382	953_VC_006A	VC	0.21	Silty SAND	-	-	0.51	Silty GRAVEL	-	-	0.1	SAND	-	-
2	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	14.383	953_CPT_006	CPT	0.26	Silty SAND	Very Loose to Loose	-	0.84	Silty GRAVEL	Dense	-	0.14	Silty Sand	Dense	
2	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	14.382	953_CPT_006A	CPT	0.2	Silty SAND	Very Loose to Loose		0.24	Silty SAND	Medium Dense to Dense	-	0.72	Silty GRAVEL	Dense	-
3	Medium Dense SAND with 0.15m Veneer of Very Loose SAND	16.263	953_VC_007	VC	0.37	Sandy GRAVEL	-	-								
3	Medium Dense SAND with 0.15m Veneer of Very Loose SAND	16.259	953_CPT_007	CPT	0.15	Sandy GRAVEL	Very Loose to Loose	-	0.41	Sandy GRAVEL	Very Dense	-				
3	Medium Dense SAND with 0.15m Veneer of Very Loose SAND	16.259	953_CPT_007A	CPT	0.72	Sandy GRAVEL	Medium Dense to Dense	-								
3	Medium Dense SAND with 0.15m Veneer of Very Loose SAND	17.743	953_VC_008A	VC	0.48	SAND	-	-	0.49	Sandy SILT	-	-	0.11	SAND	-	-
3	Medium Dense SAND with 0.15m Veneer of Very Loose SAND	17.743	953_CPT_008A	CPT	0.46	Silty SAND	Medium Dense to Dense	-	0.76	Sandy SILT	Dense to Very Dense	-				
3	Medium Dense SAND with 0.15m Veneer of Very Loose SAND	17.745	953_CPT_008	CPT	1.26	Silty SAND	Medium Dense to Dense	-								
3	Medium Dense SAND with 0.15m Veneer of Very Loose SAND	18.861	953_VC_009A	VC	1.54	SAND	-	-								
3	Medium Dense SAND with 0.15m Veneer of Very Loose SAND	18.861	953_CPT_009	CPT	0.4	Silty SAND	Medium Dense to Dense	-	0.88	Sandy SILT	Dense to Very Dense	-				
3	Medium Dense SAND with 0.15m Veneer of Very Loose SAND	18.861	953_CPT_009A	CPT	1.28	Silty SAND	Dense to Very Dense	-								
3	Medium Dense SAND with 0.15m Veneer of Very Loose SAND	20.169	953_VC_010	VC	0.27	SAND	-	-								
3	Medium Dense SAND with 0.15m Veneer of Very Loose SAND	20.166	953_CPT_010	CPT	0.28	SAND	Dense to Very Dense									
3	Medium Dense SAND with 0.15m Veneer of Very Loose SAND	20.167	953_CPT_010A	CPT	0.48	SAND	Medium Dense to Dense	-	0.24	Gravelly SAND	Dense to Very Dense	-				
3	Medium Dense SAND with 0.15m Veneer of Very Loose SAND	22.586	953_VC_011	VC	0.08	SAND	-	-	0.49	Sandy GRAVEL	-	-				
3	Medium Dense SAND with 0.15m Veneer of Very Loose SAND	22.585	953_CPT_011	CPT	0.1	Silty SAND	Very Loose to Loose		0.16	Silty SAND	Dense		0.74	Sandy GRAVEL	Dense	
3	Medium Dense SAND with 0.15m Veneer of Very Loose SAND	22.589	953_CPT_011A	CPT	0.26	Silty SAND	Medium Dense to Dense		0.34	Sandy GRAVEL	Dense					
3	Medium Dense SAND with 0.15m Veneer of Very Loose SAND	23.675	953_VC_012A	VC	0.23	Silty SAND	-	-	0.91	Silty CLAY	-	-	0.33	SAND	-	-
3	Medium Dense SAND with 0.15m Veneer of Very Loose SAND	23.676	953_CPT_012	CPT	0.68	Silty SAND	Medium Dense to Dense	-	0.7	CLAY	-	Very High Strength				
3	Medium Dense SAND with 0.15m Veneer of Very Loose SAND	23.678	953_CPT_012A	CPT	0.4	Silty SAND	Medium Dense to Dense	-	0.8	CLAY	-	Medium Strength	0.78	CLAY	-	Very High Strength
3	Medium Dense SAND with 0.15m Veneer of Very Loose SAND	24.872	953_VC_013	VC	2.29	SAND	-	-								
3	Medium Dense SAND with 0.15m Veneer of Very Loose SAND	24.874	953_CPT_013A	CPT	0.26	SAND	Loose to Medium Dense	-	1.62	SAND	Very Dense					
3	Medium Dense SAND with 0.15m Veneer of Very Loose SAND	26.447	953_VC_014	VC	0.5	SAND	-	-	0.5	Sandy GRAVEL	-	-	1.31	SAND	-	-
3	Medium Dense SAND with 0.15m Veneer of Very Loose SAND	26.45	953_CPT_014A	CPT	0.2	SAND	Medium Dense	-	0.5	SAND	Dense	-	0.52	Sandy GRAVEL	Very Dense	-
4	Medium Dense SAND with 0.2m Veneer of Very Loose SAND	26.451	953_CPT_014	CPT	0.26	SAND	Very Loose to Loose		0.32	SAND	Medium Dense to Dense	-	0.46	Sandy GRAVEL	Very Dense	-
4	Medium Dense SAND with 0.2m Veneer of Very Loose SAND	28.032	953_VC_015	VC	0.22	SAND	-	-	0.49	Silty CLAY	-	-				
4	Medium Dense SAND with 0.2m Veneer of Very Loose SAND	28.031	953_CPT_015	CPT	0.62	Silty SAND	Loose to Medium Dense	-	0.12	Silty SAND	Dense	-	0.38	Silty CLAY	-	Very High Strength
4	Medium Dense SAND with 0.2m Veneer of Very Loose SAND	28.031	953_CPT_015A	CPT	0.1	Silty SAND	Very Loose to Loose	-	0.6	Silty SAND	Loose to Medium Dense	-	0.38	Silty CLAY	-	Very High Strength
4	Medium Dense SAND with 0.2m Veneer of Very Loose SAND	29.532	953_VC_016A	VC	0.8	Silty CLAY	-	-								
4	Medium Dense SAND with 0.2m Veneer of Very Loose SAND	29.53	953_CPT_016	CPT	0.2	Silty SAND	Very Loose to Loose	-	0.98	Silty SAND	Medium Dense to Dense	-	0.7	Silty CLAY	-	High to Very High Strength
4	Medium Dense SAND with 0.2m Veneer of Very Loose SAND	30.994	953_VC_017	VC	1.29	Silty SAND	-	-								
4	Medium Dense SAND with 0.2m Veneer of Very Loose SAND	30.994	953_CPT_017	CPT	0.22	Gravelly SAND	Very Loose to Loose	-	0.9	Silty SAND	Medium Dense to Dense	-				
4	Medium Dense SAND with 0.2m Veneer of Very Loose SAND	32.317	953_VC_018A	VC	0.16	SAND	-	-	0.22	Sandy GRAVEL	-	-	1.93	Silty SAND	-	-
4	Medium Dense SAND with 0.2m Veneer of Very Loose SAND	32.32	953_CPT_018	CPT	0.4	Gravelly SAND	Loose to Medium Dense	-	0.12	Sandy GRAVEL	Medium Dense	-	2.3	Silty SAND	Dense	-
4	Medium Dense SAND with 0.2m Veneer of Very Loose SAND	33.862	953_VC_019	VC	1.09	SAND	-	-	0.27	Sandy GRAVEL	-	-				
4	Medium Dense SAND with 0.2m Veneer of Very Loose SAND	33.856	953_CPT_019	CPT	0.2	Silty SAND	Very Loose to Loose	-	1.08	Silty SAND	Medium Dense to Dense	-	0.38	Sandy GRAVEL	Very Dense	-
4	Medium Dense SAND with 0.2m Veneer of Very Loose SAND	35.403	953_VC_095A	VC	1.07	SAND	-	-	1.01	Silty CLAY	-	-				
4	Medium Dense SAND with 0.2m Veneer of Very Loose SAND	35.406	953_CPT_095	CPT	0.2	Silty SAND	Very Loose to Loose	-	0.28	Silty SAND	Medium Dense to Dense	-	1.86	Silty SAND	Dense to Very Dense	-
4	Medium Dense SAND with 0.2m Veneer of Very Loose SAND	37.106	953_VC_096	VC	0.22	SAND	-	-	0.14	Silty CLAY	-	-				
4	Medium Dense SAND with 0.2m Veneer of Very Loose SAND	37.107	953_CPT_096	CPT	0.15	Silty SAND	Very Loose to Loose	-	0.42	Silty SAND	Medium Dense to Dense	-	1.58	Silty CLAY	-	High to Very High Strength
4	Medium Dense SAND with 0.2m Veneer of Very Loose SAND	39.162	953_VC_097	VC	0.12	GRAVEL	-	-	0.15	Clayey SILT	-	-				
4	Medium Dense SAND with 0.2m Veneer of Very Loose SAND	39.167	953_CPT_097	CPT	0.1	Silty GRAVEL	Loose	-	0.44	Silty GRAVEL	Medium Dense to Dense	-	1.28	Silty SAND	Dense	-
4	Medium Dense SAND with 0.2m Veneer of Very Loose SAND	40.556	953_VC_098A	VC	0.22	Clayey GRAVEL	-	-								
4	Medium Dense SAND with 0.2m Veneer of Very Loose SAND	40.555	953_CPT_098	CPT	0.24	Silty GRAVEL	Loose to Medium Dense	-	0.72	Clayey SAND	Medium Dense to Dense	-	1.02	Silty CLAY	-	High to Very High Strength
5	Medium Dense to Dense SAND with 0.2m Veneer of Very Loose SAND (max 0.52m CPT depth)		953_VC_099	VC												
5	Medium Dense to Dense SAND with 0.2m Veneer of Very Loose SAND (max 0.52m CPT depth)		953_VC_099A	VC												
5	Medium Dense to Dense SAND with 0.2m Veneer of Very Loose SAND (max 0.52m CPT depth)	42.871	953_CPT_099A	CPT	0.18	Gravelly SAND	Very Loose to Loose	-	0.3	Silty SAND	Medium Dense to Dense		0.04	Silty SAND	Very Dense	-
6	Medium Dense SAND with 0.2m Veneer of Very Loose SAND	44.735	953_VC_100	VC	1.84	SAND	-	-								
6	Medium Dense SAND with 0.2m Veneer of Very Loose SAND	44.735	953_CPT_100	CPT	0.15	Silty SAND	Very Loose to Loose	-	0.39	Silty SAND	Medium Dense to Dense	-	1.24	Silty SAND	Very Dense	-
7	Low to Medium Strength CLAY/Loose SAND with 0.3m Veneer of Very Loose SAND (Max 1m anchor penetration)	46.09	953_VC_101	VC	0.36	SAND	-	-	0.87	Silty CLAY	-		0.29	Silty GRAVEL	-	-
7	Low to Medium Strength CLAY/Loose SAND with 0.3m Veneer of Very Loose SAND (Max 1m anchor penetration)	46.092	953_CPT_101	CPT	0.34	Gravelly SAND	Loose to Medium Dense	-	0.14	Silty CLAY	-	Low Strength	0.84	Silty SAND	Dense	-
7	Low to Medium Strength CLAY/Loose SAND with 0.3m Veneer of Very Loose SAND (Max 1m anchor penetration)	47.645	953_VC_102	VC	0.23	Silty GRAVEL	-	-	1.75	Silty CLAY	-	-				
7	Low to Medium Strength CLAY/Loose SAND with 0.3m Veneer of Very Loose SAND (Max 1m anchor penetration)	47.643	953_CPT_102	CPT	0.34	GRAVEL	Very Loose to Loose	-	2.1	Clayey SAND	-	Medium to High Strength	0.32	Clayey SILT	-	High Strength
7	Low to Medium Strength CLAY/Loose SAND with 0.3m Veneer of Very Loose SAND (Max 1m anchor penetration)	48.947	953_VC_103	VC	0.57	SAND	-	-	1.72	Silty CLAY	-	-				
7	Low to Medium Strength CLAY/Loose SAND with 0.3m Veneer of Very Loose SAND (Max 1m anchor penetration)	48.947	953_CPT_103	CPT	0.1	Clayey SAND	Very Loose to Loose		0.68	Clayey SAND	Loose to Medium Dense	-	0.56	Silty CLAY	-	High Strength
8	Medium Dense SAND with 0.5m Veneer of Very Loose SAND	50.628	953_VC_104	VC	1.57	SAND	-	-	0.42	Silty CLAY	-	-				
8	Medium Dense SAND with 0.5m Veneer of Very Loose SAND	50.627	953_CPT_104	CPT	0.2	Silty SAND	Very Loose to Loose	-	0.3	Silty SAND	Loose	-	0.94	Silty SAND	Medium Dense to Dense	-
8	Medium Dense SAND with 0.5m Veneer of Very Loose SAND	52.26	953_VC_105	VC	1.11	SAND	-	-	1.89	Silty CLAY	-	-				
8	Medium Dense SAND with 0.5m Veneer of Very Loose SAND	52.257	953_CPT_105	CPT	0.1	Silty SAND	Very Loose to Loose	-	0.5	Silty SAND	Medium Dense to Loose	-	0.2	Silty SAND	Very Loose	-
9	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	53.671	953_VC_020	VC	0.82	SAND	-	-	1.18	Sandy GRAVEL	-	-	1.07	Silty CLAY	-	-
9	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	53.668	953_CPT_020	CPT	0.32	Gravelly SAND	Very Loose to Loose	-	0.76	Gravelly SAND	Medium Dense	-	1.74	Sandy GRAVEL	Medium Dense to Dense	-
9	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	55.506	953_VC_021	VC	0.29	SAND	-	-	5.39	Silty CLAY	-	-				
9	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	55.504	953_CPT_021	CPT	0.1	Gravelly SAND	Very Loose to Loose	-	0.62	Gravelly SAND	Medium Dense	-	1.94	Silty CLAY	-	Medium Strength
9	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	57.52	953_VC_022B	VC	0.19	SAND	-	-	5.35	Silty CLAY	-	-				
9	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	57.523	953_CPT_022A	CPT	0.3	Silty SAND	Very Loose to Loose	-	0.86	Silty SAND	Medium Dense	-	1.32	Silty CLAY	-	Medium to High Strength
10	Very Loose SAND with 0.3m Veneer of Medium Dense SAND	58.608	953_VC_023A	VC	2.07	SAND	-	-	0.87	Silty CLAY	-	-				
10	Very Loose SAND with 0.3m Veneer of Medium Dense SAND	58.608	953_CPT_023	CPT	0.3	Silty SAND	Medium Dense to Very Loose	-	0.6	Silty SAND	Very Loose		1.54	Silty SAND	Medium Dense to Very Dense	-
11	Medium Dense SAND with 0.1m Veneer of Very Loose SAND	60.283	953_VC_024	VC	2.25	SAND	-	-								
11	Medium Dense SAND with 0.1m Veneer of Very Loose SAND	60.283	953_CPT_024	CPT	0.1	Silty SAND	Very Loose to Loose	-	2	Silty SAND	Medium Dense	-				
11	Medium Dense SAND with 0.1m Veneer of Very Loose SAND	61.364	953_VC_025A	VC	2.34	SAND	-	-								
11	Medium Dense SAND with 0.1m Veneer of Very Loose SAND	61.366	953_CPT_025	CPT	0.1	Silty SAND	Very Loose to Loose	-	0.68	Silty SAND	Medium Dense	-	2.44	Silty SAND	Medium Dense to Dense	-
12	Loose SAND	62.827	953_VC_026A	VC	0.25	SAND	-	-	4.43	Silty CLAY	-	-				
12	Loose SAND	62.825	953_CPT_026	CPT	1	Silty SAND	Loose	-	4.98	Silty CLAY	-	Low to Medium Strength				
12	Loose SAND	64.473	953_VC_027	VC	1.13	SAND	-	-	4.57	Silty CLAY	-	-				
12	Loose SAND	64.472	953_CPT_027	CPT	0.63	Silty SAND	Very Loose to Loose	-	0.25	Silty SAND	Loose to Medium Dense	-	0.34	Silty CLAY	-	Low to Medium Strength
13	Low Strength CLAY with 0.3m Veneer of Loose SAND	65.978	953_VC_028A	VC	0.22	SAND	-	-	4.33	Silty CLAY	-					
13	Low Strength CLAY with 0.3m Veneer of Loose SAND	65.978	953_CPT_028	CPT	0.94	Silty SAND	Loose to Medium Dense to Very Loose	-	5.98	Silty CLAY	-	Low to Medium Strength				
13	Low Strength CLAY with 0.3m Veneer of Loose SAND	67.528	953_VC_029	VC	0.27	Sandy GRAVEL	-	-	5.15	Silty CLAY	-					
13	Low Strength CLAY with 0.3m Veneer of Loose SAND	67.531	953_CPT_029A	CPT	0.3	Clayey SAND	Very Loose to Loose	-	5.7	Silty CLAY		Low to Medium Strength				
14	Loose SAND with 0.2m Veneer of Very Loose SAND	69.006	953_VC_030	VC	0.89	SAND	-	-	0.12	Silty GRAVEL	-	-	0.71	Silty CLAY	-	-
14	Loose SAND with 0.2m Veneer of Very Loose SAND	69.008	953_CPT_030	CPT	0.2	Silty SAND	Very Loose	-	1.74	Silty SAND	Loose to Medium Dense	-	1.4	Silty CLAY	-	Medium Strength
14	Loose SAND with 0.2m Veneer of Very Loose SAND	70.536	953_VC_031	VC	0.65	Silty SAND	-	-	0.26	Clayey GRAVEL	-	-	1.73	Silty CLAY	-	-
14	Loose SAND with 0.2m Veneer of Very Loose SAND	70.538	953_CPT_031	CPT	0.2	Silty SAND	Very Loose	-	0.88	Silty SAND	Loose to Medium Dense	-	1.42	Silty CLAY	-	Low Strength
14	Loose SAND with 0.2m Veneer of Very Loose SAND	72.063	953_VC_032	VC	0.32	Silty SAND	-	-	2.13	Silty CLAY	-					
14	Loose SAND with 0.2m Veneer of Very Loose SAND	72.063	953_CPT_032	CPT	0.98	Silty SAND	Loose to Medium Dense	-	2.54	Silty CLAY	-	Low to Medium Strength				
15	Low to Medium Strength CLAY with 0.5m Layer of Loose SAND	73.996	953_VC_033	VC	0.33	Silty SAND	-	-	1.91	Silty CLAY	-					
15	Low to Medium Strength CLAY with 0.5m Layer of Loose SAND	73.994	953_CPT_033	CPT	0.92	Silty SAND	Medium Dense	-	2.62	Silty CLAY	-	Medium Strength				
15	Low to Medium Strength CLAY with 0.5m Layer of Loose SAND	75.188	953_VC_034A	VC	0.29	Silty SAND	-	-	2	Silty CLAY	-	-				
15	Low to Medium Strength CLAY with 0.5m Layer of Loose SAND	75.188	953_CPT_034	CPT	0.48	Silty SAND	Loose to Medium Dense	-	1.3	Silty CLAY	-	Low to Medium Strength	0.6	Silty SAND	Dense	-
15	Low to Medium Strength CLAY with 0.5m Layer of Loose SAND	76.948	953_VC_035A	VC	0.93	Silty SAND	-	-	1.81	Silty CLAY	-	-				
15	Low to Medium Strength CLAY with 0.5m Layer of Loose SAND	76.949	953_CPT_035	CPT	0.15	Silty SAND	Very Loose to Loose	-	1.23	Silty SAND	Medium Dense to Dense	-	1.94	Silty CLAY	-	Low Strength
15	Low to Medium Strength CLAY with 0.5m Layer of Loose SAND	78.809	953_VC_036A	VC	3	Silty SAND	-	-								
15	Low to Medium Strength CLAY with 0.5m Layer of Loose SAND	78.809	953_CPT_036	CPT	1.5	Silty SAND	Loose	-	0.16	Silty CLAY	-	Medium Strength				
15	Low to Medium Strength CLAY with 0.5m Layer of Loose SAND	80.38	953_VC_037A	VC	2.19	Silty SAND	-	-								
15	Low to Medium Strength CLAY with 0.5m Layer of Loose SAND	80.38	953_CPT_037	CPT	0.2	Silty SAND	Loose	-	0.9	Silty SAND	Medium Dense	-	2.4	Silty SAND	Loose to Medium Dense	-
16	Medium Dense SAND with 0.3m Veneer of Loose SAND	81.538	953_VC_038	VC	2	Silty SAND	-	-								
16	Medium Dense SAND with 0.3m Veneer of Loose SAND	81.536	953_CPT_038	CPT	0.3	Silty SAND	Loose	-	1.7	Silty SAND	Medium Dense to Dense	-				
16	Medium Dense SAND with 0.3m Veneer of Loose SAND	83.293	953_VC_039B	VC	2.88	Silty SAND	-	-								
16	Medium Dense SAND with 0.3m Veneer of Loose SAND	83.298	953_CPT_039	CPT	0.1	Silty SAND	Loose	-	1.14	Silty SAND	Medium Dense to Dense	-				

