Technical Study

Assessment of Induced Electromagnetic Field

Valid for

#GL22_DC Cable Marine

Greenlink Interconnector Project

Index of Revisions

Rev	Date	Description	Initiator	Reviewer	Approver
00	20-Feb-24	First Issue – for review	V.Foo	S.Gooding	H.Yanagawa
01	25-Mar-24	Revised to reflect GIL's comment	V.Foo	S.Gooding	H.Yanagawa
02	15-May-24	Revised to reflect GIL;s new comment_RC03	CDB	V.Foo	H.Yanagawa
03	09-Jul-24	Revised to reflect GIL's new comment_RC05	CDB	V.Foo	H.Yanagawa

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1. Project Overview

The Greenlink Interconnector Project is an electricity interconnector between County Wexford, Republic of Ireland and Pembrokeshire, Wales. The Interconnector will transfer power using high voltage direct current (HVDC) via submarine and underground cables over approximately 200km.

Greenlink Interconnector Limited is the licensee for the Project.

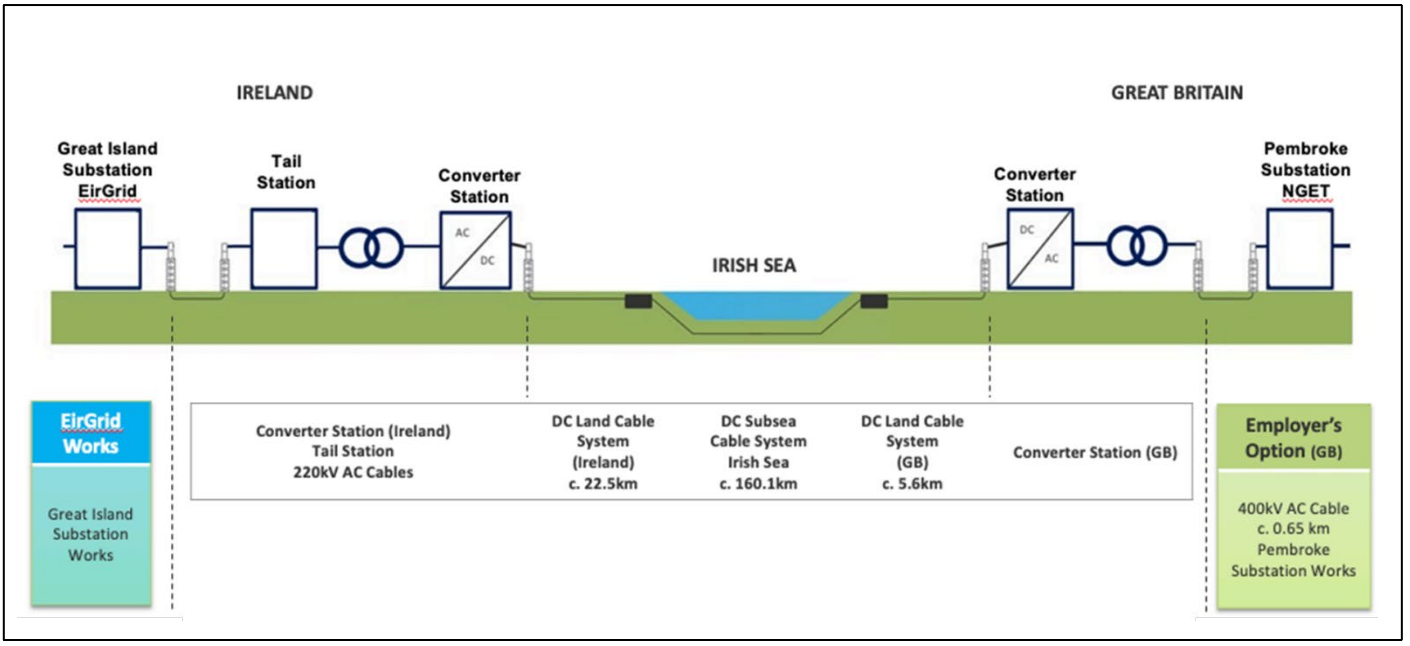

Figure 3.1-1: Overview of HVDC Cable System

2. Purpose of the document

The Marine Licence – Wales, Section 3 – Conditions, 3.38, State 'If requested by the License Authority, the Licence Holder must undertake a Compass Deviation Survey and submit a monitoring report to the Licensing Authority for written approval within 6 months of the request being made.'

Greenlink Marine Environmental Impact Assessment Report (Ireland) – Condition EM 27, Post-installation compass deviation surveys will be undertaken to confirm compass deviation levels and the results forwarded to the Irish Maritime Administration; Post-installation compass deviation surveys will be undertaken to confirm compass deviation levels and the results forwarded to the UKHO and MCA.

Sumitomo Electric on behalf of the licence holder Greenlink Interconnector seeks a derogation from the licence condition requirement on consideration of this technical assessment.

This document outlines the assessment of the magnetic fields generated by the HVDC cables under energisation installed in various forms throughout the offshore cable route in the aspects of:

- Maximum magnetic fields generated by the cables during energisation
- Magnetic compass deviations in the vicinity of the cables
- The section of cables that have potential high degree of compass deviation is approximately 1.5 km from the total offshore route length of 159 km and within the 10 m corridor from the cable centreline (i.e. 98.4 % of the offshore route is within <3% deviation requirement of MCA).

3. Cable System Description

The high voltage direct current cable system has a power capacity of 500 MW at a Direct Current (DC) operating voltage of 320 kV. The DC cable terminations are located at the AC/DC convertor stations in Campile converter station (Ireland) and Penfro converter station (Wales). The total circuit length is approximately 190 km comprised of 160km of submarine cable and 30km of land cable (in Ireland and GB)

Bundled with the DC cable (under seabed or onshore underground) is a fibre optic cable which is used for communications between the two convertor stations and to facilitate temperature monitoring of the cable using a Distributed Temperature Sensing (DTS) system. The same monitoring system has the ability to detect deviation or changes to the ground or seabed surrounding the bundled cables.

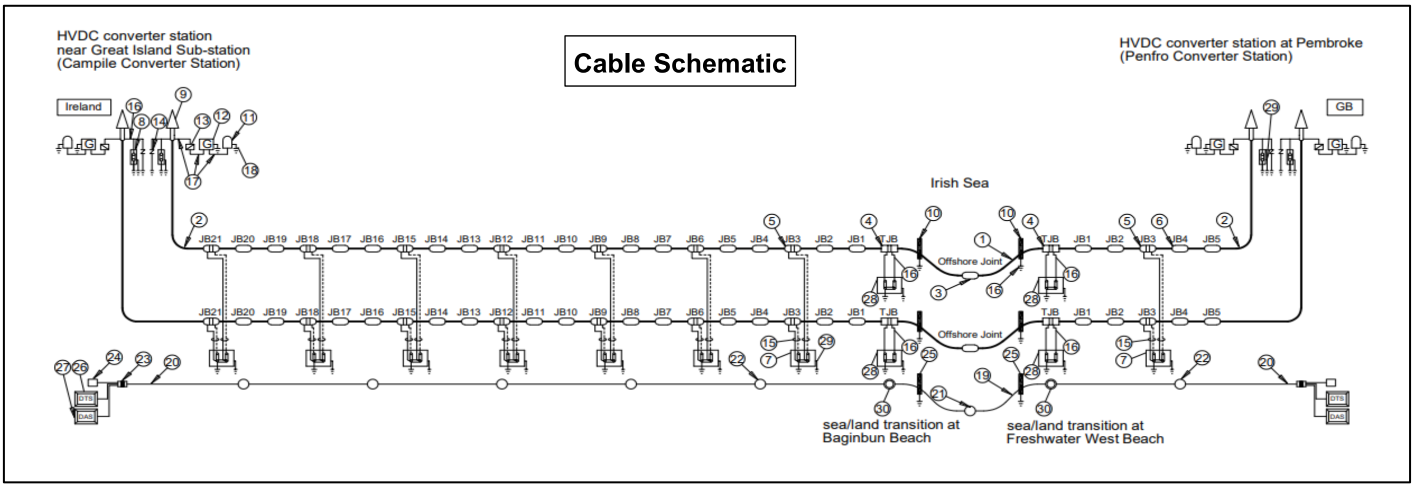

Figure 3.1-1: Schematic diagram of the HVDC Cable System

3.1. Onshore Sections

The onshore cable has been installed in a number of different arrangements. These arrangements comprise of:

- Direct buried Polyvinyl chloride (PVC) cable ducts surrounded by Cement Bound Sand (CBS)
  - Public road sections in Ireland and GB
  - Agricultural land in Ireland and GB
- Direct buried surrounded by CBS
  - Campile Converter station (Ireland) and Penfro Converter station (GB)
  - All cable snaking areas and Joint Bays (including Transition Joint Bays at landfall area)
- Horizontal Directional Drilled (HDD) bores lined with HDPE pipes which have been fusion welded
  - Various location in Ireland and GB including the landfall area
- Concrete troughs unfilled with CBS
  - Campile Convertor station (Ireland)
  - Penfro Converter station (GB)

3.2. Offshore Sections

The offshore cable is laid onto the seabed and then post lay, trenches will be used to create trenches into which the cable is allowed to settle and naturally backfill providing cover and protection. The intent is for the entire length of the offshore cable to be buried below seabed except at 5 locations where the cable crosses extant communications cables.

An overview of the offshore cable route is shown in Figure 3-2:

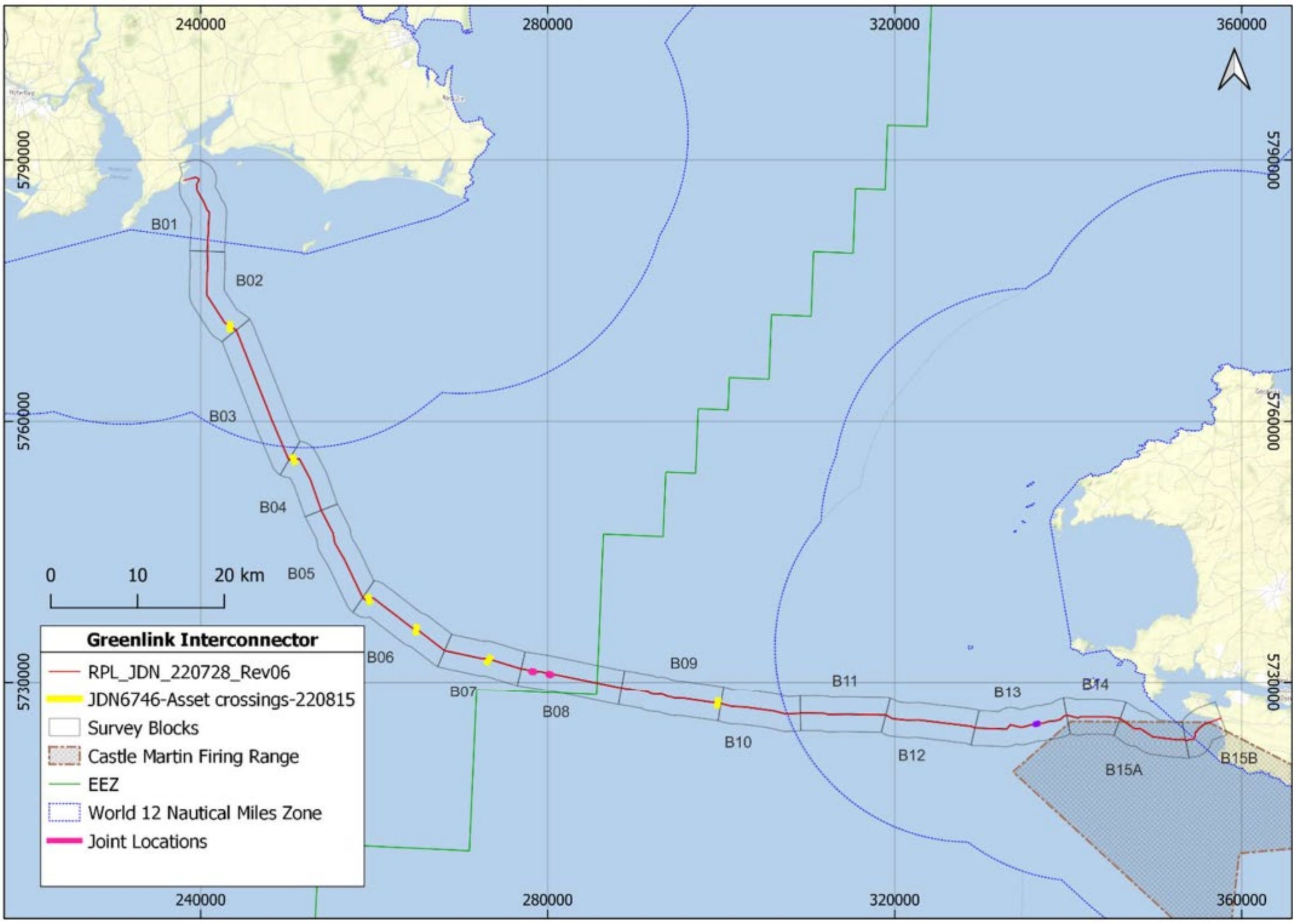

Figure 3.2-1: Overview of offshore cable route

The 5 existing service crossings are described in Table 3-1. The cable will be protected in these locations using rock berms as illustrated in Figure 3-3.

Table 3-1: Service crossings along the Greenlink offshore route

Asset Name	Operator	Type	Crossing WGS84 UTM30N			
			Easting	Northing	Lat (dd)	Long (dd)
Solas	Vodafone	Cable	250711.25	5755586.56	51.8952N	6.6234W
Pan European Crossing 1	Century Link (Level 3)	Cable	264837.47	5736056.21	51.726N	6.4052W
Pan European Crossing 2	Century Link (Level 3)	Cable	299612.36	5727528.12	51.663N	5.8975W
Hibernia Seg D	GTT Communications	Cable	273178.98	5732572.46	51.6982N	6.2824W

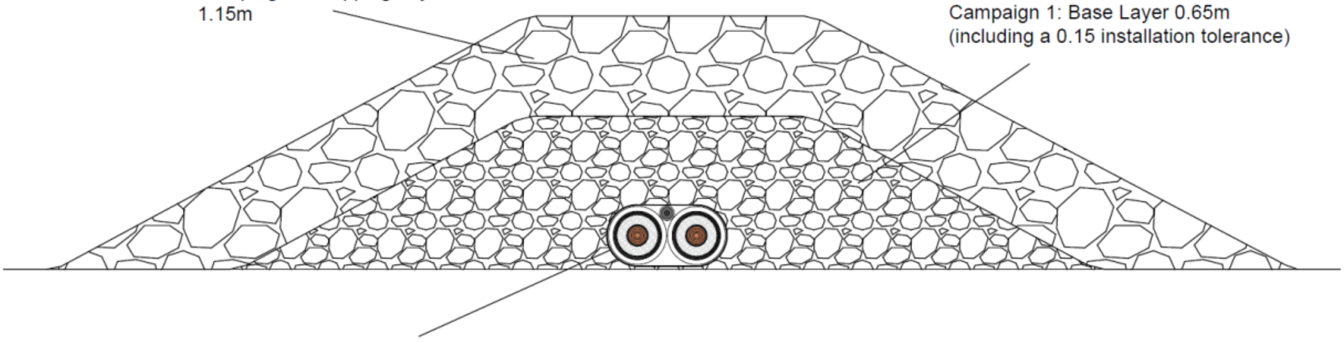

Figure 3.2-2: Schematic of Rock Berm

3.3. Submarine Cable description

The submarine cable system is made up of 3 individual cables bound together using a high strength tape; there will be two DC cables, a positive and a negative pole with a smaller Fibre Optic cable for communications. The components of the cables are illustrated in Figure 3-4 and Figure 3-5:

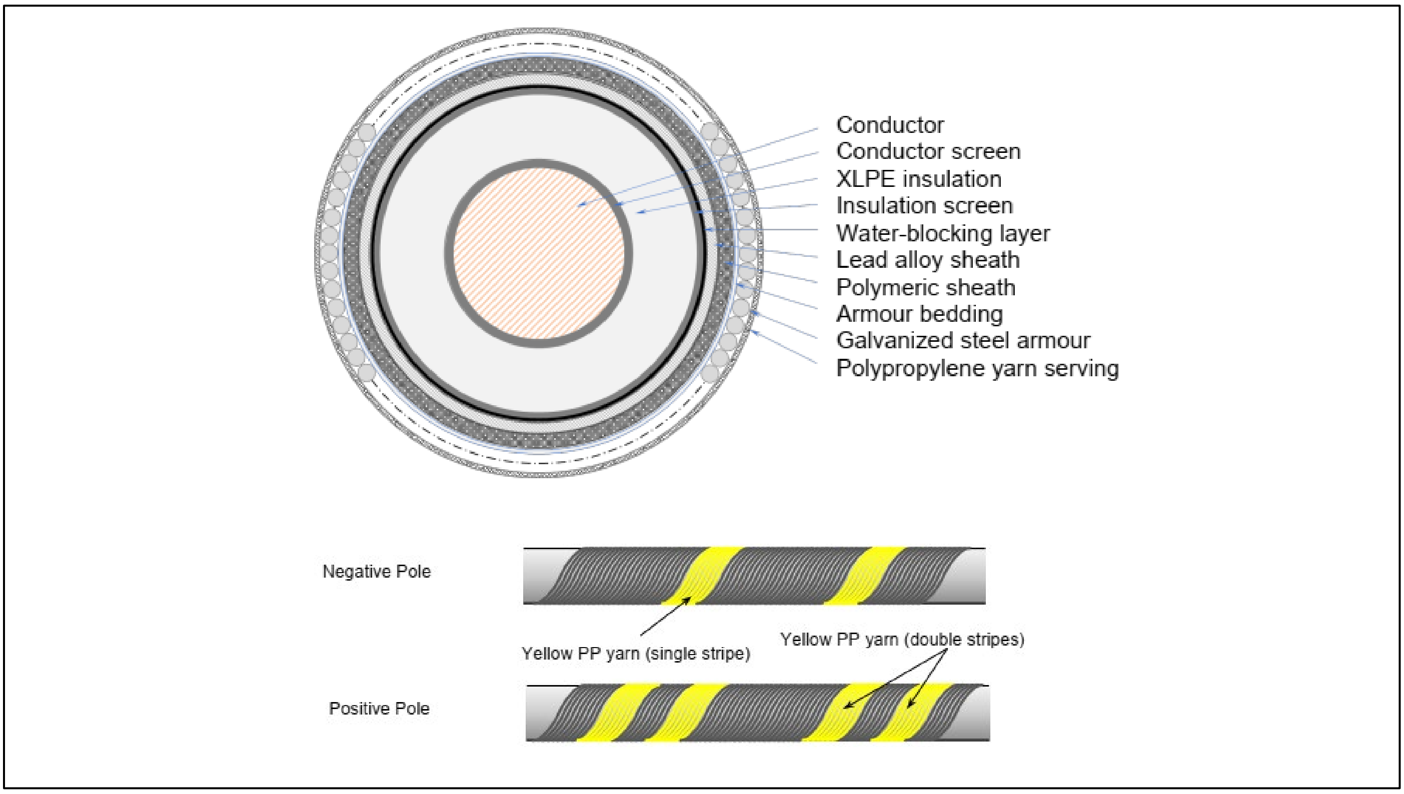

Figure 3.3-1: Submarine Cable cross-section

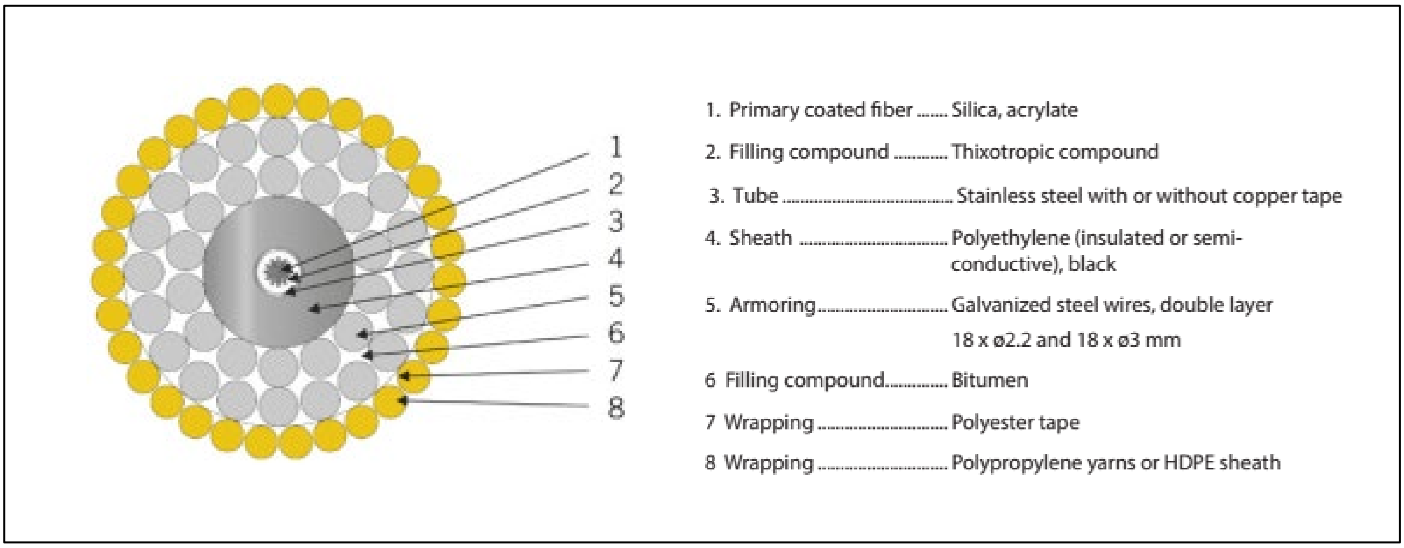

Figure 3.3-2: Submarine Fibre Optical Cable cross-section

3.4. Cable Design Criteria

The cable design criteria at specific areas and its' worst-case scenario in terms of magnetic fields generated by the energised cables are listed in Table 3-2.

Table 3-2: Cable design criteria and conditions

Location	Max. current (A)	Cable separation distance Pole-to-Pole (m)	Burial depth / Depth of cover (m)
Nearshore Baginbun Beach (Ireland)	1183	Max. 11.0	0.75
Offshore (Ireland / UK / EEZ)	1183	Bundled 0.11	0.5
Nearshore Freshwater West (Wales)	1183	Max. 16.0	0.75

Note:
Pole-to-Pole separation means distance between the pair of cable conductors

4. Assessment

4.1. Induced magnetic field

This interconnector is a HVDC symmetrical monopole with where the cables are either bundle laid in close proximity to each other; hence resulting in a cancellation of the induced magnetic field generated during energisation of the system. Contrarily, as the pair of cables are laid further apart, the cancellation effect is weakened and resulting the worst-case condition (i.e. maximum field strength) for induced magnetic fields.

The maximum magnetic field strength is calculated at the cable separation distance in the listed Table 3-2 with design criteria of a maximum overload currents of 1183 A which are equally and electrically conducted in the opposite directions in the pair of cables. Under normal system operation (continuous rating), the electrical current is significantly lower at 842 A (approximately 30% less) hence the weaker induced field strength.