16	Medium Dense SAND with 0.3m Veneer of Loose SAND	84.934	953_VC_040	VC	2.74	Silty SAND	-	-								
16	Medium Dense SAND with 0.3m Veneer of Loose SAND	84.937	953_CPT_040	CPT	0.4	Silty SAND	Loose	-	1.62	Silty SAND	Medium Dense to Dense	-				
17	Medium Dense SAND with 0.25m Veneer of Very Loose SAND	86.122	953_VC_041A	VC	1.19	Silty SAND	-	-	0.19	Clayey SILT	-	-				
17	Medium Dense SAND with 0.25m Veneer of Very Loose SAND	86.123	953_CPT_041	CPT	0.2	Silty SAND	Very Loose to Loose	-	0.92	Silty SAND	Medium Dense to Dense	-	0.52	Silty CLAY	-	High Strength
17	Medium Dense SAND with 0.25m Veneer of Very Loose SAND	87.405	953_VC_042	VC	3	Silty SAND	-	-								
17	Medium Dense SAND with 0.25m Veneer of Very Loose SAND	87.406	953_CPT_042	CPT	0.2	Silty SAND	Very Loose to Loose	-	2.28	Silty SAND	Dense to Very Dense	-				
17	Medium Dense SAND with 0.25m Veneer of Very Loose SAND	89.058	953_VC_043	VC	3	Silty SAND	-	-								
17	Medium Dense SAND with 0.25m Veneer of Very Loose SAND	89.059	953_CPT_043	CPT	0.26	Silty SAND	Loose to Medium Dense	-	3	Silty SAND	Medium Dense to Dense	-				
17	Medium Dense SAND with 0.25m Veneer of Very Loose SAND	90.819	953_VC_044	VC	2.25	Silty SAND	-	-								
17	Medium Dense SAND with 0.25m Veneer of Very Loose SAND	90.822	953_CPT_044	CPT	0.25	Silty SAND	Very Loose to Loose	-	3	Silty SAND	Medium Dense to Dense	-				
17	Medium Dense SAND with 0.25m Veneer of Very Loose SAND	92.046	953_VC_045	VC	3	Silty SAND	-	-								
17	Medium Dense SAND with 0.25m Veneer of Very Loose SAND	92.047	953_CPT_045	CPT	0.2	Silty SAND	Loose	-	3.22	Silty SAND	Medium Dense to Dense	-				
17	Medium Dense SAND with 0.25m Veneer of Very Loose SAND	93.549	953_VC_046	VC	3	Silty SAND	-	-								
17	Medium Dense SAND with 0.25m Veneer of Very Loose SAND	93.552	953_CPT_046	CPT	0.25	Silty SAND	Loose	-	3.13	Silty SAND	Medium Dense to Dense	-				
17	Medium Dense SAND with 0.25m Veneer of Very Loose SAND	94.951	953_VC_047	VC	2.1	Silty SAND	-	-								
17	Medium Dense SAND with 0.25m Veneer of Very Loose SAND	94.955	953_CPT_047A	CPT	0.2	Silty SAND	Very Loose to Loose	-	1.5	Silty SAND	Medium Dense to Dense	-				
17	Medium Dense SAND with 0.25m Veneer of Very Loose SAND	96.534	953_VC_048A	VC	1.83	Silty SAND	-	-								
17	Medium Dense SAND with 0.25m Veneer of Very Loose SAND	96.537	953_CPT_048A	CPT	0.2	Silty SAND	Very Loose to Loose	-	1.9	Silty SAND	Medium Dense to Dense	-				
17	Medium Dense SAND with 0.25m Veneer of Very Loose SAND	97.997	953_VC_049	VC	3	Silty SAND	-	-								
17	Medium Dense SAND with 0.25m Veneer of Very Loose SAND	97.997	953_CPT_049	CPT	0.2	Silty SAND	Loose	-	2	Silty SAND	Medium Dense to Dense	-				
17	Medium Dense SAND with 0.25m Veneer of Very Loose SAND	99.763	953_VC_050	VC	3	Silty SAND	-	-								
17	Medium Dense SAND with 0.25m Veneer of Very Loose SAND	99.765	953_CPT_050	CPT	0.2	Silty SAND	Very Loose to Loose	-	3.16	Silty SAND	Dense	-				
17	Medium Dense SAND with 0.25m Veneer of Very Loose SAND	100.785	953_VC_051B	VC	3	Silty SAND	-	-								
17	Medium Dense SAND with 0.25m Veneer of Very Loose SAND	100.786	953_CPT_051	CPT	0.3	Silty SAND	Very Loose to Loose	-	2.76	Silty SAND	Medium Dense to Dense	-				
18	Medium Dense SAND with 0.3m Veneer of Loose SAND	101.901	953_VC_052	VC	3	Silty SAND	-	-								
18	Medium Dense SAND with 0.3m Veneer of Loose SAND	101.903	953_CPT_052	CPT	0.2	Silty SAND	Loose	-	3.02	Silty SAND	Medium Dense to Dense	-				
18	Medium Dense SAND with 0.3m Veneer of Loose SAND	103.778	953_VC_053	VC	0.66	Silty SAND	-	-	1.49	Silty GRAVEL	-	-				
18	Medium Dense SAND with 0.3m Veneer of Loose SAND	103.778	953_CPT_053	CPT	0.2	Silty SAND	Loose	-	1.86	Silty SAND	Medium Dense to Dense	-				
18	Medium Dense SAND with 0.3m Veneer of Loose SAND	105.629	953_VC_054	VC	0.38	Silty SAND	-	-	1.4	Silty GRAVEL	-	-				
18	Medium Dense SAND with 0.3m Veneer of Loose SAND	105.63	953_CPT_054	VC	0.46	Silty SAND	Loose to Medium Dense	-	0.38	Silty SAND	Medium Dense to Dense	-	0.7	Silty GRAVEL	Very Dense	-
18	Medium Dense SAND with 0.3m Veneer of Loose SAND	107.053	953_VC_055A	VC	1.1	Silty SAND	-	-	0.37	Sandy GRAVEL	-	-				
18	Medium Dense SAND with 0.3m Veneer of Loose SAND	107.052	953_CPT_055	CPT	0.1	Silty SAND	Loose	-	3.12	Silty SAND	Medium Dense to Dense	-				
18	Medium Dense SAND with 0.3m Veneer of Loose SAND	108.905	953_VC_056	VC	2.19	Silty SAND	-	-								
18	Medium Dense SAND with 0.3m Veneer of Loose SAND	108.905	953_CPT_056	CPT	0.2	Silty SAND	Loose	-	2.16	Silty SAND	Medium Dense to Dense	-				
18	Medium Dense SAND with 0.3m Veneer of Loose SAND	110.606	953_VC_057	VC	1.51	Silty SAND	-	-	0.52	Sandy GRAVEL	-	-				
18	Medium Dense SAND with 0.3m Veneer of Loose SAND	110.607	953_CPT_057	CPT	0.3	Silty SAND	Loose	-	1.8	Silty SAND	Medium Dense to Very Dense					
18	Medium Dense SAND with 0.3m Veneer of Loose SAND	111.893	953_VC_058	VC	2.12	Silty SAND	-	-								
18	Medium Dense SAND with 0.3m Veneer of Loose SAND	111.894	953_CPT_058	CPT	0.26	Silty SAND	Loose	-	3	Silty SAND	Dense to Very Dense	-				
18	Medium Dense SAND with 0.3m Veneer of Loose SAND	113.253	953_VC_059	VC	2.29	Silty SAND	-	-								
18	Medium Dense SAND with 0.3m Veneer of Loose SAND	113.254	953_CPT_059	CPT	0.4	Silty SAND	Loose	-	2.74	Silty SAND	Medium Dense to Dense	-				
18	Medium Dense SAND with 0.3m Veneer of Loose SAND	114.906	953_VC_060A	VC	1	Silty SAND	-	-	0.95	Silty CLAY	-	-				
18	Medium Dense SAND with 0.3m Veneer of Loose SAND	114.905	953_CPT_060	CPT	0.5	Silty SAND	Medium Dense	-	1.32	Silty SAND	Dense	-				
19	Medium Dense SAND with 0.2m Veneer of Very Loose SAND	116.398	953_VC_061A	VC	2.1	Silty SAND	-	-								
19	Medium Dense SAND with 0.2m Veneer of Very Loose SAND	116.399	953_CPT_061	CPT	0.2	Silty SAND	Very Loose to Loose	-	1.84	Silty SAND	Medium Dense to Dense	-				
19	Medium Dense SAND with 0.2m Veneer of Very Loose SAND	117.765	953_VC_062A	VC	0.18	Silty SAND	-	-	0.87	Silty GRAVEL	-	-	0.12	Silty SAND	-	-
19	Medium Dense SAND with 0.2m Veneer of Very Loose SAND	117.762	953_CPT_062	CPT	0.36	Silty SAND	Loose	-	0.9	Sandy GRAVEL	Very Dense	-	0.32	Silty SAND	Dense	-
19	Medium Dense SAND with 0.2m Veneer of Very Loose SAND	120.056	953_VC_063A	VC	2.07	Silty SAND	-	-								
19	Medium Dense SAND with 0.2m Veneer of Very Loose SAND	120.057	953_CPT_063	CPT	0.1	Silty SAND	Loose	-	1.4	Silty SAND	Medium Dense to Dense	-				
19	Medium Dense SAND with 0.2m Veneer of Very Loose SAND	120.941	953_VC_064	VC	2.1	Silty SAND	-	-								
19	Medium Dense SAND with 0.2m Veneer of Very Loose SAND	120.941	953_CPT_064	CPT	0.2	Silty SAND	Very Loose to Loose	-	1.06	Silty SAND	Medium Dense	-	0.54	Silty SAND	Dense	-
20	Medium Dense SAND with 0.2m Veneer of Loose SAND	122.412	953_VC_065	VC	0.91	Silty SAND	-	-	0.93	Silty GRAVEL	-	-				
20	Medium Dense SAND with 0.2m Veneer of Loose SAND	122.413	953_CPT_065	CPT	0.1	Silty SAND	Loose	-	1.16	Silty SAND	Medium Dense	-	0.92	Silty SAND	Dense	-
20	Medium Dense SAND with 0.2m Veneer of Loose SAND	123.92	953_VC_066	VC	2.1	Silty SAND	-	-								
20	Medium Dense SAND with 0.2m Veneer of Loose SAND	123.922	953_CPT_066	CPT	0.2	Silty SAND	Loose	-	3.04	Silty SAND	Medium Dense	-				
20	Medium Dense SAND with 0.2m Veneer of Loose SAND	125.849	953_VC_067A	VC	0.87	Silty SAND	-	-								
20	Medium Dense SAND with 0.2m Veneer of Loose SAND	125.85	953_CPT_067	CPT	0.15	Silty SAND	Loose	-	2.13	Silty SAND	Medium Dense	-				
20	Medium Dense SAND with 0.2m Veneer of Loose SAND	126.914	953_VC_068	VC	2.22	Silty SAND	-	-								
20	Medium Dense SAND with 0.2m Veneer of Loose SAND	126.915	953_CPT_068	CPT	0.2	Silty SAND	Loose	-								
20	Medium Dense SAND with 0.2m Veneer of Loose SAND	128.419	953_VC_069A	VC	2.36	Silty SAND	-	-								
20	Medium Dense SAND with 0.2m Veneer of Loose SAND	128.42	953_CPT_069	CPT	0.1	Silty SAND	Loose	-	2.46	Silty SAND	Medium Dense	-				
20	Medium Dense SAND with 0.2m Veneer of Loose SAND	130.285	953_VC_070	VC	2.47	Silty SAND	-	-								
20	Medium Dense SAND with 0.2m Veneer of Loose SAND	130.285	953_CPT_070	CPT	0.1	Silty SAND	Loose	-	2.88	Silty SAND	Medium Dense	-				
20	Medium Dense SAND with 0.2m Veneer of Loose SAND	132.33	953_VC_071	VC	2.12	Silty SAND	-	-								
20	Medium Dense SAND with 0.2m Veneer of Loose SAND	132.331	953_CPT_071	CPT	0.1	Silty SAND	Loose	-	3.14	Silty SAND	Medium Dense	-				
20	Medium Dense SAND with 0.2m Veneer of Loose SAND	134.198	953_VC_072	VC	2.5	Silty SAND	-	-								
20	Medium Dense SAND with 0.2m Veneer of Loose SAND	134.199	953_CPT_072	CPT	0.1	Silty SAND	Loose	-	3	Silty SAND	Medium Dense	-				
21	Medium Dense SAND	135.918	953_VC_073	VC	2.2	Silty SAND	-	-								
21	Medium Dense SAND	135.92	953_CPT_073	CPT	3.44	Silty SAND	Medium Dense	-								
21	Medium Dense SAND	137.41	953_VC_074	VC	2.28	Silty SAND	-	-								
21	Medium Dense SAND	137.411	953_CPT_074	CPT	3.36	Silty SAND	Medium Dense	-								
21	Medium Dense SAND	138.846	953_VC_075	VC	2.43	Silty SAND	-	-								
21	Medium Dense SAND	138.846	953_CPT_075	CPT	3.34	Silty SAND	Medium Dense	-								
21	Medium Dense SAND	140.409	953_VC_076	VC	2.39	Silty SAND	-	-								
21	Medium Dense SAND	140.41	953_CPT_076	CPT	3.3	Silty SAND	Medium Dense	-								
21	Medium Dense SAND	141.922	953_VC_077	VC	2.2	Silty SAND	-	-								
21	Medium Dense SAND	141.924	953_CPT_077	CPT	3.32	Silty SAND	Medium Dense	-								
21	Medium Dense SAND	143.427	953_VC_078	VC	2.12	Silty SAND	-	-								
21	Medium Dense SAND	143.428	953_CPT_078	CPT	3.28	Silty SAND	Medium Dense	-								
21	Medium Dense SAND	144.913	953_VC_079	VC	2.16	Silty SAND	-	-								
21	Medium Dense SAND	144.914	953_CPT_079	CPT	3.42	Silty SAND	Medium Dense	-								
21	Medium Dense SAND	146.421	953_VC_080	VC	2.62	Silty SAND	-	-								
21	Medium Dense SAND	146.422	953_CPT_080	CPT	1	Silty SAND	Medium Dense	-	2.1	Silty SAND	Very Loose to Loose	-				
21	Medium Dense SAND	147.952	953_VC_081	VC	0.61	Silty SAND	-	-	1.73	Silty GRAVEL	-	-				
21	Medium Dense SAND	147.952	953_CPT_081A	CPT	0.5	Silty SAND	Medium Dense	-	0.34	Silty SAND	Loose	-	0.96	Silty GRAVEL	Very Dense	-
22	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	149.4	953_VC_082	VC	2.12	Silty SAND	-	-								
22	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	149.401	953_CPT_082	CPT	0.36	Silty SAND	Loose to Medium Dense	-	2.06	Silty SAND	Medium Dense to Dense	-				
22	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	150.922	953_VC_083	VC	2.52	Silty SAND	-	-								
22	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	150.933	953_CPT_083	CPT	0.2	Silty SAND	Very Loose to Loose	-	0.9	Silty SAND	Medium Dense to Very Dense	-				
22	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	152.419	953_VC_084A	VC	2.9	Silty GRAVEL	-	-								
22	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	152.421	953_CPT_084	CPT	0.3	Silty GRAVEL	Very Loose to Loose	-	1.78	Silty GRAVEL	Very Dense	-				
22	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	154.117	953_VC_085	VC	2.08	Silty SAND	-	-								
22	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	154.119	953_CPT_085	CPT	0.3	Gravelly SAND	Very Loose to Loose	-	2.76	Silty SAND	Medium Dense to Dense	-				
22	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	155.403	953_VC_086	VC	1.48	Silty SAND	-	-								
22	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	155.406	953_CPT_086A	CPT	0.24	Silty SAND	Loose	-	1.98	Silty SAND	Dense to Very Dense	-				
22	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	156.535	953_VC_087A	VC	2.2	Silty GRAVEL	-	-								
22	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	156.536	953_CPT_087A	CPT	0.3	Silty GRAVEL	Very Loose to Loose	-	2.22	Silty GRAVEL	Medium Dense to Dense	-				
22	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	156.954	953_VC_091A	VC	1.39	Silty CLAY	-	-								
22	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	156.954	953_CPT_091A	CPT	0.22	Silty SAND	Loose to Medium Dense	-	3.04	Silty CLAY	-	Low Strength				
22	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	157.209	953_VC_088A	VC	1.83	Silty SAND	-	-								
22	Medium Dense SAND with 0.3m Veneer of Very Loose SAND	157.212	953_CPT_088	CPT	0.24	Gravelly SAND	Very Loose to Loose	-	2.9	Silty SAND	Medium Dense to Dense	-				
23	Medium Dense SAND with 0.3m Veneer of Low Strength CLAY	158.226	953_VC_089	VC	0.3	Clayey SILT	-	-	0.41	Silty SAND	-	-	1.29	Silty CLAY	-	-
23	Medium Dense SAND with 0.3m Veneer of Low Strength CLAY	158.223	953_CPT_089	CPT	0.32	Clayey SILT	-	Low to Medium Strength	1.14	Silty SAND	Medium Dense to Dense	-	0.4	Silty CLAY	-	Low Strength
23	Medium Dense SAND with 0.3m Veneer of Low Strength CLAY	158.93	BH_005	BH	1.6	Silty Sand	Medium Dense	-	0.9	Gravelly CLAY	-	High Strength				
24	Weathered Mudstone	159.06	BH_06	BH	-	-	-	-	25.2	MUDSTONE	Weak/Weathered					
24	Weathered Mudstone	159.26	KP END	-	-	-	-	-	25.2	MUDSTONE	Weak/Weathered					

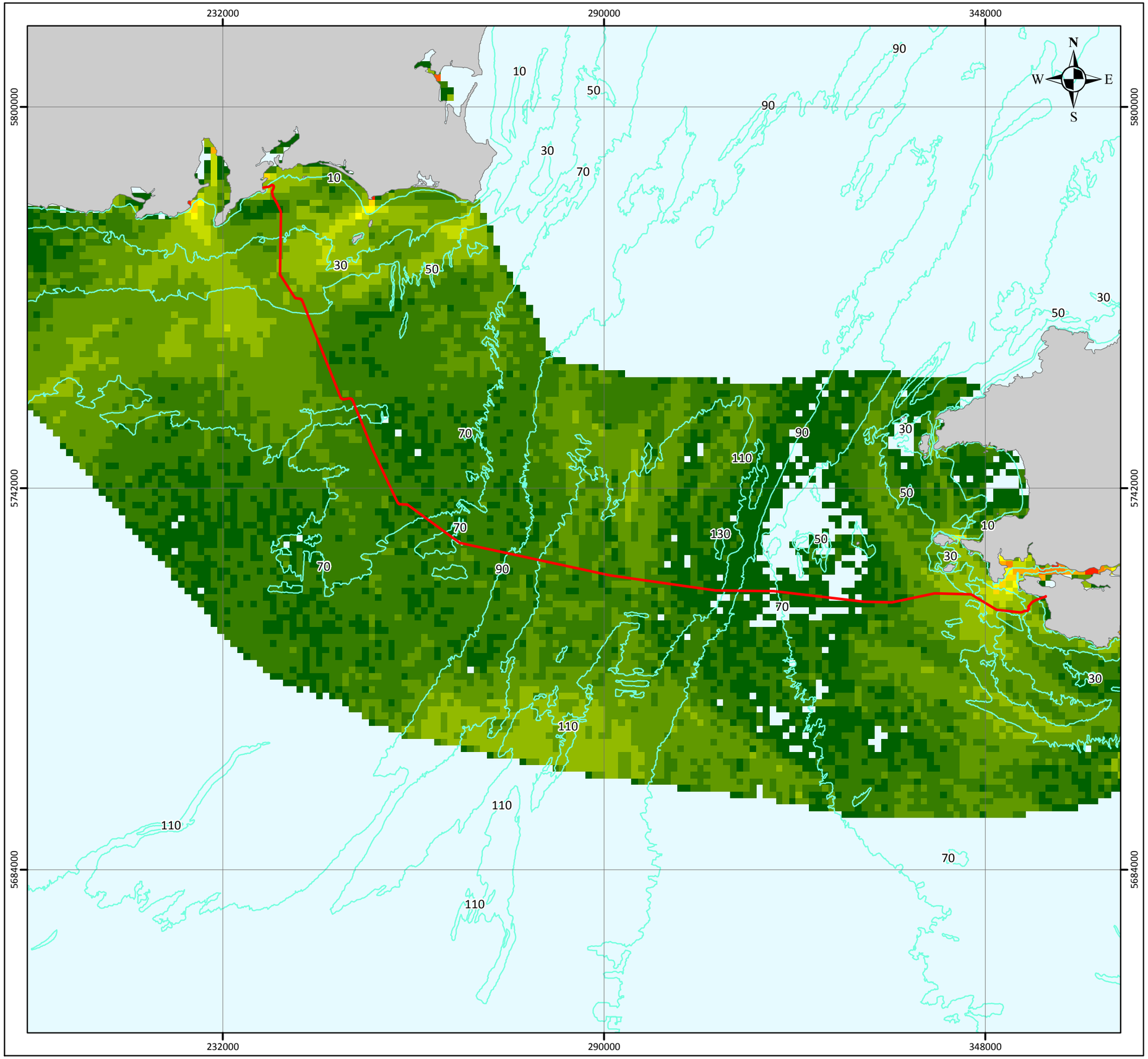
APPENDIX B

Risk Register

Hazard log Ref No.	Hazard Class	Hazard Description (potential)	Risk Description	Initial Risk Rating			Mitigation	Residual Risk Rating		
				Likelihood	Severity	Risk rating		Likelihood	Severity	Risk rating
Natural										
1	Bathymetry	Influences presence of other natural and anthropogenic hazards.	No bathymetric features identified (e.g steep slopes) which could lead to specific risks. **Not scored**							
2	Seabed topography	Uneven seabed topography may lead to more variable burial requirements.	The selected cables route avoid largest sandwaves and megaripples in the areas. However, smaller sandwaves may be present along the cable route (KP X to Y). Local burial depth may be adjusted upwards by the sandwave height resulting in degraded thermal performance leading to potential derating.	4	2	8	Ensure cable's design can tolerate short spans of increased burial depths.	1	2	2
3	Seabed obstructions	Obstruction will result in section out of burial specification.	Not applicable, only applicable to as-built cable. **Not scored**							
4	Shallow gas	Represent a danger to vessels / personnel.	Review of literature report indicates presence of linear seabed depressions or trenches due to shallow gas in the Celtic Sea near the cable's proposed route. (see SEA6_Gas_CMRC.pdf). Applicable to installation and as-built cable but not to present CBRA. **Not scored.**							
5	Currents / waves	Abrasion, stress and fatigue where cable crosses rock/rough terrrain. Can induce loading on cable connectors. Can mobilise sediment exposing cables to further primary hazards. Metocean conditions likely to impact on surface laid cable and also influence sediment mobility.	Risk associated with protection for rocky terrain is design specific, thus outside CBRA scope. **Not scored.** See hazard No.12 for risk from Mobile Sediment. For surface laid there would be potential for damage from wave/current actions, predominantly in shallow waters.	2	3	6	CBRA to include consideration of wave/current action should surface laid be acceptable from anthropogenic threats. For protection in rocky areas, a design risk assessment would be required.	1	2	2
6	Density / turbidity currents	These may results from a number of phenomena and can travel at speed over great distances to significant depths. Can cause tensional breaks, abrasions or may bury cables.	Risk associated with unprotected cables (torsional breaks and abrasions) is design specific, thus outside CRBA scope. **Not Scored.** See hazard No.12 for risk from increased burial depth (Mobile Sediment).							
7	Fish bites	Can damage insulation: historically mainly occurred with telegraph cables but recent occurences have been noted occasionally.	Not plausible threat to a power cable.							
8	Extreme weather	An increase in current and wave strengh, can increase sediment input and bury cables deeper than designed.	See hazard No.12 for risk from increased burial depth (Mobile Sediment).							
9	Submarine earthquakes	Cause submarine landslides or turbidity currents reducing sediment cover exposing cables to primary risk.	Review of the routing report indicates that significant hazards of this nature are not expected along the cable's route. This will be reviewed after completion of the seabed survey.	1	3	3	Mitigation to be determined after review of seabed survey data.			
10	Submarine volcanoes	Directly impact cables through contact or trigger submarine landslides (see above).	None present at site. **Not scored.**							
11	Icebergs	Can directly impact on cables in shallow water depth as they scour the seabed. Not anticipated along the cable's route.	Not plausible. **Not scored.**							
Soil Conditions										
12	Mobile Sediment	Sand Wave or megaripple mobility could cause deburial of increased burial of the cable.	Potential mobile sediments identified from review of data for KP57 to KP147 (Route A) leading to uncertainties to actual burial depth at any time. The risk is that information gaps concerning the extent of sediment mobility means that the recommended DoL contingency is either too low or too high. The consequence is either lower protection or higher CAPEX.	3	3	9	Re-assess contingency requirements following survey.	2	3	6
Anthropogenic										
13	Fishing	Snagging of cables with fishing gear and damage during retrieval of gear. Seabed interacting gear reducing sediment coverage above cable.	Due to inaccurate characterisation of presence of mobile fishing types there is a risk of misunderstanding the risk of mechanical damage to the installed cable. Consequence is misspecification of recommended minimum DoL leading to either greater CAPEX or greater risk of damege to the installed cable. Leads to requirement to inspect and potentially to repair. Other consequence is cable outtage and increase of monitoring requirements.	1	1	1	No further mitigation expected. Base case assumes sufficient burial to protect from known regional fishing threats applied to the whole cable route.	1	1	1
14.A	Shipping/Anchoring	Snagging of cables during normal or emergency anchoring procedures.	Due to inaccurate characterisation of shipping or soils there is a risk of misunderstanding the risk of mechanical damage to the installed cable. Consequence is misspecification of recommended minimum DoL leading to either greater CAPEX or greater risk of damege to the installed cable. Leads to requirement to inspect and potentially to repair. Other consequence is cable outtage and increase of monitoring requirements.	3	3	9	Revise the CBRA following receipt of survey data, or significant changes to shippings patterns. (scored on a basis of shipping pattern changes).	2	2	4
14.B			Due to cable design for a return period of 40 years, there is a residual risk of mechanical damage.	1	2	2	No further mitigation required.	1	2	2
15	Dredging / Aggregate Extraction / Subsea Mining / Dumping	Direct contact to the cable from the dredging equipment or reduction in seabed cover increasing risk to cable.	The routing report indicates that the present cable route would avoid present dredging / Aggregate Extraction / Subsea Mining / Dumping areas. **Not scored.**							
16	Other cables, umbilical, Pipelines	Reduced depth of lowering at crossing and/or proximity of third-party operation.	6 cables crossing identified along the route. Outside of CBRA scope, thus **not scored.**				Crossings will be subject to design risk assessment.			
17	Misc. Activities	Such as construction, rock dumping, marine surveys, leisure activities. Any activity that directly interacts with the seabed and reduces the seabed cover.	Misc, activities are outside of the CBRA scope. N**ot scored.**							
18	Exclusions physical	Defense and acts of aggressions.	The portion of the route (KP x to Kpy) is within the Castlemartin firing range. Outside CBRA scope, thus **not scored.**							
19	Exclusions planning	Updated information which significantly changes the recommendations of the CBRA	Potential to require re-routing outside of survey corridor. **Not scored.**							

APPENDIX C

Vessel Density Heat Maps



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GREENLINK AIS DATA

Band A: 0 - 1k DWT (Vessel Hours Per Year)

Legend

- Greenlink Route
- Bathymetry Contour (m)

Vessel Hours Per Year (1km x 1km grid)

- 0.0 - 0.5
- 0.5 - 1.5
- 1.5 - 5.0
- 5 - 20
- 20 - 50
- 50 - 100
- 100 - 250
- 250 - 1000
- 1000 - 5000
- 5000 - 10000
- 10000 - 50000

NOTE: Not to be used for Navigation

Date	Tuesday, August 27, 2019 16:49:29
Projection	WGS_1984_UTM_Zone_30N
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Datum	D_WGS_1984
Data Source	OCEANEERING, ESRI, EMODNET, Greenlink
File Reference	J:\P1975\Mxd\AIS\ AIS_BandA_vhpy.mxd
Created By	Chris Goode
Reviewed By	Chris Carroll
Approved By	Alan Redman