As a basis, the cables are either laid buried on seabed or surface laid then covered by a layer of protection materials The induced magnetic field strength by the cables are dependent on its installed form and the geomagnetic field is then combined to estimate the total field effect. The total field effect will depend on background field and cable orientation / heading with reference to the Earth's geomagnetic field angle. In this assessment, the calculations are based on Earth's magnetic field at 49.0 μT with geomatic field angle of dip at 66.6° (WMM-2020).

The highest magnetic field induced by the pair of cables when in operation is 2094 μT at the cable surface observed on the surface and onshore land cable. The induced magnetic field from the pair of DC cables are compliant with the International Commission on Non-Ionizing Radiation Protection (ICNIRP 1998) guideline for public exposure at the field strength of 40,000 μT.

4.2. Magnetic compass deviations

During system operation, the electrical currents that flow in the DC cables produce a magnetic field around it, whose horizontal vector components has the potential to influence or alter the reading on a magnetic compass. The amount of this compass deviation is dependent on a few factors such as the amount of electrical current flowing in the DC cables, proximity of the physical compass to the cable in energisation, the separation between the pair of cables, and the installed cable orientation with reference to the earth's magnetic field (i.e. magnetic north).

In principle, the separation distance between the pair of laid cable will determine the amount of compass deviation; if the pair of cables are laid in proximity, the equal currents flowing in opposite directions will have a greater cancellation effect that cause less compass deviation and the effect is reversed when cables are further apart.

The induced magnetic field from the pair of HVDC cables were calculated along the cable installation route with the effect of Earth’s geomatic field. The representative background geomagnetic field and inclination for areas of interest are calculated base on table below. Since the cable route has approximately 160 km offshore between Ireland and Wales, the calculations were carried out with the conservative approach (i.e. severe conditions – shallow burial, maximum cable separation, etc.).

The section with expected high degree of compass deviation will be the section nearshore at landfalls of Baginbun beach in Ireland and Freshwater West in Wales; this is due to the pairs of cables being unbundled before pulled through the Horizontal Directional Drills (HDD) bore holes before landing and fixated at the transition joint bay. In Greenlink’s case, the worst-case scenario is assumed with approximately 2 km of unbundled cables from the entry of the HDD bore holes (i.e. at seabed) in Wales and approximately 1.5 km in Ireland in a similar manner.

Table 4-1: Earth’s magnetic fields assumed for calculations (WMM-2020)

	Nearshore Ireland	Offshore / Mid-section	Nearshore Wales
Geomagnetic magnitude (μT)	49.1	48.9	49.0
Geomagnetic inclination (degree °)	66.8	66.4	66.4

Table 4-2: Cable magnetic field for HVDC cables operating at ±320kV, max. 1183 A.

Vertical distance above seabed (m)	**Cable surface**	**Seabed**	**0.1m**	**0.5m**	**1.0m**	**1.5m**	**2m**	**5m**	**10m**	**20m**
Bundled (0.11m) @Offshore	1675	105.6	73.6	26.7	11.9	6.68	4.28	0.88	0.24	0.06
Unbundled (11m) @Baginbun Beach	2094	314.7	277.5	188.1	134.3	105.2	85.8	41.1	17.9	5.65
Unbundled (16m) @Freshwater West	2094	315.1	278.0	188.7	134.4	104.9	86.0	41.2	21.1	7.65
Vertical distance below ground (m)	**Cable surface**	**ground level**		**0.9m**	**1.05m**					
Duct (0.3m) @Onshore	2094	82.3		19.5	X					
Duct (12m) @HDD	2094	262.2		124.0	X					
Unbundled (11m) @TJB Ireland	2094	224.3		X	115.3					
Unbundled (16m) @TJB Wales	2094	224.9		X	114.8					

Table 4-3: Total cable magnetic field from cable and geomagnetic field for HVDC cables operating at ±320kV, max. 1183 A.

Vertical distance above seabed (m)	Cable surface	Seabed	0.1m	0.5m	1.0m	1.5m	2m	5m	10m	20m
Bundled (0.11m) @Offshore	1719	151.7	120.1	74.1	60.0	55.1	52.9	49.8	49.2	49.0
Unbundled (11m) @Baginbun Beach	2095	321.5	285.2	209.0	160.8	136.3	121.8	88.2	65.7	54.2
Unbundled (16m) @Freshwater West	2095	321.0	284.6	205.7	157.3	132.5	117.3	86.1	68.8	56.1

5. Conclusion

- The closely bundled cable will have cancellation effect on the cable magnetic field; however, this cancellation effect is weakened when the pair of cables are separated apart.
- The induced magnetic field from the bundled cables decreases over distance and will have no significant effect on Earth's geomatic field at a distance greater than 5 m from the cable. Similarly, for unbundled cables this magnetic field is lower than Earth's geomagnetic field at the distance of 5 m; but this effect is very small and deemed insignificant.
- The calculated compass deviation over the cable route is as expected where the deviation is larger at shallow water nearshore due to landfall unbundling of cables and is extremely low for bundled cables for most cable route which is deemed insignificant.
- The section of cables that have potential high degree of compass deviation is approximately 1.5 km from the total offshore route length of 159 km and within the 10 m corridor from the cable centreline (i.e. 98.4 % of the offshore route is within <3% deviation requirement of MCA).
- The stated section of 1.5 km above are in close to the coastline at length of approximately 1.0 km in Wales and 0.5 km in Ireland.
- All calculated DC cables induced magnetic field are compliant with EMF exposure ICNIRP guideline.
- Further assessment has been carried out for Psophometric noise carried out– See Vol 3_Appendix K - Magnetic Fields and induced voltages (P1975_R4500_RevF1), and P-021001_EC_30113#GL10&EED010 - Electromagnetic Coupling (DC) - Design Calculation.
- The Contractor on behalf of the Licence Holder would request an acceptance of the derogation outlined in Section 2 – Purpose of the document; with technical assessment provided to achieve the conclusions aforementioned.

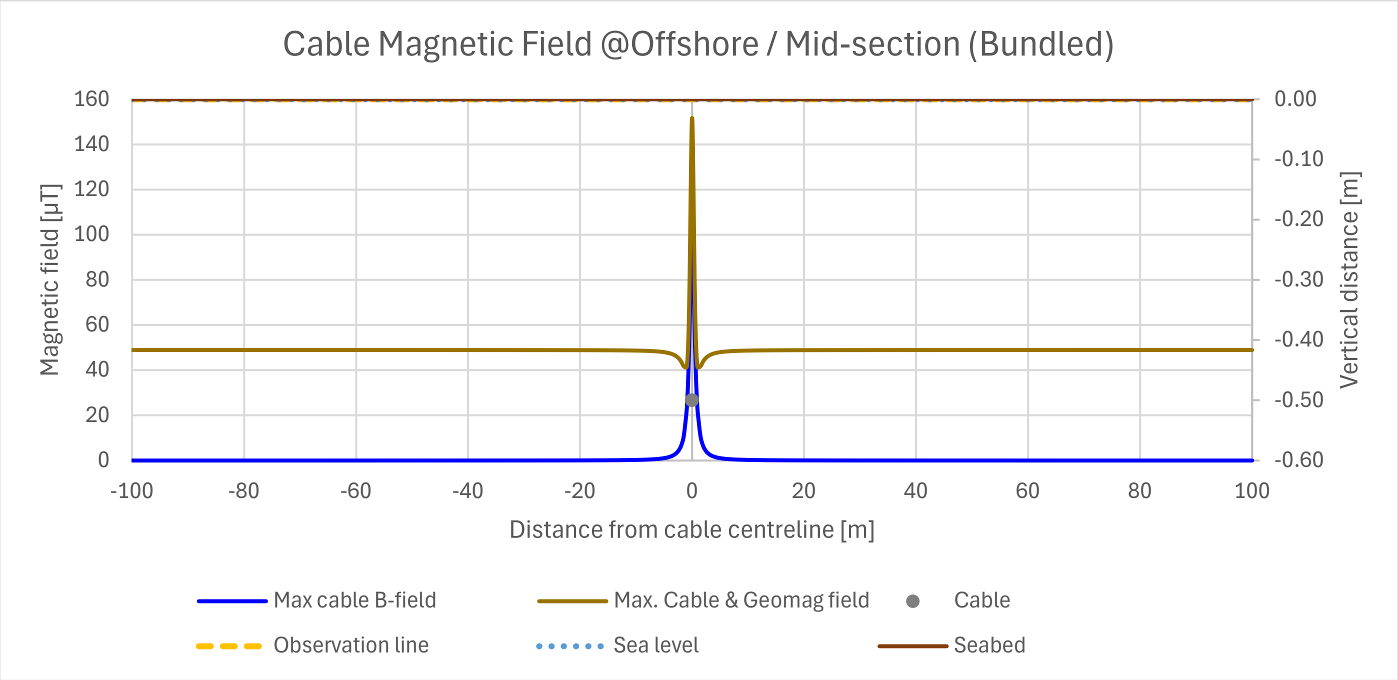

Figure 4.2-1: Calculated cable and Geomagnetic field on seabed for bundled cables. Calculations were made with maximum overload current.