Greenlink

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0 3 6 9 12 km

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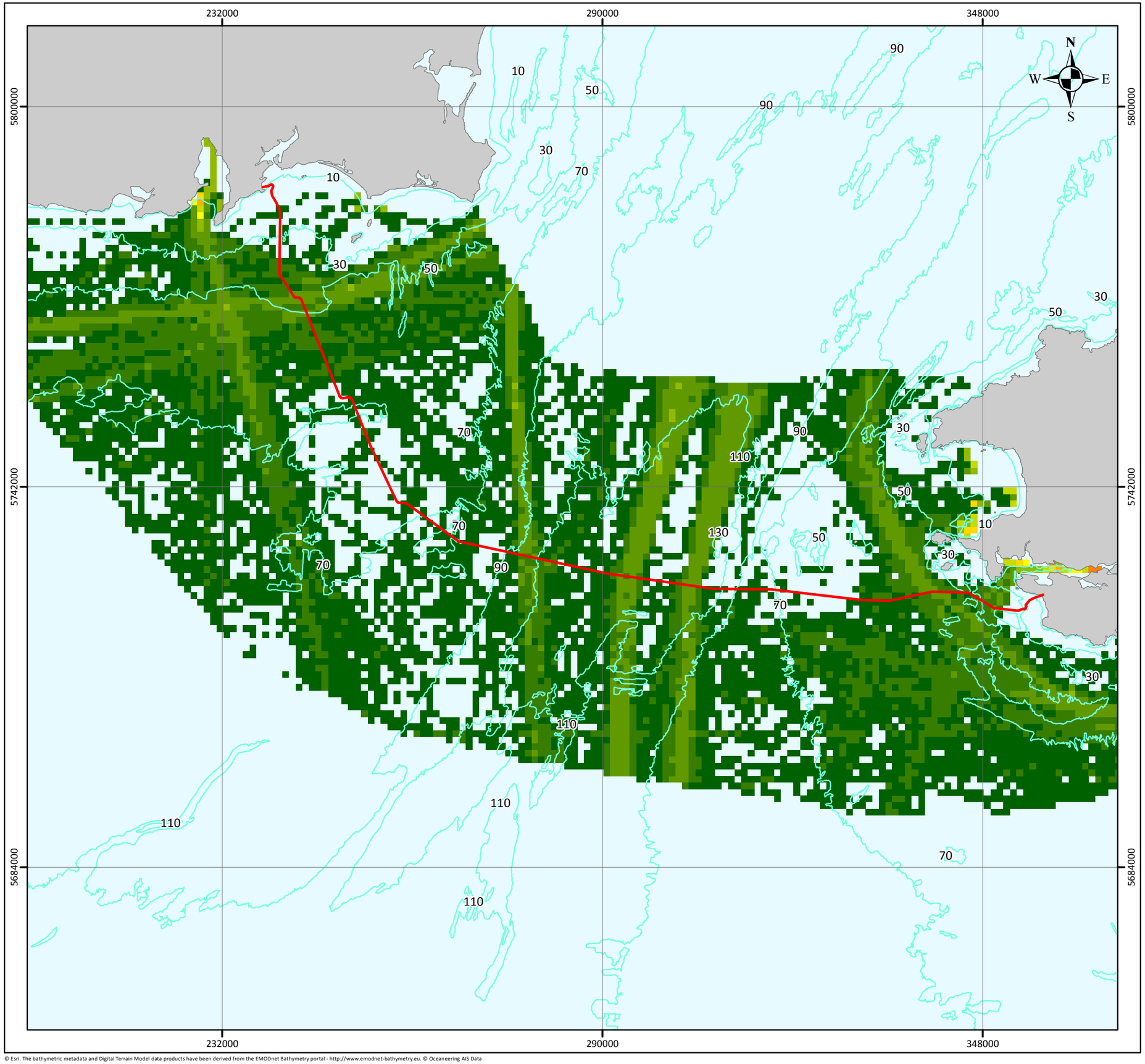


GREENLINK AIS DATA

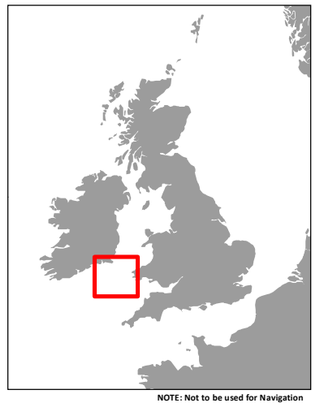
Band B: 1k - 3.5k DWT (Vessel Hours Per Year)

Legend

- Greenlink Route
- Bathymetry Contour (m)

Vessel Hours Per Year (1km x 1km grid)

- 0.0 - 0.5
- 0.5 - 1.5
- 1.5 - 5.0
- 5 - 20
- 20 - 50
- 50 - 100
- 100 - 250
- 250 - 1000
- 1000 - 5000
- 5000 - 10000
- 10000 - 50000



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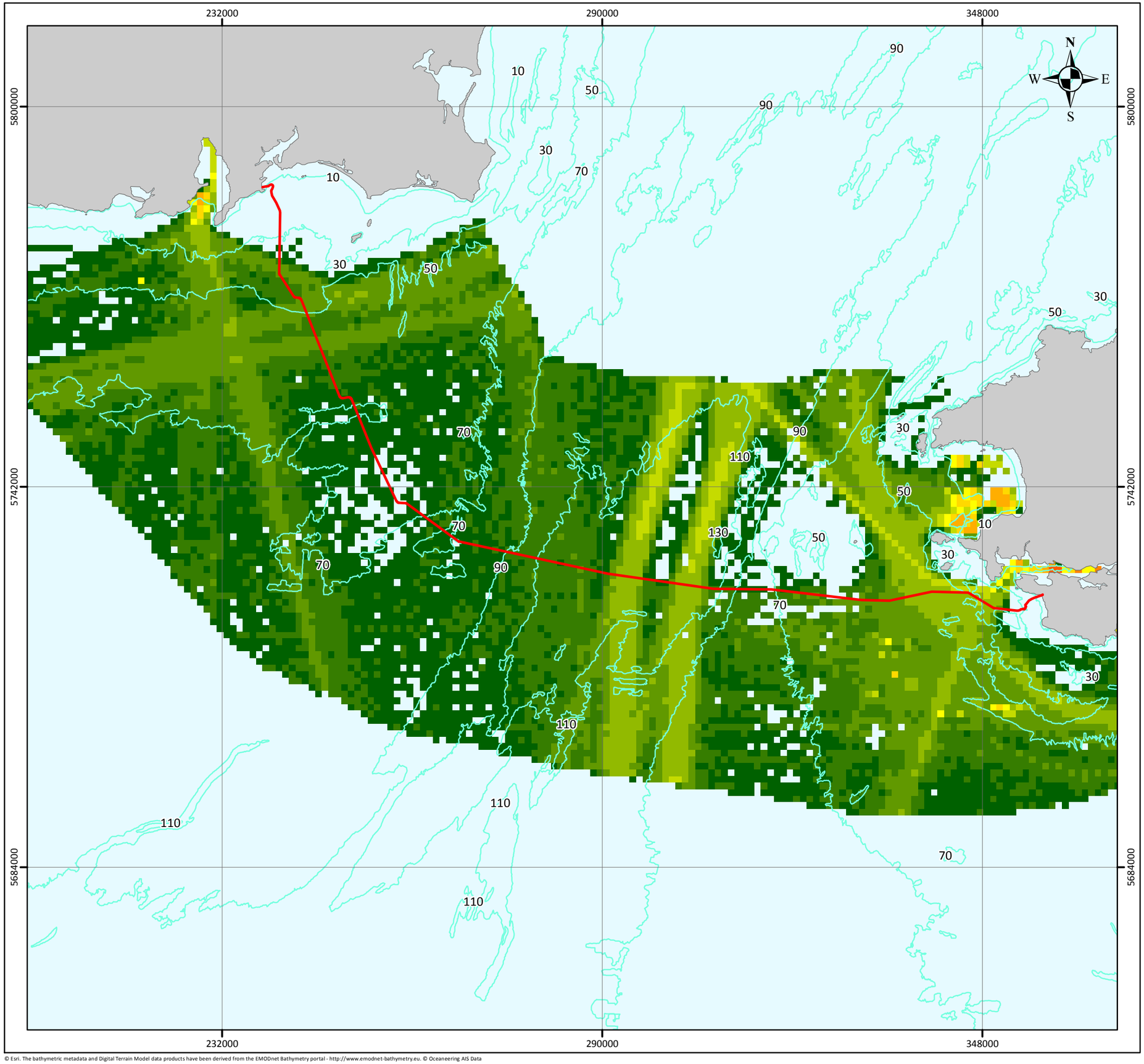


GREENLINK AIS DATA

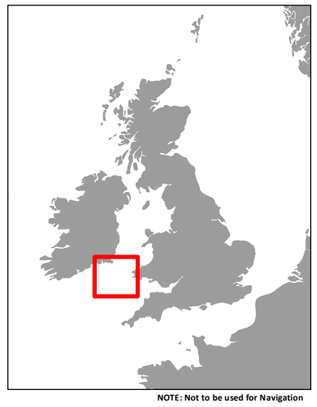
Band C: 3.5k - 20k DWT (Vessel Hours Per Year)

Legend

- Greenlink Route
- Bathymetry Contour (m)

Vessel Hours Per Year (1km x 1km grid)

- 0.0 - 0.5
- 0.5 - 1.5
- 1.5 - 5.0
- 5 - 20
- 20 - 50
- 50 - 100
- 100 - 250
- 250 - 1000
- 1000 - 5000
- 5000 - 10000
- 10000 - 50000



NOTE: Not to be used for Navigation

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File Reference	J:\P1975\Mxd\AIS\ AIS_BandC_vhpy.mxd
Created By	Chris Goode
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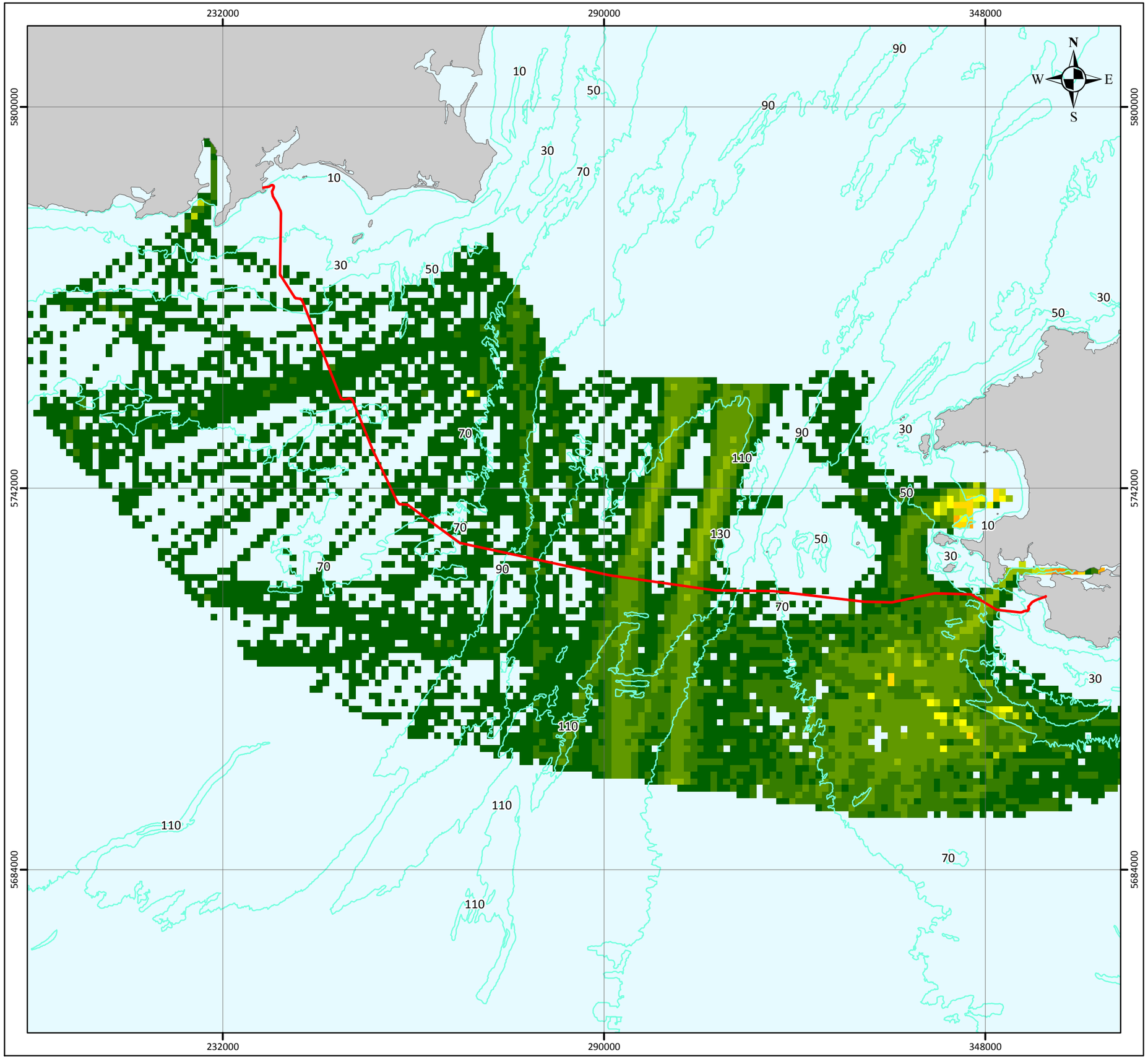

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GREENLINK AIS DATA

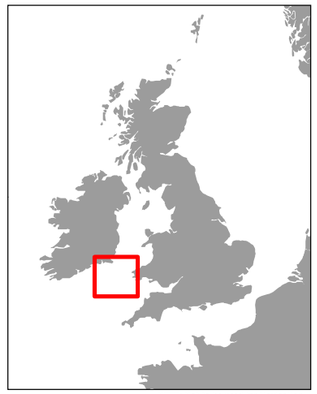
Band D: 20k - 40k DWT (Vessel Hours Per Year)

Legend

- Greenlink Route
- Bathymetry Contour (m)

Vessel Hours Per Year (1km x 1km grid)

- 0.0 - 0.5
- 0.5 - 1.5
- 1.5 - 5.0
- 5 - 20
- 20 - 50
- 50 - 100
- 100 - 250
- 250 - 1000
- 1000 - 5000
- 5000 - 10000
- 10000 - 50000



NOTE: Not to be used for Navigation

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Created By	Chris Goode
Reviewed By	Chris Carroll
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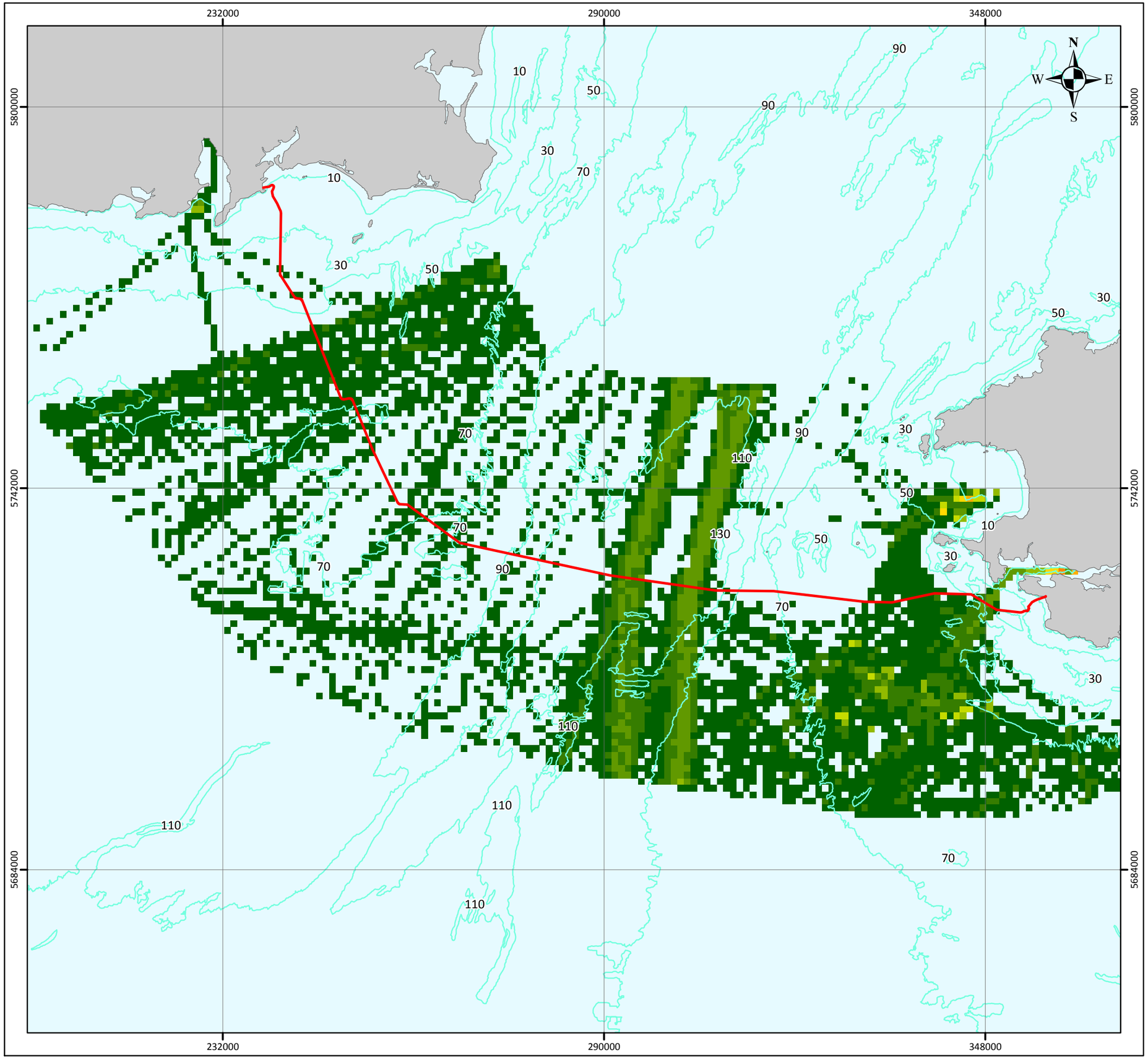

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GREENLINK AIS DATA

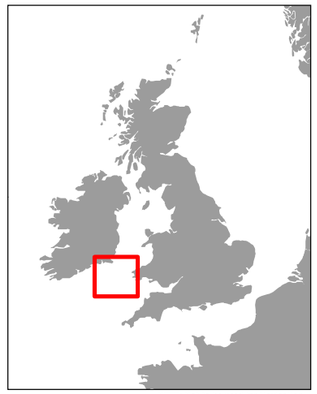
Band E: 40k - 80k DWT (Vessel Hours Per Year)

Legend

- Greenlink Route
- Bathymetry Contour (m)

Vessel Hours Per Year (1km x 1km grid)

- 0.0 - 0.5
- 0.5 - 1.5
- 1.5 - 5.0
- 5 - 20
- 20 - 50
- 50 - 100
- 100 - 250
- 250 - 1000
- 1000 - 5000
- 5000 - 10000
- 10000 - 50000



NOTE: Not to be used for Navigation

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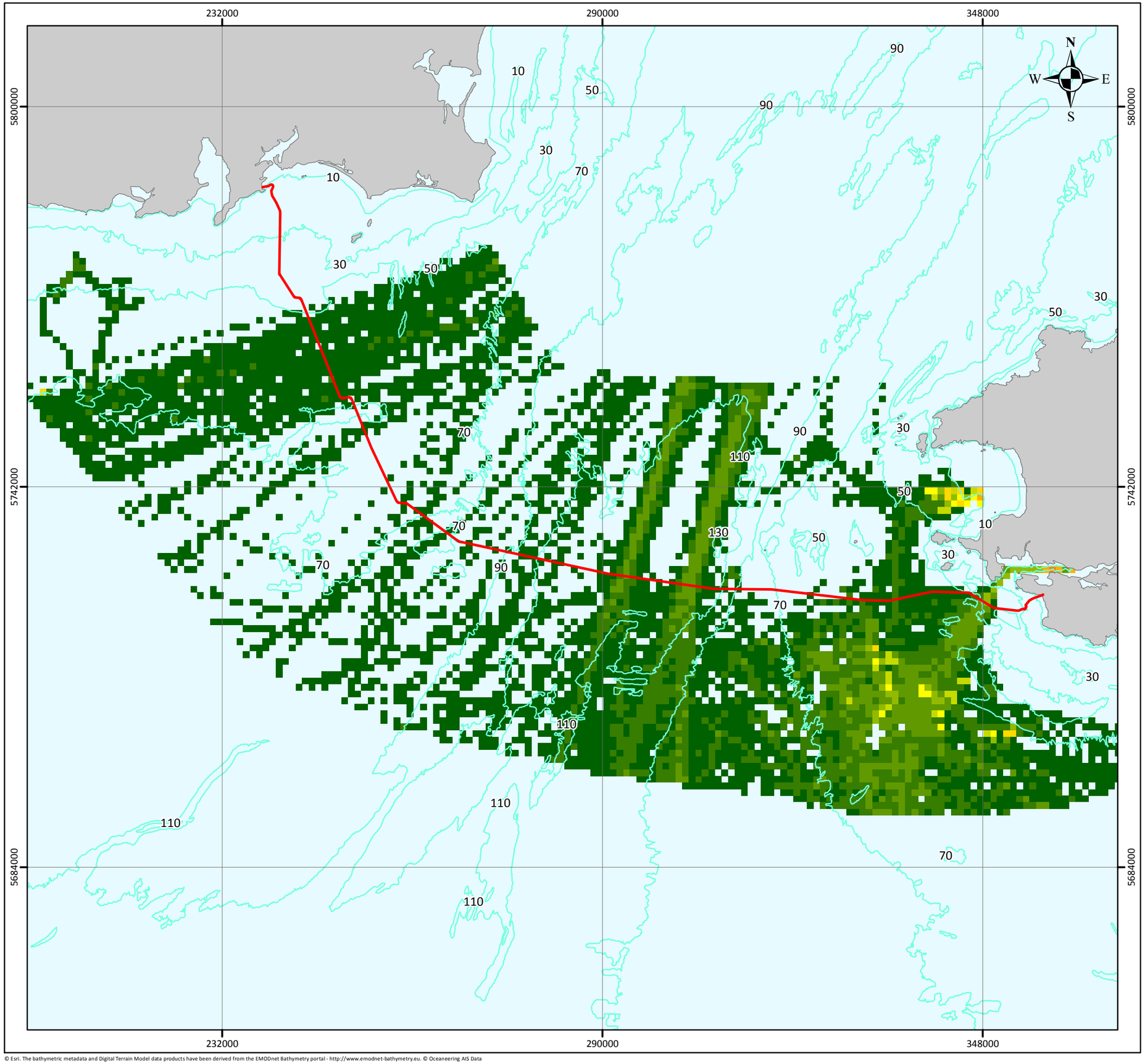

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GREENLINK AIS DATA

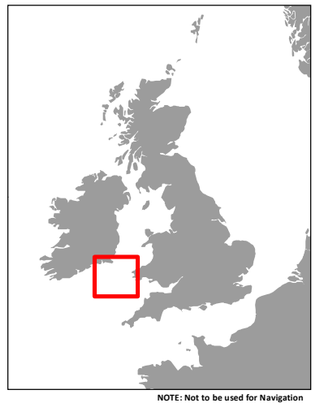
Band F: 80k - 175k DWT (Vessel Hours Per Year)

Legend

- Greenlink Route
- Bathymetry Contour (m)

Vessel Hours Per Year (1km x 1km grid)

- 0.0 - 0.5
- 0.5 - 1.5
- 1.5 - 5.0
- 5 - 20
- 20 - 50
- 50 - 100
- 100 - 250
- 250 - 1000
- 1000 - 5000
- 5000 - 10000
- 10000 - 50000



NOTE: Not to be used for Navigation

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km
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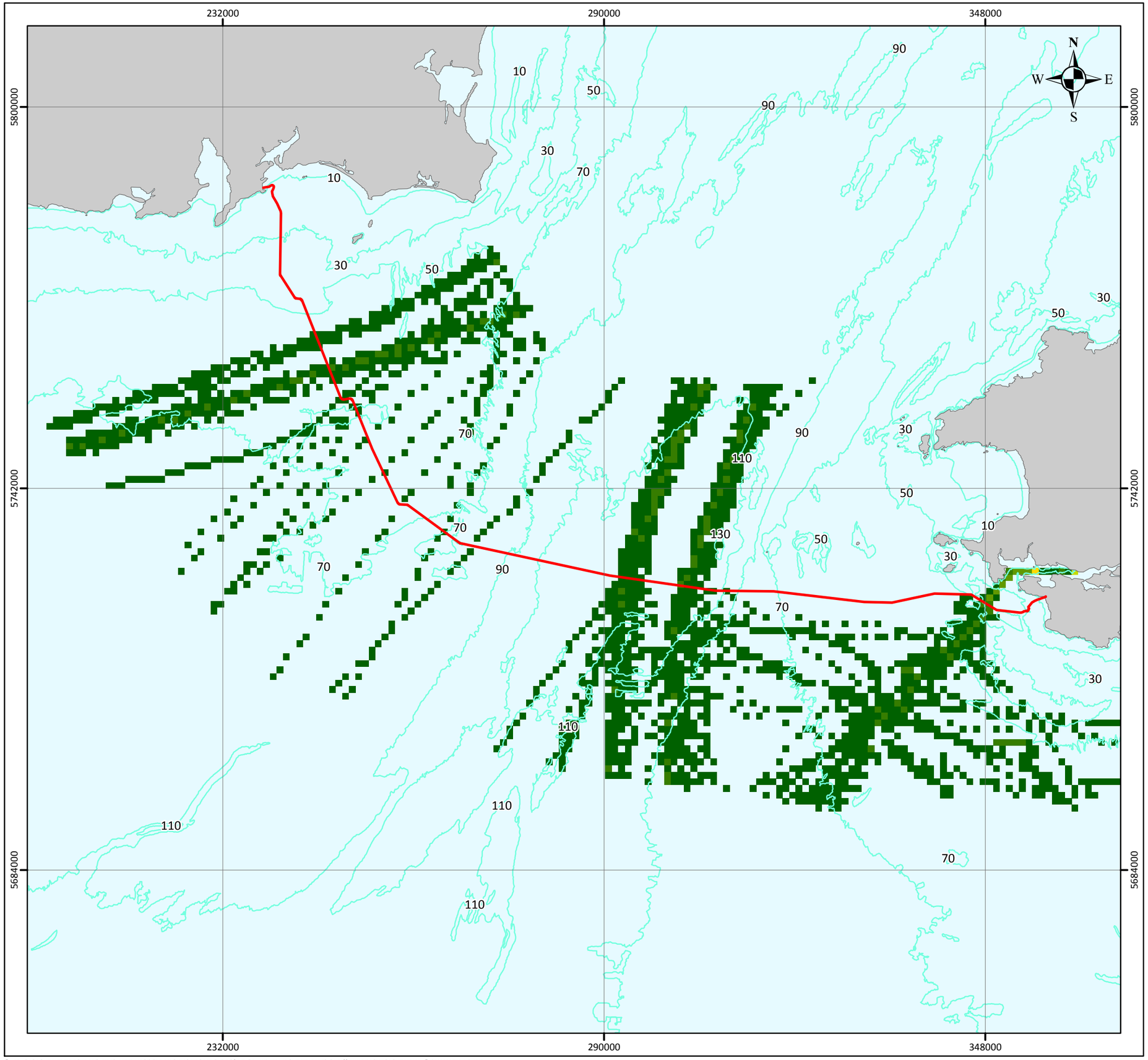

GREENLINK AIS DATA

Band G: 175k - 325k DWT (Vessel Hours Per Year)

Legend

- Greenlink Route
- Bathymetry Contour (m)

Vessel Hours Per Year (1km x 1km grid)

- 0.0 - 0.5
- 0.5 - 1.5
- 1.5 - 5.0
- 5 - 20
- 20 - 50
- 50 - 100
- 100 - 250
- 250 - 1000
- 1000 - 5000
- 5000 - 10000
- 10000 - 50000

NOTE: Not to be used for Navigation

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Created By	Chris Goode
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Greenlink

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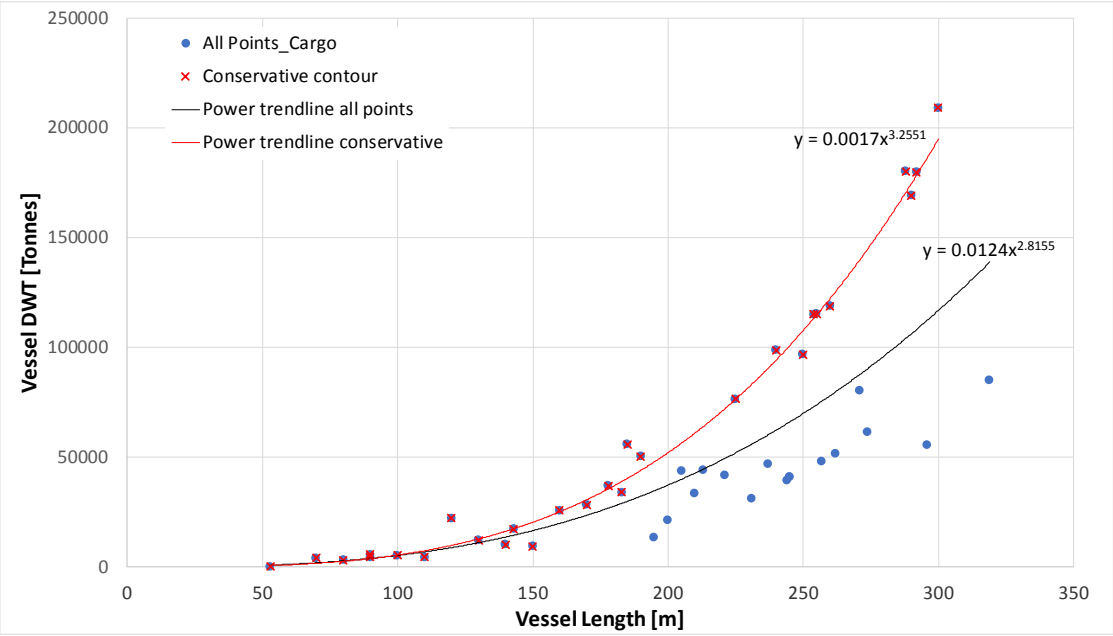
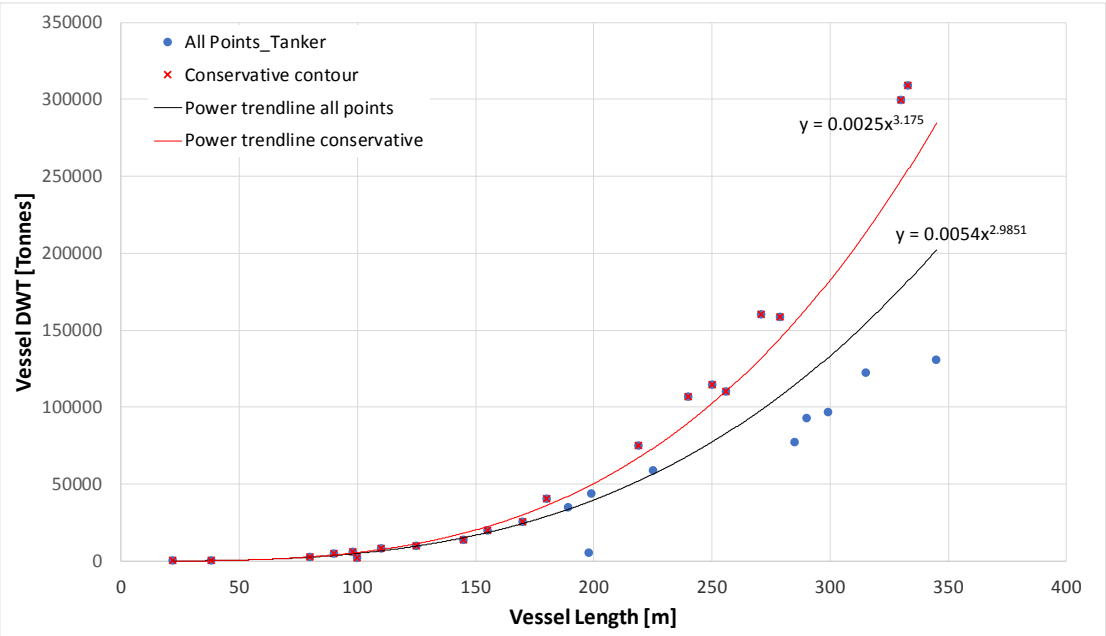
APPENDIX D