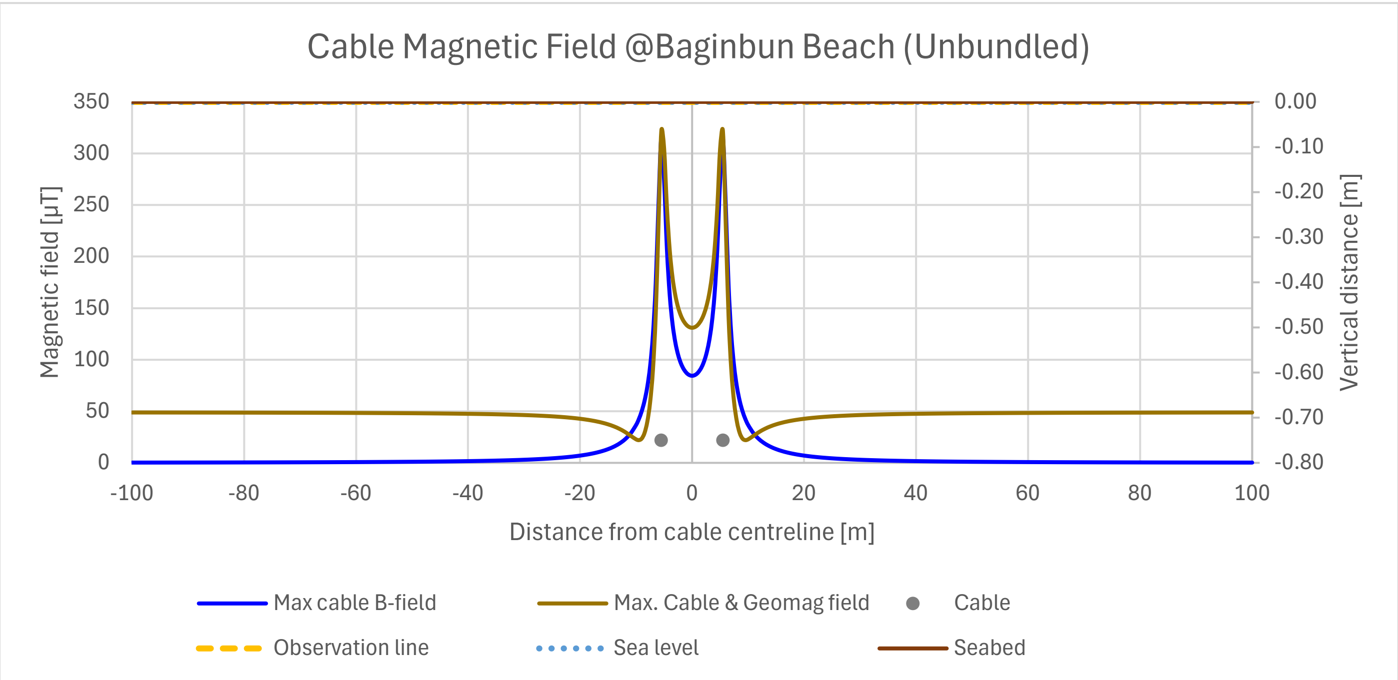

Figure 4.2-2: Calculated cable and Geomagnetic field on seabed for unbundled cables. Calculations were made with maximum overload current.

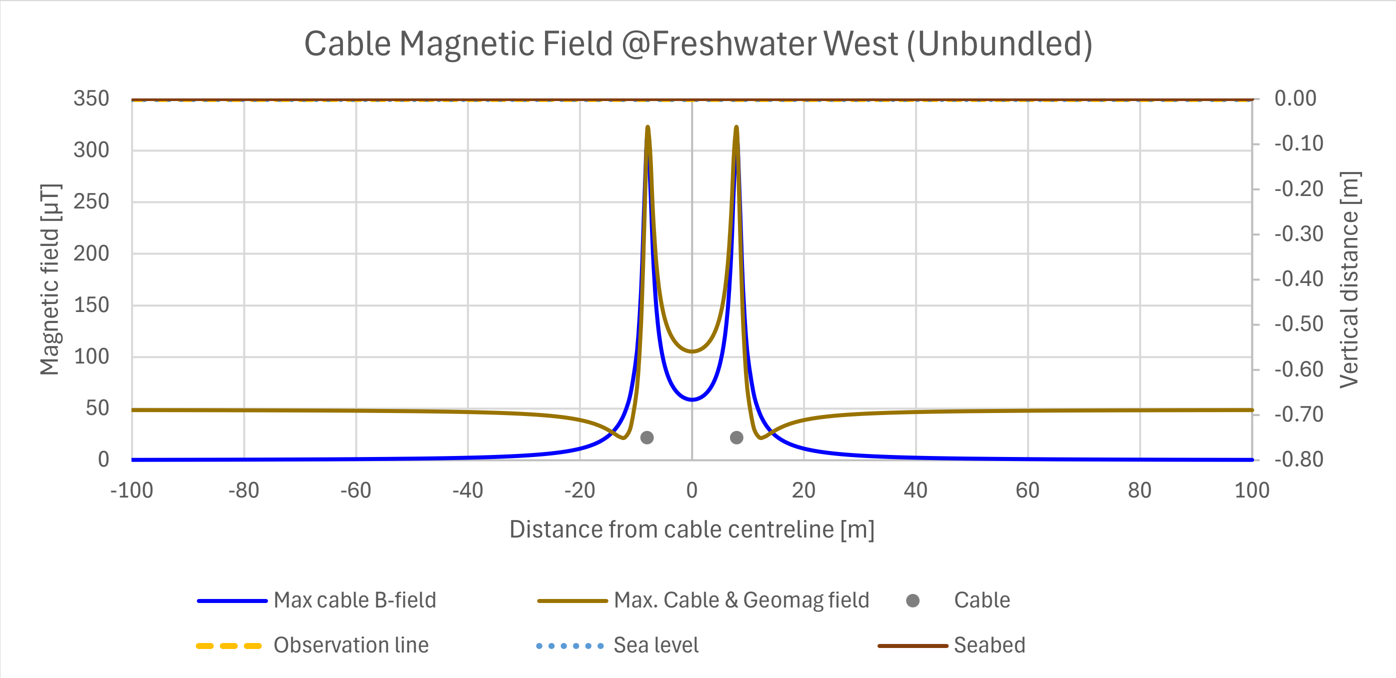

Figure 4.2-3: Calculated cable and Geomagnetic field on seabed for unbundled cables. Calculations were made with maximum overload current.