Vessel Deadweight Tonnage (DWT) Charts

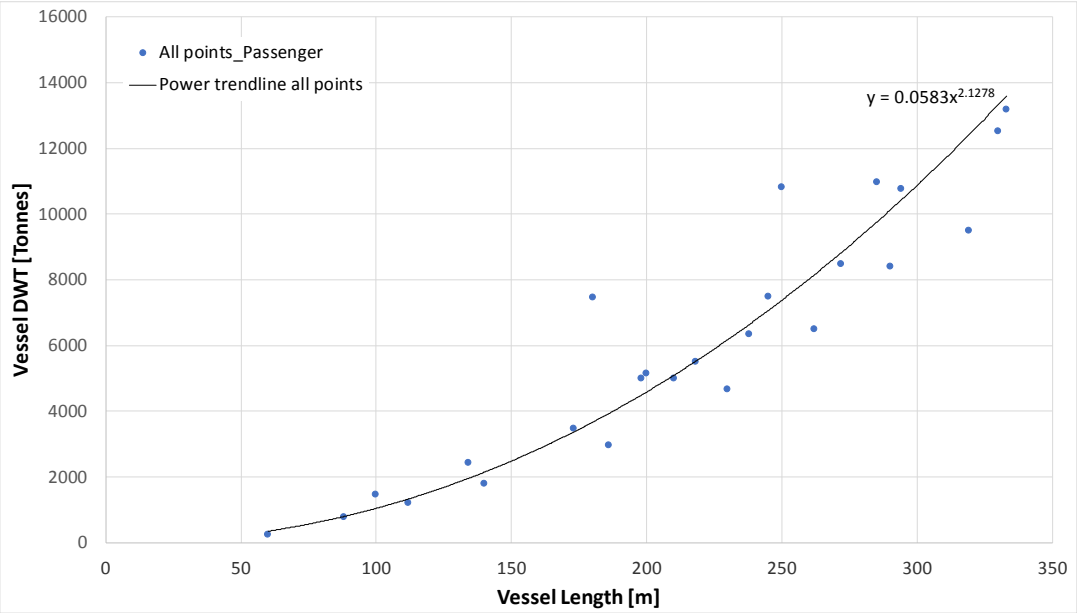
D.1 CARGO VESSELS



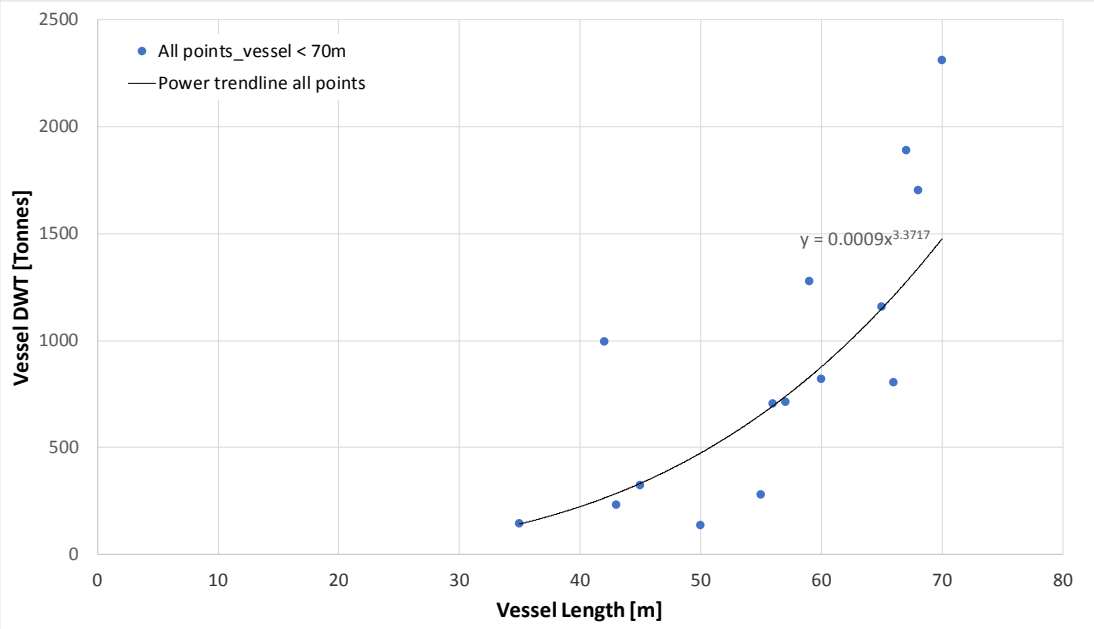
D.2 TANKER VESSELS



D.3 PASSENGER VESSELS



D.4 VESSEL SMALLER THAN 70 METRES



APPENDIX E

Vessel Density

Zone identification	KP Range		Water Depth Range (m)			K - Sample box vessel densities P90						
						Band A	Band B	Band C	Band D	Band E	Band F	Band G
	From	To	Max	Min	Mean	[hr/km2/yr]	[hr/km2/yr]	[hr/km2/yr]	[hr/km2/yr]	[hr/km2/yr]	[hr/km2/yr]	[hr/km2/yr]
Zone 1	0.000	1.149	10.01	-8.29	1.78	5.89	0.00	0.00	0.00	0.00	0.00	0.00
Zone 2	1.149	4.737	35.00	10.01	25.97	7.16	0.00	0.00	0.00	0.00	0.00	0.00
Zone 3	4.737	14.382	50.93	29.86	41.07	26.27	1.55	27.18	5.36	1.36	2.18	0.36
Zone 4	14.382	26.451	59.55	50.87	55.81	9.11	1.60	17.35	1.33	0.36	0.64	0.00
Zone 5	26.451	40.555	68.32	57.71	61.91	0.64	0.36	3.00	0.64	0.15	0.73	0.00
Zone 6	40.555	42.871	69.88	66.49	67.46	0.36	0.09	1.16	0.18	0.00	0.00	0.00
Zone 7	42.871	43.941	75.00	69.78	72.57	0.39	0.12	1.05	0.18	0.00	0.00	0.00
Zone 8	43.941	44.735	76.87	74.75	75.88	0.36	0.18	0.95	0.18	0.00	0.05	0.00
Zone 9	44.735	48.947	91.48	76.48	83.10	0.44	0.18	1.09	0.27	0.09	0.44	0.00
Zone 10	48.947	50.134	99.96	90.69	95.27	0.45	0.21	1.12	0.21	0.12	0.51	0.09
Zone 11	50.134	52.257	118.59	99.96	109.22	0.55	0.45	2.68	0.64	0.27	0.64	0.09
Zone 12	52.257	57.523	127.86	114.07	119.05	0.64	2.11	17.53	4.56	2.27	2.27	0.29
Zone 13	57.523	58.608	116.68	113.73	115.24	0.91	2.13	18.18	4.78	2.42	2.35	0.36
Zone 14	58.608	61.366	116.72	110.22	113.16	1.74	1.15	13.38	3.60	1.61	1.60	0.34
Zone 15	61.366	64.472	113.60	110.66	111.82	2.27	2.66	13.59	3.66	1.85	1.42	0.27
Zone 16	64.472	67.531	116.25	110.54	114.01	2.27	2.67	13.64	3.67	1.85	1.58	0.36
Zone 17	67.531	72.063	115.90	111.73	113.84	1.96	1.87	12.62	2.65	1.35	1.55	0.33
Zone 18	72.063	80.380	115.92	103.66	112.70	1.88	1.61	1.36	0.55	0.06	0.15	0.00
Zone 19	80.380	81.043	104.35	99.94	102.44	1.45	1.86	1.23	0.55	0.09	0.18	0.00
Zone 20	81.043	84.937	100.04	88.07	92.37	1.18	1.64	1.09	0.55	0.09	0.09	0.00
Zone 21	84.937	88.154	88.15	74.93	82.77	1.25	0.27	0.64	0.27	0.09	0.09	0.00
Zone 22	88.154	100.786	75.00	65.70	70.21	1.30	0.18	0.55	0.27	0.09	0.09	0.03
Zone 23	100.786	114.905	68.68	63.98	67.29	1.27	0.18	0.33	0.18	0.09	0.09	0.00
Zone 24	114.905	120.941	72.52	66.79	69.50	1.54	0.18	0.45	0.18	0.26	0.18	0.09
Zone 25	120.941	134.199	67.08	52.64	60.11	2.70	0.82	2.09	0.27	0.36	0.36	0.25
Zone 26	134.199	135.969	53.10	49.97	52.00	4.59	2.15	3.00	0.09	0.27	0.27	0.09
Zone 27	135.969	147.952	49.99	31.23	40.09	6.15	2.16	2.98	0.09	0.09	0.09	0.00
Zone 28	147.952	157.212	31.61	14.03	24.94	10.73	0.18	0.09	0.00	0.00	0.00	0.00
Zone 29	157.212	158.713	14.18	10.02	13.15	19.45	0.00	0.00	0.00	0.00	0.00	0.00
Zone 30	158.713	159.060	10.02	3.87	7.18	20.47	0.00	0.00	0.00	0.00	0.00	0.00
Zone 31	159.060	159.267	3.88	-4.47	1.41	20.47	0.00	0.00	0.00	0.00	0.00	0.00

APPENDIX F

Probabilistic Risk Assessment

Zone	Dominant Sediment Type (within Anchor Penetration Depths)	Surface Lay	Scenario 1 - Protection against Band A		Scenario 2 - Protection against Bands A to B		Scenario 3 - Protection against Bands A to C		Scenario 4 - Protection against Bands A to D		Scenario 5 - Protection against Bands A to E		Scenario 6 - Protection against Bands A to F		Scenario 7 - Protection against Bands A to G		Scenario 8 Selected Protection Section by Section		Target DoL (m)	
		Segment annual failure probability	Recommended Minimum DoL (m)	Segment annual failure probability	Recommended Minimum DoL (m)	Segment annual failure probability	Recommended Minimum DoL (m)	Segment annual failure probability	Recommended Minimum DoL (m)	Segment annual failure probability	Recommended Minimum DoL (m)	Segment annual failure probability	Recommended Minimum DoL (m)	Segment annual failure probability	Recommended Minimum DoL (m)	Segment annual failure probability	Recommended Minimum DoL (m)	Segment annual failure probability	Target DoL (m)	Segment annual failure probability
		$P_{anchor\ damage}$		$P_{anchor\ damage}$		$P_{anchor\ damage}$		$P_{anchor\ damage}$		$P_{anchor\ damage}$		$P_{anchor\ damage}$		$P_{anchor\ damage}$		$P_{anchor\ damage}$		$P_{anchor\ damage}$		$P_{anchor\ damage}$
Zone 1	Medium Dense Sand with Loose Sand Veneer (0.5m)	3.05E-05	0.45	0.00E+00	0.55	0.00E+00	0.75	0.00E+00	0.80	0.00E+00	0.85	0.00E+00	0.90	0.00E+00	0.95	0.00E+00	0.60	0.00E+00	1.50	0.00E+00
Zone 2	Medium Dense Sand with Loose Sand Veneer (0.5m)	1.16E-04	0.45	0.00E+00	0.55	0.00E+00	0.75	0.00E+00	0.80	0.00E+00	0.85	0.00E+00	0.90	0.00E+00	0.95	0.00E+00	0.60	0.00E+00	1.50	0.00E+00
Zone 3	Medium Dense Sand with Very Loose Sand Veneer (0.3m)	2.79E-03	0.45	1.65E-03	0.50	1.58E-03	0.70	4.02E-04	0.75	1.70E-04	0.80	1.10E-04	0.85	1.58E-05	0.90	0.00E+00	0.85	1.58E-05	1.50	0.00E+00
Zone 4	Medium Dense Sand with Very Loose Sand Veneer (0.15m)	2.72E-04	0.35	2.22E-04	0.40	2.14E-04	0.60	2.53E-05	0.65	1.09E-05	0.70	6.91E-06	0.75	0.00E+00	0.80	0.00E+00	0.60	2.53E-05	1.50	0.00E+00
Zone 5	Medium Dense Sand with Very Loose Sand Veneer (0.2m)	6.36E-05	0.40	5.95E-05	0.45	5.72E-05	0.65	1.92E-05	0.70	1.11E-05	0.75	9.23E-06	0.80	0.00E+00	0.85	0.00E+00	0.60	5.72E-05	1.00	0.00E+00
Zone 6	Medium Dense Sand with Loose Sand Veneer (0.2m) (Termination depth of CPT 0.52m)	3.28E-06	0.35	2.90E-06	0.40	2.80E-06	0.55	0.00E+00	0.55	0.00E+00	0.55	0.00E+00	0.55	0.00E+00	0.55	0.00E+00	0.60	0.00E+00	1.50	0.00E+00
Zone 7	Medium Dense Sand with Loose Sand Veneer (0.2m)	1.44E-06	0.35	1.25E-06	0.40	1.19E-06	0.60	1.75E-07	0.65	0.00E+00	0.70	0.00E+00	0.75	0.00E+00	0.80	0.00E+00	0.60	1.75E-07	1.00	0.00E+00
Zone 8	Medium Dense Sand with Loose Sand Veneer (0.2m)	4.22E-07	0.35	4.22E-07	0.40	4.22E-07	0.60	8.12E-08	0.65	1.62E-08	0.70	1.62E-08	0.75	0.00E+00	0.80	0.00E+00	0.60	8.12E-08	1.00	0.00E+00
Zone 9	Medium Strength CLAY/Loose SAND with Very Loose SAND Veneer (0.3m) (Max 1m anchor penetration)	3.58E-06	0.65	3.58E-06	0.85	3.58E-06	1.00	0.00E+00	1.00	0.00E+00	1.00	0.00E+00	1.00	0.00E+00	1.00	0.00E+00	0.65	3.58E-06	1.00	0.00E+00
Zone 10	Medium Dense Sand with Very Loose Sand Veneer (0.5m)	1.09E-06	0.55	1.09E-06	0.60	1.09E-06	0.80	4.95E-07	0.85	3.83E-07	0.90	3.20E-07	0.95	4.85E-08	1.00	0.00E+00	0.60	1.09E-06	1.00	0.00E+00
Zone 11	Medium Dense Sand with Very Loose Sand Veneer (0.5m)	0.00E+00	0.55	0.00E+00	0.60	0.00E+00	0.80	0.00E+00	0.85	0.00E+00	0.90	0.00E+00	0.95	0.00E+00	1.00	0.00E+00	0.60	0.00E+00	1.00	0.00E+00
Zone 12	Medium Dense Sand with Very Loose Sand Veneer (0.3m)	0.00E+00	0.45	0.00E+00	0.50	0.00E+00	0.70	0.00E+00	0.75	0.00E+00	0.80	0.00E+00	0.85	0.00E+00	0.90	0.00E+00	0.60	0.00E+00	1.50	0.00E+00
Zone 13	Very Loose Sand with Medium Dense Sand Veneer (0.3m)	0.00E+00	0.25	0.00E+00	0.30	0.00E+00	0.80	0.00E+00	0.95	0.00E+00	1.05	0.00E+00	1.20	0.00E+00	1.25	0.00E+00	0.60	0.00E+00	1.50	0.00E+00
Zone 14	Medium Dense Sand with Very Loose Sand Veneer (0.1m)	0.00E+00	0.35	0.00E+00	0.40	0.00E+00	0.60	0.00E+00	0.65	0.00E+00	0.70	0.00E+00	0.75	0.00E+00	0.80	0.00E+00	0.60	0.00E+00	1.50	0.00E+00
Zone 15	Loose Sand	0.00E+00	0.45	0.00E+00	0.60	0.00E+00	0.95	0.00E+00	1.10	0.00E+00	1.20	0.00E+00	1.30	0.00E+00	1.30	0.00E+00	0.60	0.00E+00	1.50	0.00E+00
Zone 16	Low Strength CLAY with Loose Sand Veneer (0.3m)	0.00E+00	0.55	0.00E+00	0.75	0.00E+00	1.25	0.00E+00	1.50	0.00E+00	1.65	0.00E+00	1.80	0.00E+00	1.80	0.00E+00	0.60	0.00E+00	1.50	0.00E+00
Zone 17	Loose Sand with Very Loose Sand Veneer (0.2m)	0.00E+00	0.50	0.00E+00	0.65	0.00E+00	1.00	0.00E+00	1.15	0.00E+00	1.25	0.00E+00	1.35	0.00E+00	1.35	0.00E+00	0.60	0.00E+00	1.50	0.00E+00
Zone 18	Medium Strength CLAY with Loose Sand Veneer (0.3m)	0.00E+00	0.55	0.00E+00	0.75	0.00E+00	1.25	0.00E+00	1.50	0.00E+00	1.65	0.00E+00	1.80	0.00E+00	1.80	0.00E+00	0.60	0.00E+00	1.00	0.00E+00
Zone 19	Medium Dense Sand with Loose Sand Veneer (0.3m)	0.00E+00	0.40	0.00E+00	0.45	0.00E+00	0.65	0.00E+00	0.70	0.00E+00	0.75	0.00E+00	0.80	0.00E+00	0.85	0.00E+00	0.60	0.00E+00	1.50	0.00E+00
Zone 20	Medium Dense Sand with Loose Sand Veneer (0.3m)	3.19E-06	0.40	3.19E-06	0.45	3.19E-06	0.65	1.27E-06	0.70	3.19E-07	0.75	1.59E-07	0.80	0.00E+00	0.85	0.00E+00	0.60	3.19E-06	1.50	0.00E+00
Zone 21	Medium Dense Sand with Very Loose Sand Veneer (0.25m)	1.58E-06	0.40	1.58E-06	0.45	1.58E-06	0.65	6.58E-07	0.70	2.63E-07	0.75	1.32E-07	0.80	0.00E+00	0.85	0.00E+00	0.60	1.58E-06	1.50	0.00E+00
Zone 22	Medium Dense Sand with Very Loose Sand Veneer (0.25m)	2.01E-05	0.40	1.27E-05	0.45	1.17E-05	0.65	5.48E-06	0.70	2.38E-06	0.75	1.34E-06	0.80	3.10E-07	0.85	0.00E+00	0.60	1.17E-05	1.50	0.00E+00
Zone 23	Medium Dense Sand with Loose Sand Veneer (0.3m)	1.80E-05	0.40	9.93E-06	0.45	8.78E-06	0.65	4.62E-06	0.70	2.31E-06	0.75	1.16E-06	0.80	0.00E+00	0.85	0.00E+00	0.60	8.78E-06	1.50	0.00E+00
Zone 24	Medium Dense Sand with Very Loose Sand Veneer (0.2m)	1.10E-05	0.40	6.86E-06	0.45	6.37E-06	0.65	3.90E-06	0.70	2.91E-06	0.75	1.48E-06	0.80	4.94E-07	0.85	0.00E+00	0.60	6.37E-06	1.00	0.00E+00
Zone 25	Medium Dense Sand with Loose Sand Veneer (0.2m)	6.08E-05	0.35	4.47E-05	0.40	3.98E-05	0.60	1.49E-05	0.65	1.16E-05	0.70	7.27E-06	0.75	2.93E-06	0.80	0.00E+00	0.60	1.49E-05	1.50	0.00E+00
Zone 26	Medium Dense Sand	1.13E-05	0.25	7.65E-06	0.30	5.94E-06	0.50	1.16E-06	0.55	1.01E-06	0.60	5.79E-07	0.65	1.45E-07	0.70	0.00E+00	0.60	5.79E-07	1.50	0.00E+00
Zone 27	Medium Dense Sand	6.24E-04	0.25	2.92E-04	0.30	1.75E-04	0.50	1.47E-05	0.55	9.80E-06	0.60	4.90E-06	0.65	0.00E+00	0.70	0.00E+00	0.60	4.90E-06	1.50	0.00E+00
Zone 28	Medium Dense Sand with Loose Sand Veneer (0.3m)	4.58E-04	0.40	1.14E-05	0.45	3.79E-06	0.65	0.00E+00	0.70	0.00E+00	0.75	0.00E+00	0.80	0.00E+00	0.85	0.00E+00	0.60	3.79E-06	1.50	0.00E+00
Zone 29	Medium Dense Sand with Low Strength Clay Veneer (0.3m)	1.31E-04	0.45	0.00E+00	0.50	0.00E+00	0.70	0.00E+00	0.75	0.00E+00	0.80	0.00E+00	0.85	0.00E+00	0.90	0.00E+00	0.60	0.00E+00	1.00	0.00E+00
Zone 30	Medium Dense Sand with Low Strength Clay Veneer (0.3m)	3.20E-05	0.45	0.00E+00	0.50	0.00E+00	0.70	0.00E+00	0.75	0.00E+00	0.80	0.00E+00	0.85	0.00E+00	0.90	0.00E+00	0.60	0.00E+00	1.00	0.00E+00
Zone 31	Weathered Mudstone	#N/A	Mechanical Protection	#N/A	Mechanical Protection	#N/A	Mechanical Protection	#N/A	Mechanical Protection	#N/A	Mechanical Protection	#N/A	Mechanical Protection	#N/A	Mechanical Protection	#N/A	0.40 (or equivalent mechanical protection)	#N/A	0.60 (or equivalent mechanical protection)	#N/A
Annual Failure Probability for Entire route		**0.47%**	**0.23%**		**0.21%**		**0.05%**		**0.02%**		**0.01%**		**0.00%**		**0.00%**		**0.02%**		**0.00%**	
Return Period (years)		**214.95**	**429.07**		**471.95**		**2023.05**		**4492.12**		**6945.40**		**50738.78**		**#DIV/0!**		**6291.05**		**#DIV/0!**	
Failure Probability in the lifetime (40 years)		**17.02%**	**8.91%**		**8.13%**		**1.96%**		**0.89%**		**0.57%**		**0.08%**		**0.00%**		**0.63%**		**0.00%**	

Appendix B

WFD Scoping – Milford Haven Inner Water Body

Water Framework Directive assessment: scoping template for activities in estuarine and coastal waters

Use this template to record the findings of the scoping stage of your Water Framework Directive (WFD) assessment for an activity in an estuary or coastal water.