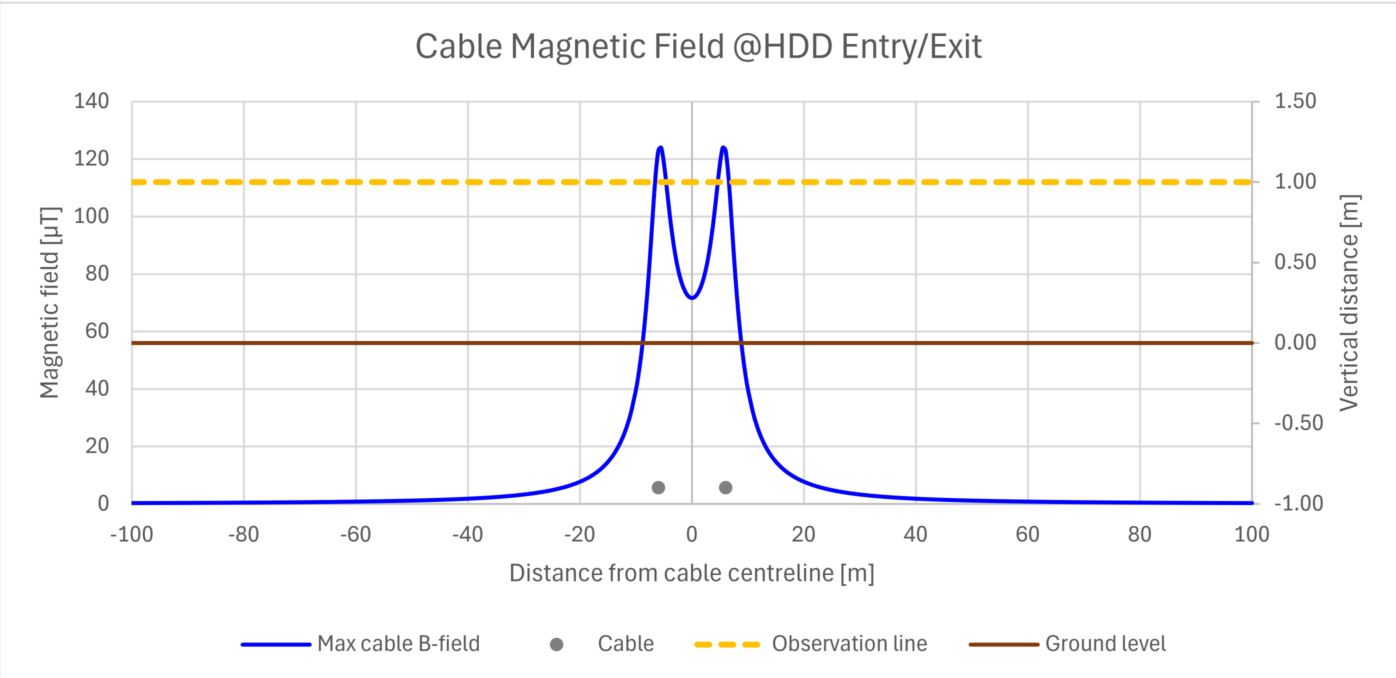

Figure 4.2-4: Calculated cable magnetic field on land cables at HDD entry/exit. Calculations were made with maximum overload current.

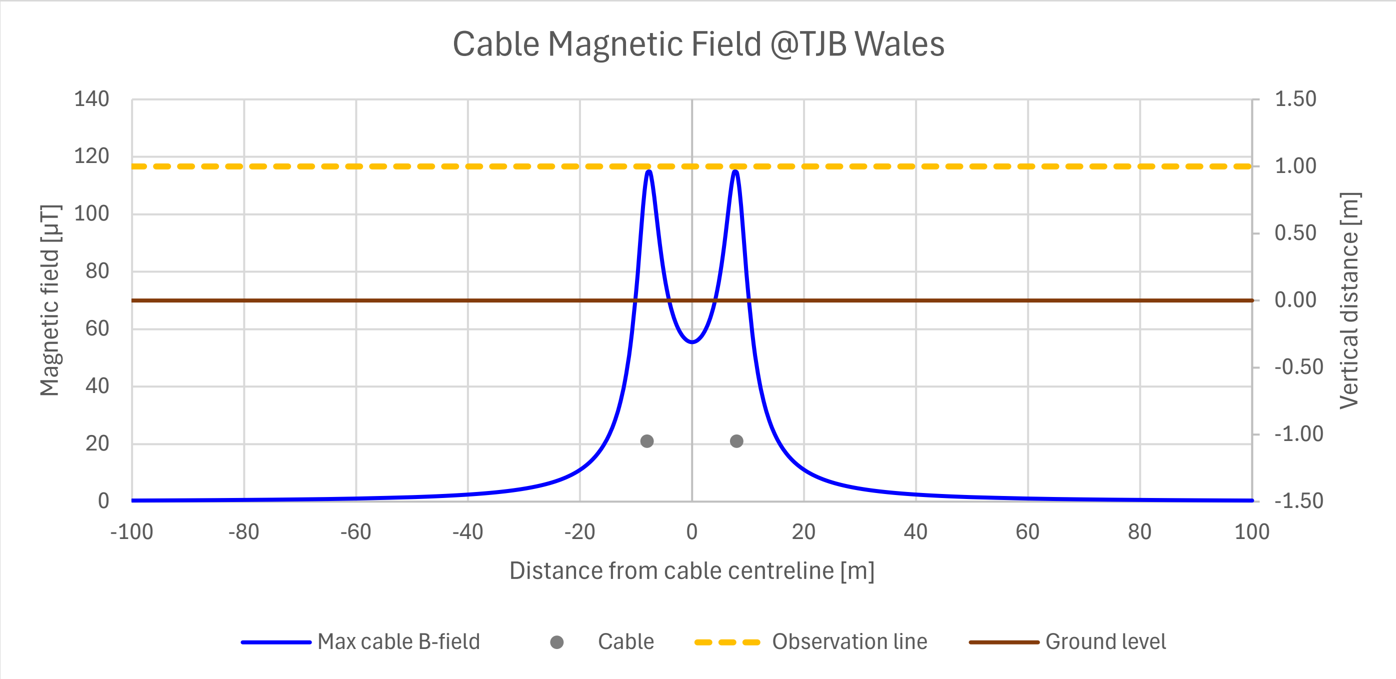

Figure 4.2-5: Calculated cable magnetic field at sea-land cable transition joint bay (TJB) Ireland. Calculations were made with maximum overload current.