If your activity will:

- take place in or affect more than one water body, complete a template for each water body
- include several different activities or stages as part of a larger project, complete a template for each activity as part of your overall WFD assessment

The WFD assessment guidance for estuarine and coastal waters will help you complete the table.

Your activity	Description, notes or more information
Applicant name	Greenlink Interconnector Limited
Application reference number (where applicable)	Not available
Name of activity	Greenlink Interconnector (Marine Wales)
Brief description of activity	The proposed Greenlink Interconnector (Greenlink) is a high voltage direct current (HVDC) electrical interconnector. This assessment applies to the Proposed Development, the Welsh Marine components of Greenlink, from mean high-water springs at Freshwater West, Pembrokeshire to the median line between Wales and the Republic of Ireland; approximately 73.9km route length from the coast. The Proposed Development comprises: • Two high voltage direct current (HVDC) electricity power cables; • A smaller fibre-optic cable for control and communication purposes; and • All associated works required to install, operate, maintain, repair and decommission the aforementioned cables.

Location of activity (central point XY coordinates or national grid reference)	Please refer to coordinate shapefile provided with the Marine Licence application.
Footprint of activity (ha)	The Proposed Development lies outside of the Milford Haven Inner water body. The Marine Licence Application covers 3776 ha within Welsh waters. This is based on the distance the Proposed Development passes through the territorial and offshore waters (73.9km) and the width of the corridor which is nominally 500m although it does vary in places. The exact area has been calculated in GIS. Two pressures from cable installation have the potential to extend outside of the Marine Licence Application Area: suspended sediment and underwater noise. A sediment plume from cable installation has the potential to extend outside of the Marine Licence Application Area. Water depth, dilution and dispersion will all play an important role in determining the extent of the sediment plume. At 500m distance from the centerline suspended sediment concentrations (SSC) will reduce to 112mg/l at a water depth of 10m and 22mg/l at 50m water depth. 500m is therefore a realistic footprint where changes in SSC will be detectable from cable burial under all tidal conditions and is representative of elevated SSCs in all directions from the location of cable burial. Underwater noise modelling indicates that continuous sound levels generated by vessel movements, cable trenching and placement of deposits on the seabed will not exceed ambient background sound levels outside of the Marine Licence Application Area. Impulsive sound levels from geophysical survey have the potential to exceed thresholds for disturbance level effects in fish 586m from the Marine Licence Application Area. Impulsive sound levels from deflagration of a UXO has the potential to exceed thresholds for disturbance of fish within 1.8km of the Marine Licence Application Area.
Timings of activity (including start and finish dates)	An indicative schedule is presented in Greenlink Marine ES – Wales, Chapter 4. In summary: • Landfall preparations Q2 – Q4 2021 • Submarine route preparation: Q2 2022 • Cable lay and burial: Q2 – Q3 2022 • Operation: 2023 onwards

	It is not known when decommissioning will occur but it is likely to be after 2062.
Extent of activity (for example size, scale frequency, expected volumes of output or discharge)	The main activities associated with the Proposed Development will be submarine cable laying, burial and protection. The submarine cable route length is 73.9km in Welsh waters and two cables will be installed, bundled together in one trench. The following extent applies: • Depth of burial range – 0.6 to 1.0m • Installation footprint of installation machines – 15m width As described above the footprint of the activity will not overlap with the Milford Haven Inner water body.
Use or release of chemicals (state which ones)	There will be no planned release of chemicals within the waterbody. Trenchless installation at the landfall e.g. by horizontal directional drilling (HDD) will require the use of drilling fluids, however Environmental Protection Measures will be in place as part of the Construction Environmental Management plan to prevent release to the environment and water bodies.

Water body[1]	**Description, notes or more information**
WFD water body name	Milford Haven Inner
Water body ID	GB531006114100
River basin district name	Western Wales
Water body type (estuarine or coastal)	Estuarine
Water body total area (ha)	138,066.4
Overall water body status (2015)	Moderate
Ecological status	Moderate
Chemical status	Fail
Target water body status and deadline	Good Status
Hydromorphology status of water body	Supports good
Heavily modified water body and for what use	No

Higher sensitivity habitats present	Yes
Lower sensitivity habitats present	Yes
Phytoplankton status	High
History of harmful algae	No data available
WFD protected areas within 2km	Yes

Specific risk information

Consider the potential risks of your activity to each of these receptors: hydromorphology, biology (habitats and fish), water quality and protected areas. Also consider invasive non-native species (INNS).

Section 1: Hydromorphology

Consider if hydromorphology is at risk from your activity.

Use the water body summary table to find out the hydromorphology status of the water body, if it is classed as heavily modified and for what use.

Consider if your activity:	Yes	No	Hydromorphology risk issue(s)
Could impact on the hydromorphology (for example morphology or tidal patterns) of a water body at high status	~~Requires impact assessment~~	Impact assessment not required	No – The water body is not at high status for hydromorphology. There will be no works conducted in the water body. Works outside the waterbody are sufficient distance (>15km) and in open coastal waters to not effect the hydromorphology of the water body.
Could significantly impact the hydromorphology of any water body	~~Requires impact assessment~~	Impact assessment not required	No – see above.
Is in a water body that is heavily modified for the same use as your activity	~~Requires impact assessment~~	Impact assessment not required	No. The water body is not heavily modified.

Record the findings for hydromorphology and go to section 2: biology.

Section 2: Biology

Habitats

Consider if habitats are at risk from your activity.

Use the water body summary table and Magic maps, or other sources of information if available, to find the location and size of these habitats.

Higher sensitivity habitats [2]	**Lower sensitivity habitats [3]**
chalk reef	cobbles, gravel and shingle
clam, cockle and oyster beds	intertidal soft sediments like sand and mud
intertidal seagrass	rocky shore
maerl	subtidal boulder fields
mussel beds, including blue and horse mussel	subtidal rocky reef
polychaete reef	subtidal soft sediments like sand and mud
saltmarsh	
subtidal kelp beds	
subtidal seagrass	

[2] *Higher sensitivity habitats have a low resistance to, and recovery rate, from human pressures.*

[3] *Lower sensitivity habitats have a medium to high resistance to, and recovery rate from, human pressures.*

Consider if the footprint[4] of your activity is:	**Yes**	**No**	**Biology habitats risk issue(s)**
0.5km^2 or larger	~~Yes to one or more – requires impact assessment~~	No to all – impact assessment not required	No – There will be no works within the water body. The zone of influence for effects does not overlap with the waterbody.
1% or more of the water body's area			No – There will be no works within the water body. The zone of influence for effects does not overlap with the waterbody.
Within 500m of any higher sensitivity habitat			No – There will be no works within the water body. The zone of influence for effects does not overlap with the waterbody.
1% or more of any lower sensitivity habitat			No – There will be no works within the water body. The zone of influence for effects does not overlap with the waterbody.

[4] *Note that a footprint may also be a temperature or sediment plume. For dredging activity, a footprint is 1.5 times the dredge area.*

Fish

Consider if fish are at risk from your activity, but only if your activity is in an estuary or could affect fish in or entering an estuary.

Consider if your activity:	Yes	No	Biology fish risk issue(s)
Is in an estuary and could affect fish in the estuary, outside the estuary but could delay or prevent fish entering it or could affect fish migrating through the estuary	Continue with questions	Go to next section	Yes – The Proposed Development is not within an estuary, but it lies approximately 3.5km from the mouth of Milford Haven.
Could impact on normal fish behaviour like movement, migration or spawning (for example creating a physical barrier, noise, chemical change or a change in depth or flow)	Requires impact assessment	~~Impact assessment not required~~	Yes – Allis shad, Twaite shad, Sea lamprey and River lamprey are known to migrate through the water body to coastal and offshore waters and may be found within the Proposed Development. There is the potential that the Proposed Development could act as a barrier to migration e.g. by generating underwater noise. Underwater noise modelling indicates that continuous sound levels generated by vessel movements, cable trenching and placement of deposits on the seabed will not exceed ambient background sound levels outside of the Marine Licence Application Area. Impulsive sound levels from geophysical survey have the potential to exceed thresholds for disturbance level effects in fish 586m from the Marine Licence Application Area. Impulsive sound levels from deflagration of a UXO has the potential to exceed thresholds for disturbance of fish within 1.8km of the Marine Licence Application Area. The Proposed Development lies at least 15km from the Milford Haven Inner water body and therefore there will not be an overlap between the zone of influence for underwater noise and the water body. The Proposed Development also lies 3.5km from the mouth of Milford Haven and therefore the zone of influence for noise will not act as a barrier at the estuary mouth. The Greenlink Marine ES Wales, Chapter 8 concluded that underwater noise from the Proposed Development will not prevent fish entering or migrating through nearby estuaries or coastal waters. As assessment of effects is presented in the Greenlink Marine ES Wales, Chapter 8 and the Greenlink Marine Habitats Regulations Assessment (HRA).

Could cause entrainment or impingement of fish	~~Requires impact assessment~~	Impact assessment not required	No.

Record the findings for biology habitats and fish and go to section 3: water quality.

Section 3: Water quality

Consider if water quality is at risk from your activity.

Use the water body summary table to find information on phytoplankton status and harmful algae.

Consider if your activity:	Yes	No	Water quality risk issue(s)
Could affect water clarity, temperature, salinity, oxygen levels, nutrients or microbial patterns continuously for longer than a spring neap tidal cycle (about 14 days)	~~Requires impact assessment~~	Impact assessment not required	No.
Is in a water body with a phytoplankton status of moderate, poor or bad	~~Requires impact assessment~~	Impact assessment not required	Milford Haven Inner was assessed as high for phytoplankton and DIN (dissolved inorganic nitrogen). However, the Proposed Development will not affect oxygen levels or levels of nutrients so will not effect phytoplankton status. Impact assessment is not required.
Is in a water body with a history of harmful algae	~~Requires impact assessment~~	Impact assessment not required	Unknown – there is no information available on the history of harmful algae for this waterbody. However, as the zone of influence for the Proposed Development does not overlap with the water body there is no pathway for effect and impact assessment is not required.

Consider if water quality is at risk from your activity through the use, release or disturbance of chemicals.

If your activity uses or releases chemicals (for example through	Yes	No	Water quality risk issue(s)

sediment disturbance or building works) consider if:			
The chemicals are on the Environmental Quality Standards Directive (EQSD) list	~~Requires impact assessment~~	Impact assessment not required	Not applicable. No chemicals will be released in the water body
It disturbs sediment with contaminants above Cefas Action Level 1	~~Requires impact assessment~~	Impact assessment not required	The Greenlink cable route survey undertook grab samples and the tested samples indicated no contamination.

If your activity has a mixing zone (like a discharge pipeline or outfall) consider if:	**Yes**	**No**	**Water quality risk issue(s)**
The chemicals released are on the Environmental Quality Standards Directive (EQSD) list	Requires impact assessment[5]	Impact assessment not required	Not applicable

[5] *Carry out your impact assessment using the Environment Agency's surface water pollution risk assessment guidance, part of Environmental Permitting Regulations guidance.*

Record the findings for water quality go on to section 4: WFD protected areas.

Section 4: WFD protected areas

Consider if WFD protected areas are at risk from your activity. These include:

- special areas of conservation (SAC)
- special protection areas (SPA)
- shellfish waters
- bathing waters
- nutrient sensitive areas

Use Magic maps to find information on the location of protected areas in your water body (and adjacent water bodies) within 2km of your activity.

Consider if your activity is:	**Yes**	**No**	**Protected areas risk issue(s)**

Within 2km of any WFD protected area[6]	Requires impact assessment	~~Impact assessment not required~~	Yes – The Proposed Development lies within the Pembrokeshire Marine/ Sir Benfro Forol Special Area of Conservation which also overlaps with the waterbody. An assessment of the potential for likely significant effects is provided in the Greenlink Marine Habitats Regulation Assessment (HRA) and is summarised in the Greenlink Marine ES Wales, Chapter 11.

[6] *Note that a regulator can extend the 2km boundary if your activity has an especially high environmental risk.*

Record the findings for WFD protected areas and go to section 5: invasive non-native species.

Section 5: Invasive non-native species (INNS)

Consider if there is a risk your activity could introduce or spread INNS.

Risks of introducing or spreading INNS include:

- materials or equipment that have come from, had use in or travelled through other water bodies
- activities that help spread existing INNS, either within the immediate water body or other water bodies

Consider if your activity could:	Yes	No	INNS risk issue(s)
Introduce or spread INNS	Requires impact assessment	~~Impact assessment not required~~	Yes – The deposit of external cable protection material in the form of rock berms or concrete mattresses has the potential to introduce INNS. This has been assessed in the Greenlink Marine ES Wales, Chapter 7. However, it should be noted that this activity is outside of the water body in open coastal waters.

Record the findings for INNS and go to the summary section.

Summary

Summarise the results of scoping here.

Receptor	Potential risk to receptor?	Note the risk issue(s) for impact assessment
Hydromorphology	No	-
Biology: habitats	No	-
Biology: fish	Yes	Yes – There is the potential that noise from the Proposed Development could act as a barrier to the migration of Allis shad, Twaite shad, Sea lamprey and River lamprey. As assessment of effects is presented in the Greenlink Marine ES Wales, Chapter 8 and the Greenlink Marine Habitats Regulations Assessment (HRA).
Water quality	No	-
Protected areas	Yes	The Proposed Development and waterbody are both within the Pembrokeshire Marine / Sir Benfro Forol SAC. An assessment of the potential for likely significant effects is provided in the Greenlink Marine Habitats Regulation Assessment (HRA) and is summarised in the Greenlink Marine ES Wales, Chapter 11.
Invasive non-native species	Yes	Potential pathway for effects from the deposit of external cable protection material outside the waterbody. Assessed in Greenlink Marine ES Wales, Chapter 7.

If you haven't identified any receptors at risk during scoping, you don't need to continue to the impact assessment stage and your WFD assessment is complete.

If you've identified one or more receptors at risk during scoping, you should continue to the impact assessment stage.

Include your scoping results in the WFD assessment document you send to your activity's regulator as part of your application for permission to carry out the activity.

Appendix C

Compass Deviation Technical Note (WSP 2020)

Greenlink

GREENLINK INTERCONNECTOR

Offshore HVDC Cable Route – Magnetic Fields

70044124 - 440
JUNE 2020

CONFIDENTIAL

GREENLINK INTERCONNECTOR

Offshore HVDC Cable Route – Magnetic Fields

REPORT (FINAL) CONFIDENTIAL

PROJECT NO. 70044124

OUR REF. 70044124 - 440

DATE: JUNE 2020

Greenlink

GREENLINK INTERCONNECTOR

Offshore HVDC Cable Route – Magnetic Fields

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QUALITY CONTROL

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Remarks	-	Intertek comments addressed
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1 BACKGROUND

The Greenlink interconnector is a 500MW link between the UK and the Republic of Ireland, the offshore cables will be 320kVDC cables with XLPE insulation, installed in a bundle.