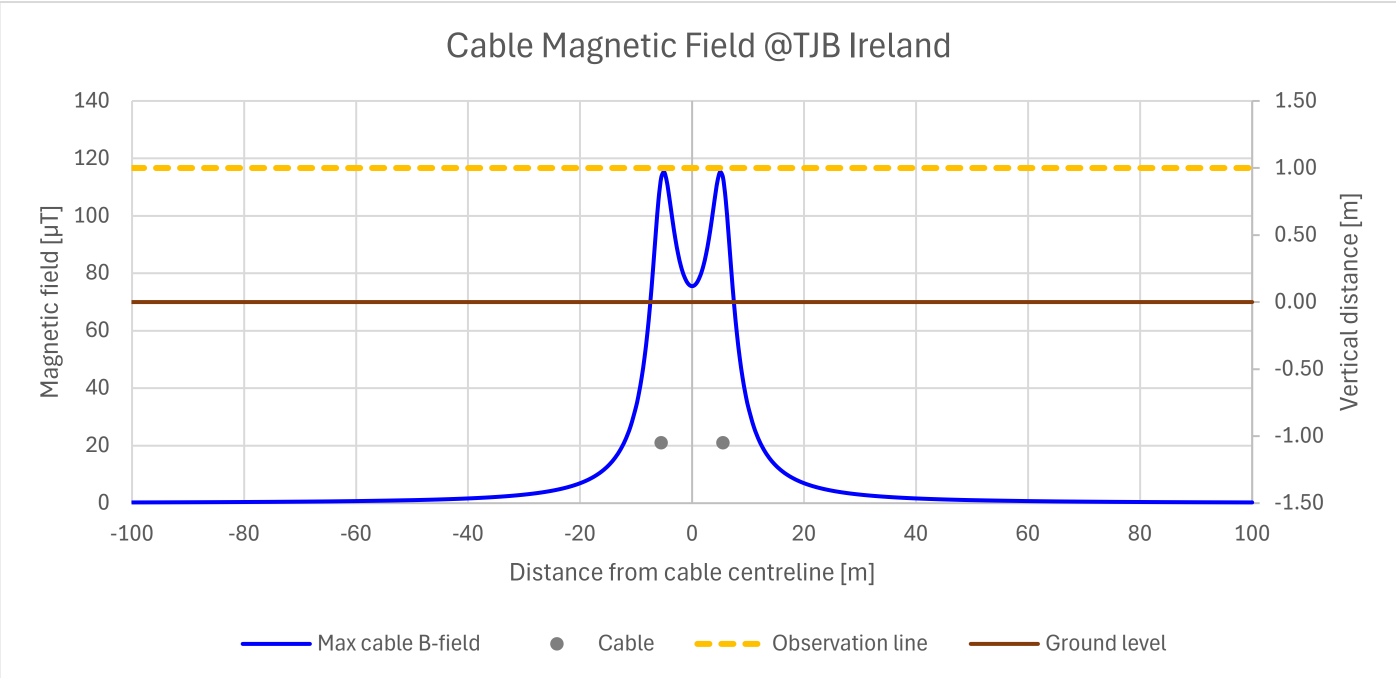

Figure 4.2-6: Calculated cable magnetic field at sea-land cable transition joint bay (TJB) Wales. Calculations were made with maximum overload current.

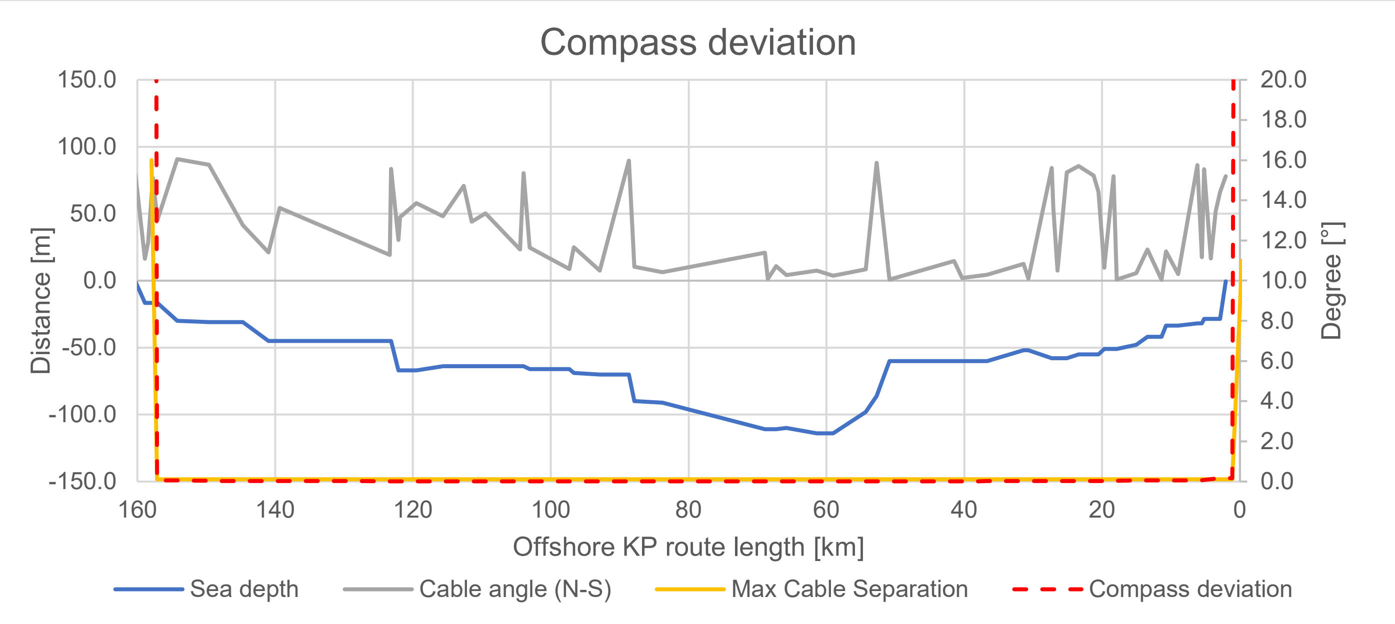

Figure 4.2-7: Calculated compass deviation along the Greenlink offshore cable route observed at sea level with consideration of the cable separation during installation.

Figure 4.2-8: Calculated compass deviation along the Greenlink offshore cable route with 5° angle threshold.

Figure 4.2-9: Calculated compass deviation along the Greenlink offshore cable route with 10° angle threshold.

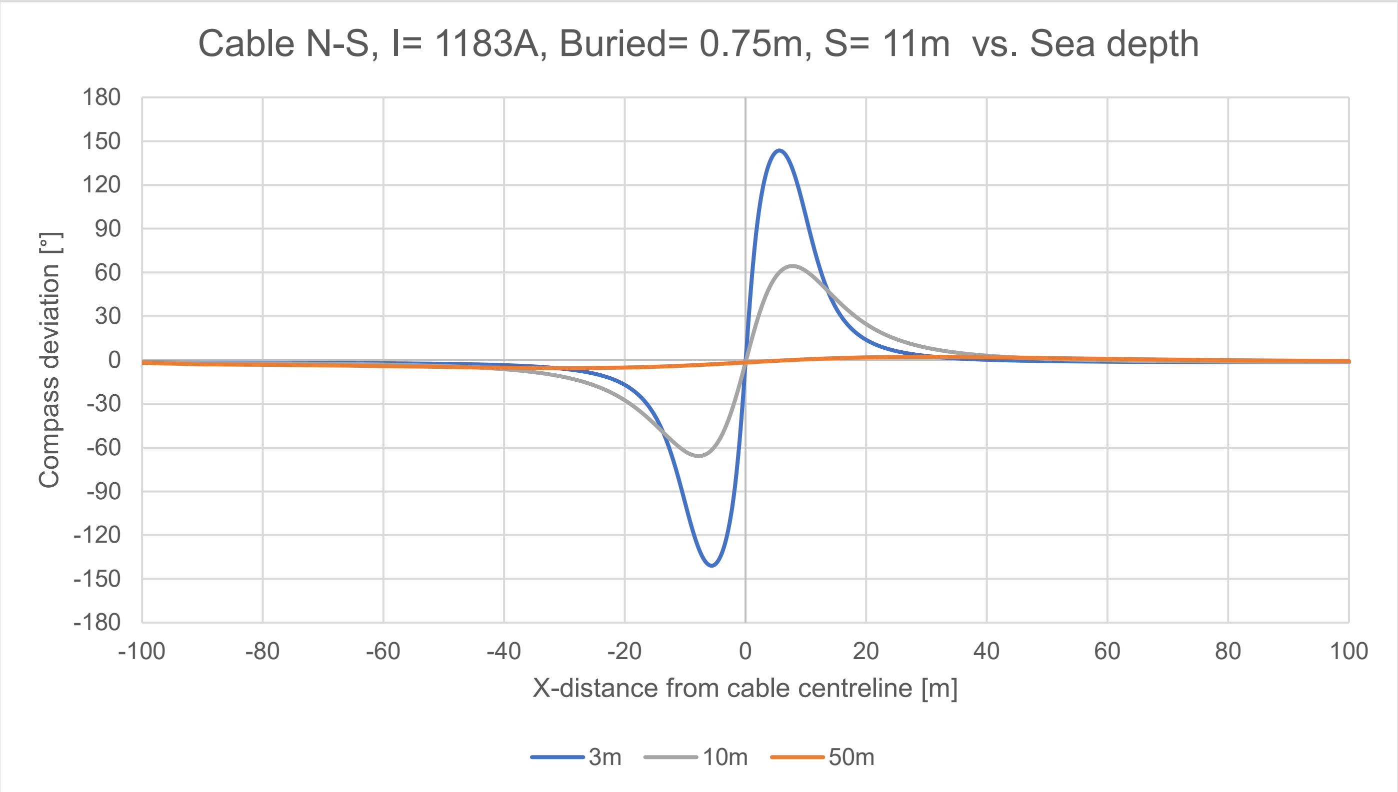

Figure 4.2-10: Calculated compass deviation at nearshore landfall Baginbun Beach against sea depth

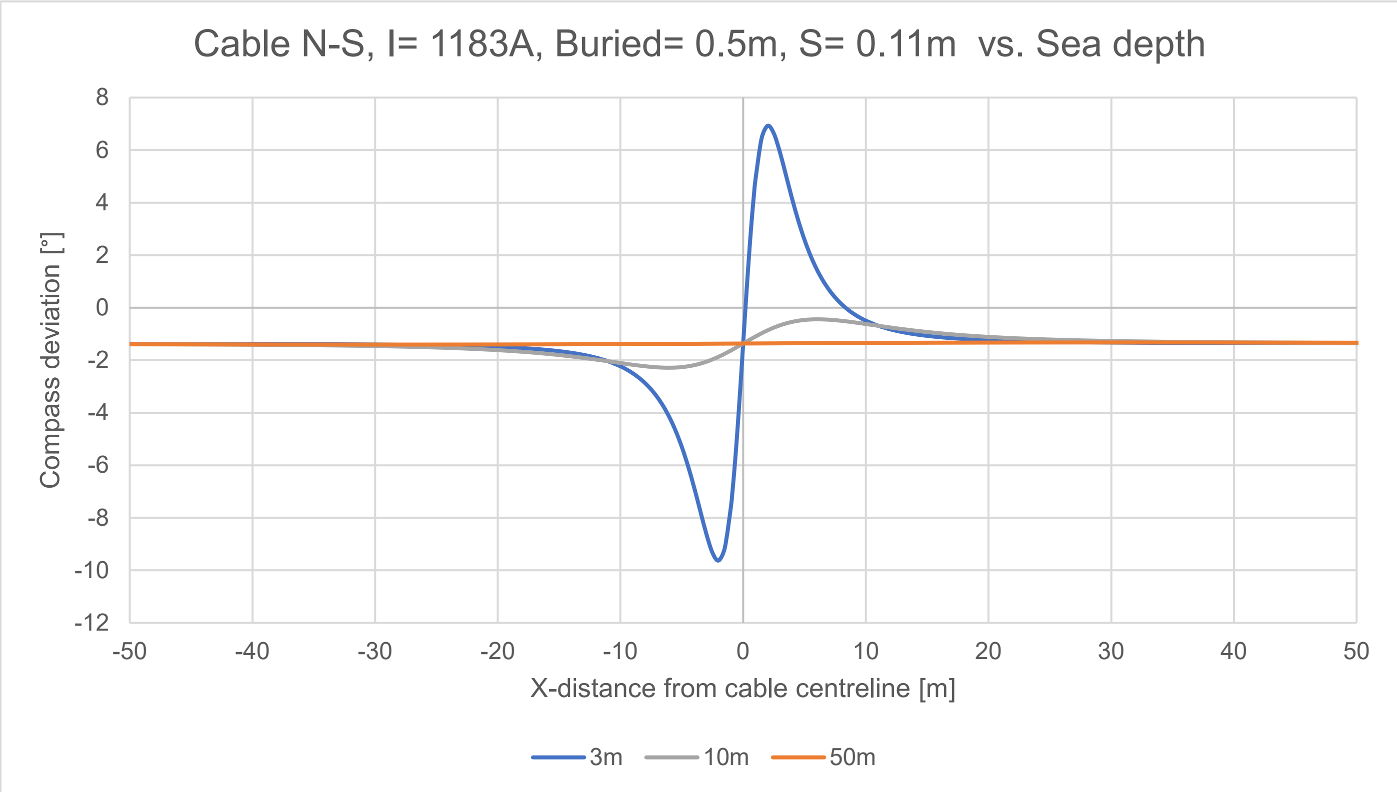

Figure 4.2-12: Calculated compass deviation at offshore bundled cable against sea depth

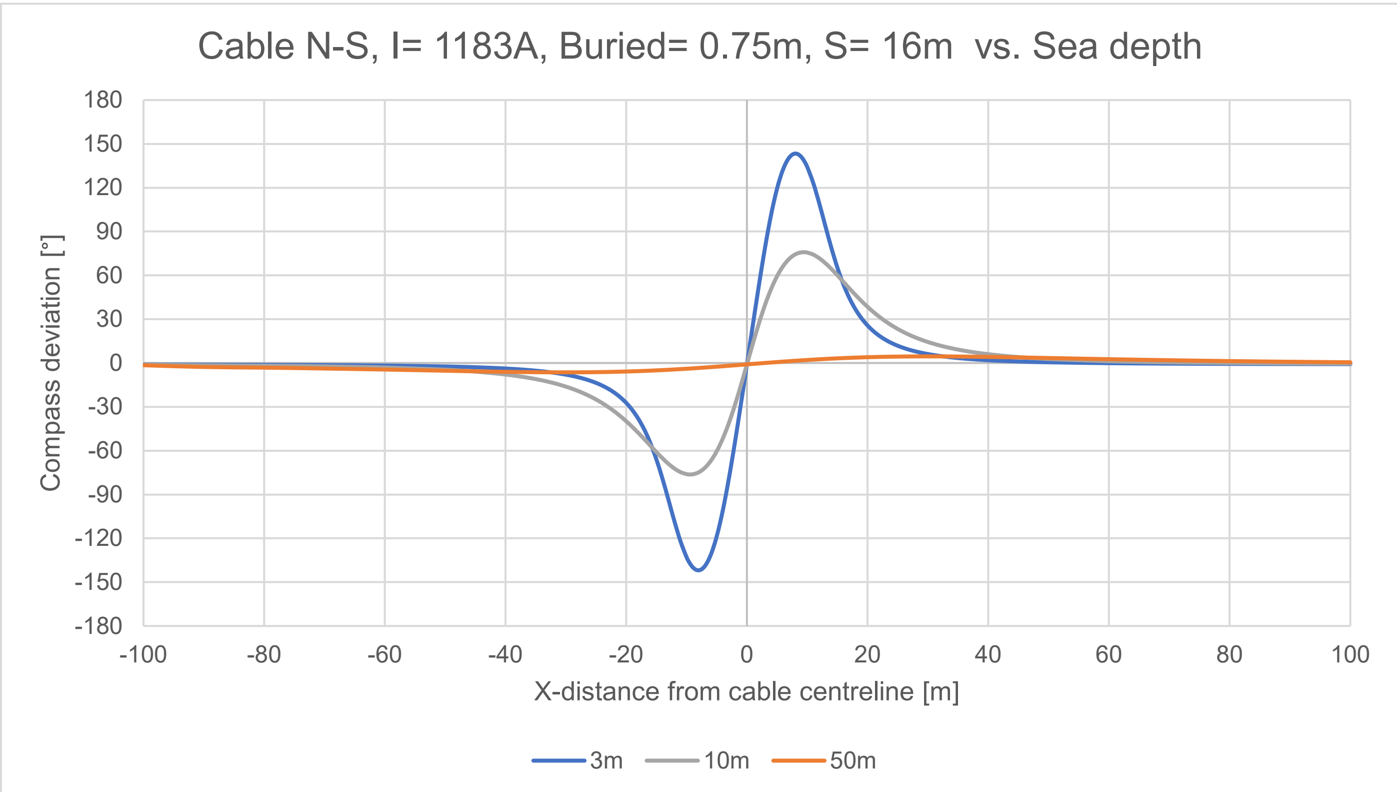

Figure 4.2-11: Calculated compass deviation at nearshore landfall Freshwater West against sea depth