WSP have been asked to assess the magnitude of the magnetic field, at the seabed, generated by the cables, and to provide assurance that there will be no deleterious impact on the lifeforms that live on the seabed.

2 ELECTRIC FIELD

Because the cables will have continuous metallic sheaths the electric field generated by the conductor will be contained within the cable's electrical core, there will be no external electric field.

3 PARAMETERS

3.1 MAGNITUDE OF MAGNETIC FIELD

A report prepared by Messrs Intertek, for another interconnector project, quotes a limit for the magnetic field of 64μT, in order

“Marine Effects of Electro-Magnetic Fields”, dated 28 March 2019, quotes a typical value (p.6) for magnetic fields at a strength of 64μT, at the seabed, and establishes that the effects on marine life are acceptable.

The magnitude of the magnetic field is a function of the current in a conductor and the distance from the conductor.

The design of the bipole is such that the current in one cable is opposite to that in the other, so the magnetic fields generated by each cable is reverse of the other. Because the cables are close together the magnetic fields cancel each other to some extent.

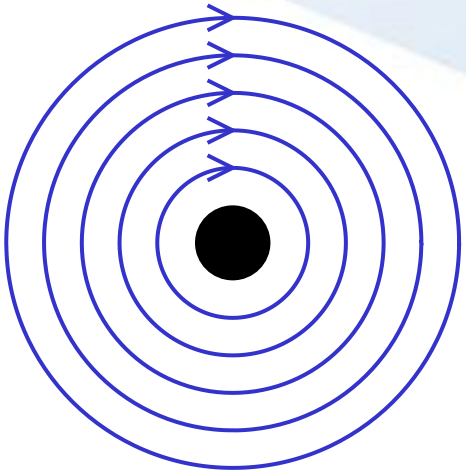


Figure 1 - Magnetic field due to a single conductor - current flowing into page

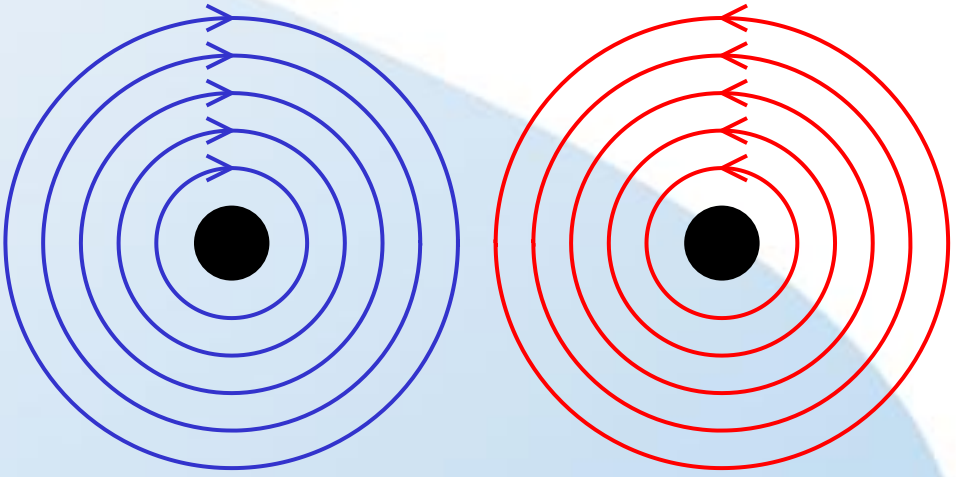


Figure 2 - Magnetic fields due to two conductors - current flowing in opposite directions

When the magnetic fields overlap, the horizontal components of the fields cancel each other, leaving a vertical component, which is strong immediately between the conductors.

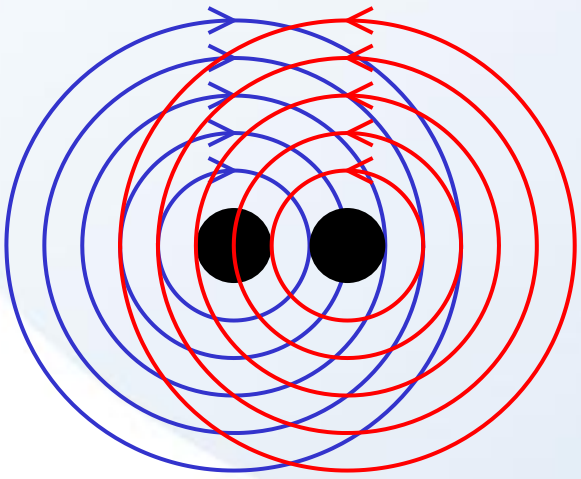


Figure 3 - Magnetic field due to two conductors in close proximity

A magnetic field generated by DC cables is referred to as a static field, the same as the earth's.

The magnitude will vary with current, and the direction will be reversed when the current flow is reversed, when the interconnector is used to import, rather than export, energy.

3.2 EARTH'S MAGNETIC FIELD

The static magnetic field generated by the earth (between the magnetic north and south poles) is approximately 50µT in the southern Irish Sea (approximately 25µT at the equator and 65µT at the magnetic poles). The field runs from pole to pole.

3.3 ACCEPTABLE LEVELS OF MAGNETIC FIELD STRENGTH

Published levels of magnetic field strength that would not harm animals on the seabed vary, and some reports are referred to in section 6. In general, 3mT (3000µT) is considered acceptable, both for health and the effect on navigation.

3.4 SYSTEM DESIGN

The offshore cables for Greenlink will be 320kVDC armoured cables with XLPE insulation, they will be installed in a bundle, i.e. touching, and nominally arranged horizontally.

Allowing for losses in the system, it is assumed that the continuously rated current for the 500MW interconnector will be 797A.

3.5 INSTALLATION DESIGN

Whilst the target installation depth is considerably greater, we have been asked to consider a minimum installation depth of 600mm, to the top of the cables.

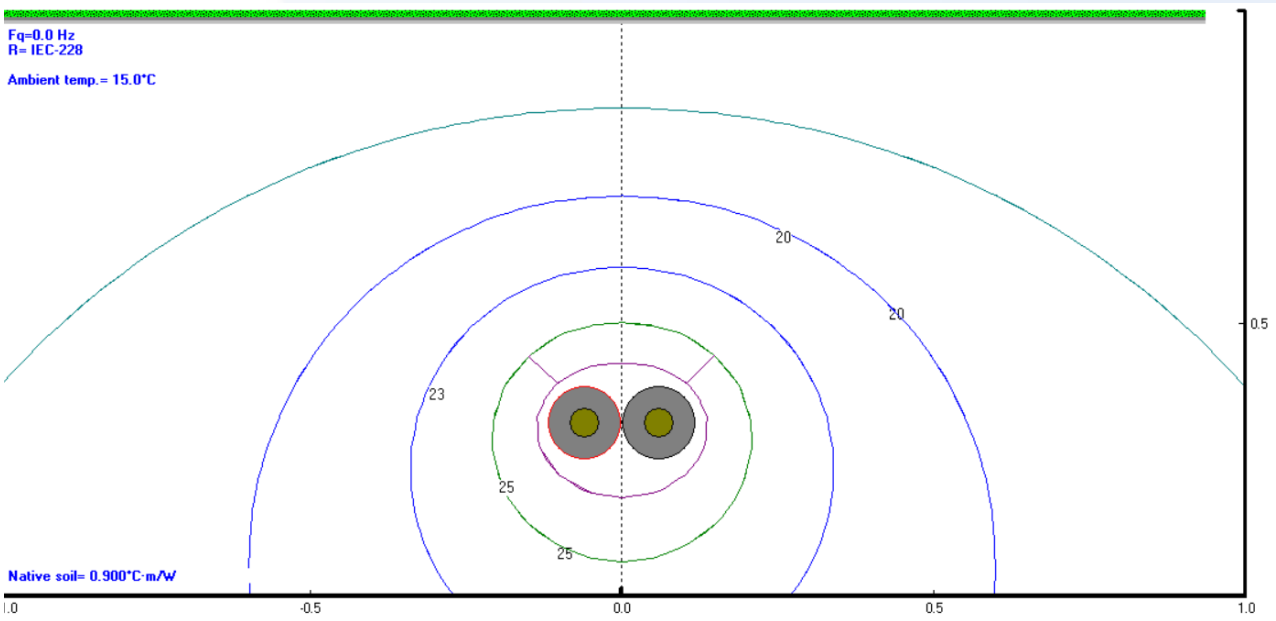
3.6 CALCULATION METHOD

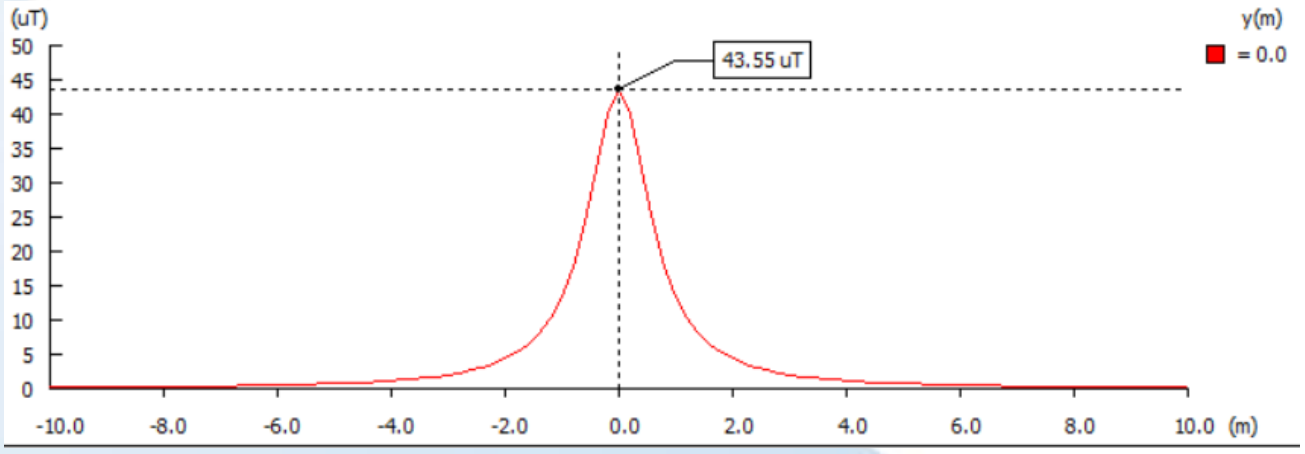
The magnetic field profiles were generated by the CYMCAP® cable rating programme.

4 CALCULATED MAGNETIC FIELD STRENGTH DUE TO CABLES

4.1 CABLES INSTALLED 600mm BELOW THE SEABED

The thermal and (static) magnetic field plots at the seabed for the Greenlink submarine cables, installed at a depth of 600mm, to the tops of the cables, are shown below.





The calculated static magnetic field strength, immediately above the cables is 44µT. 2m from the cables, the calculated static magnetic field strength is 5µT.

It may be noted that a single cable conducting 797A would generate a magnetic field of 240µT at the seabed, which indicates the cancelling effect of the two bundled cables.

4.1.1 RESULTANT MAGNETIC FIELD STRENGTH

As the magnetic fields due to the earth and to the cables act at right angles, the magnitude of the magnetic field will be:

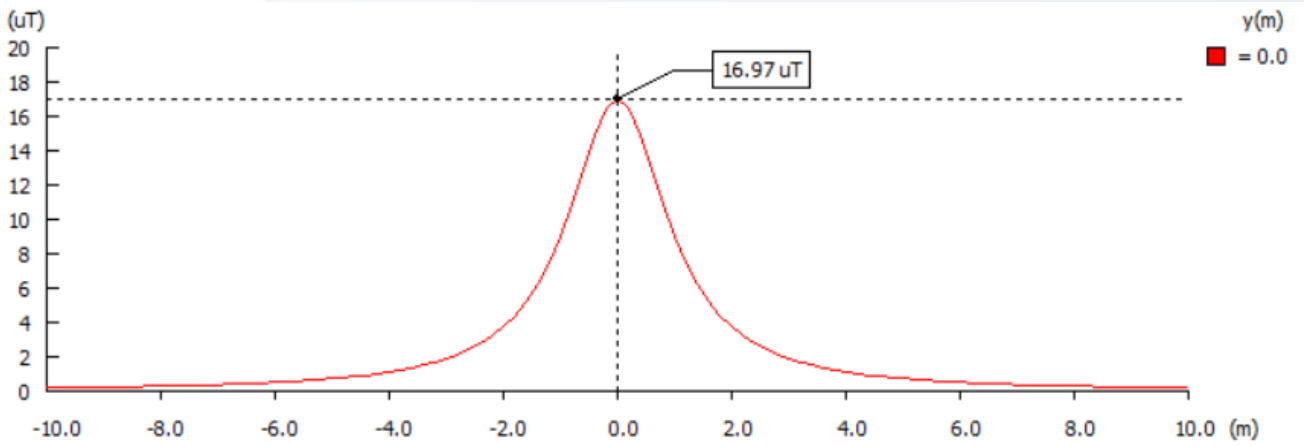
$$|B| = \sqrt{(B_{earth}^2 + B_{cable}^2)}$$

$$= \sqrt{(50^2 + 44^2)}$$

$$= 67\mu T$$

4.2 CABLES INSTALLED 1000mm BELOW THE SEABED

The (static) magnetic field plots at the seabed for the Greenlink submarine cables, installed at a depth of 1000mm, to the tops of the cables, is shown below.



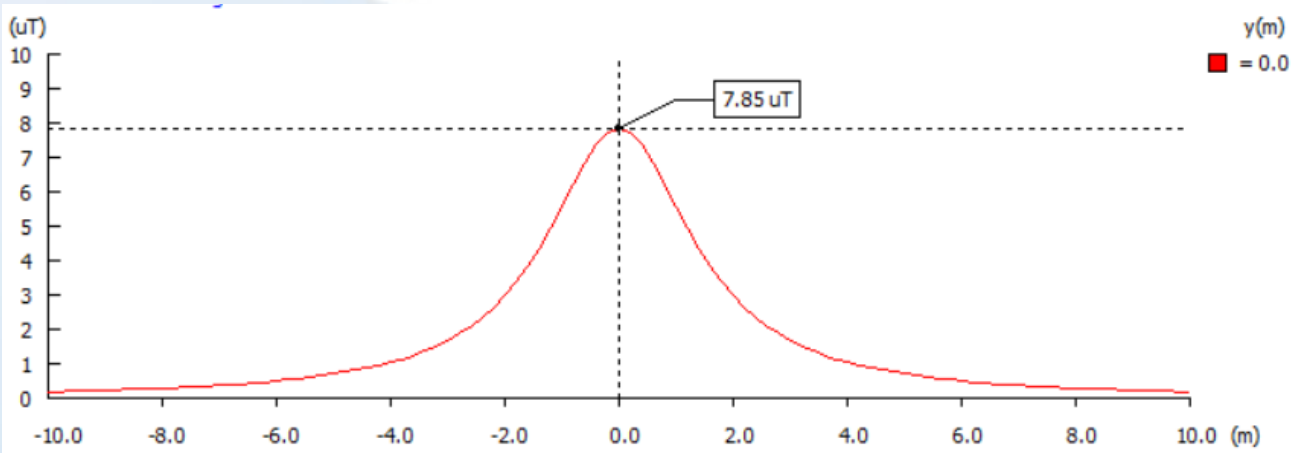
The calculated static magnetic field strength, immediately above the cables is 17µT.

4.2.1 RESULTANT MAGNETIC FIELD STRENGTH

As the magnetic fields due to the earth and to the cables act at right angles, the magnitude of the magnetic field will be 53µT, so the effect on the resultant magnetic field is negligible.

4.3 CABLES INSTALLED 1500mm BELOW THE SEABED

The (static) magnetic field plots at the seabed for the Greenlink submarine cables, installed at a depth of 1000mm, to the tops of the cables, is shown below.



The calculated static magnetic field strength, immediately above the cables is 7.9µT.

4.3.1 RESULTANT MAGNETIC FIELD STRENGTH

As the magnetic fields due to the earth and to the cables act at right angles, the magnitude of the magnetic field will be 51µT, so the effect on the resultant magnetic field is negligible.

4.4 CALCULATED MAGNETIC FIELD STRENGTH AT CABLES

The calculated static magnetic field strength, at the level of the tops of the cables and between them in plan, is 2660μT, as is the resultant strength, when considering the earth's magnetic field, to 3 significant figures.

This is still within the value of 3mT referred to in section 3.3.

5 CONCLUSIONS

The calculated strength of the static magnetic field due to the Greenlink cables, even installed at only 600mm depth in the seabed, is of the same order of magnitude as the earth's magnetic field, and significantly less than those used in experiments, in which fish and invertebrates were not adversely affected by magnetic fields orders of magnitude greater than those generated by the Greenlink cables.

In addition, it has been recorded that the effect on navigation of migrating fish is not adversely affected by the static magnetic fields generated by HVDC submarine cables.

6 REFERENCES

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(ii) The effect of static magnetic field on melanophores in the sea trout (Salmo trutta m. trutta Linnaeus, 1758) embryos and larvae

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(iii) Assessment of Potential Impact of Electromagnetic Fields from Undersea Cable on Migratory Fish Behavior

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