Appendix 8-A: Electric and Magnetic Field Assessment

B&B Engineers & Geologists
of new york, p.c.
an affiliate of Geosyntec Consultants

10777 Westheimer Rd., Suite 900
Houston, TX 77042
PH 281 920 4601
www.geosyntec.com

Memorandum

Date: December 10, 2024
To: Neil Henderson and Casey Sengstaken – CHPE LLC | TDI-USA Holdings LLC
Copies to: Rudy Bonaparte, Ph.D., P.E. (NY) and Jared Brisman, P.E. (NY) – B&B Engineers & Geologists of New York, P.C.
From: Chris Long, Sc.D., DABT, Jiayang Chien, MPH, and Logan Brant, Ph.D., P.E. (NY) – B&B Engineers & Geologists of New York, P.C.
Subject: Electric and Magnetic Field (EMF) Assessment for the Champlain Hudson Power Express® Transmission Project: Harlem Riverbed Installation Case for the 1,250 MW DC Transmission Cables
B&B Project No. GHZ3285/600

EXECUTIVE SUMMARY

This memorandum summarizes the electric and magnetic field (EMF) assessment performed by B&B Engineers & Geologists of New York, P.C. (B&B), an affiliate of Geosyntec Consultants, Inc., in support of the submarine installation of high voltage direct current (HVDC) cables for the Champlain Hudson Power Express® (CHPE) directly on the riverbed of the Harlem River. The objective of this EMF assessment was to determine, for the riverbed surface installation of the HVDC cables, whether electric and magnetic fields above the river surface will comply with the New York State Public Service Commission (NYSPSC) interim standards for electric and magnetic fields at utility right-of-way (ROW) edges. Magnetic fields were calculated at a height of 1 meter above the river surface for several representative water depths including minimum, average, and maximum depths. There will be no external electric fields outside the HVDC cable bundle, since electric fields associated with the voltage on the cables will be completely shielded by the metallic cable armoring and sheathing. Based on the magnetic field modeling results and

State of New York Licensed Professional Engineer
Logan Brant
088171
12-10-24

the lack of any external electric fields, B&B concludes that electric and magnetic fields above the Harlem River surface for the installation of the CHPE HVDC cables directly on the bed of the river will comply with the NYSPSC edge-of-ROW electric and magnetic field interim standards.

INTRODUCTION

The CHPE (Project) is being developed by Transmission Developer, Inc. USA Holdings LLC (TDI-USA). The power transmission project will deliver renewable electric power to New York from hydroelectric sources in Quebec, Canada, through a pair of nominal 5-inch diameter buried HVDC power cables. The buried cables will extend from the United States-Canada border to a converter station in Astoria, Queens. For the 6.2-mile segment of the Project through the Harlem River, the cable bundle will be installed directly on the riverbed (*i.e.*, unburied installation).

B&B was retained by TDI-USA to provide geotechnical engineering, thermal modeling, and electric and magnetic field (EMF) services for the segment within the Harlem River where the CHPE HVDC cables will be placed on top of the sediment at the bottom of the river (referred to below as the "riverbed installation" of the HVDC cables). This memorandum summarizes B&B's EMF assessment for the riverbed installation of the HVDC cables, as requested by the New York State Department of State (NYS DOS). Given the prior submission of a number of reports and memos that provide EMF calculations for a variety of different submarine cable installation cases and locations along the Project route (*e.g.*, TRC, 2010; Exponent, 2021), this EMF assessment was focused on determining whether electric and magnetic fields above the surface of the Harlem River will comply with the NYSPSC electric and magnetic field interim standards for utility ROW edges.

BACKGROUND ON ELECTRIC AND MAGNETIC FIELDS

During normal operation of the CHPE HVDC cables, electricity passing through the cables will generate DC magnetic fields (MFs) that will surround the area of the cables. In contrast to the time-varying magnetic fields generated by 60-hertz (Hz) alternating current (AC) power frequency transmission, steady (*i.e.*, static) DC magnetic fields with a frequency of 0 Hz are produced by HVDC power transmission. The voltage on the CHPE HVDC cables will also produce DC electric fields, but these electric fields will be completely shielded by the metallic cable armoring and sheathing and there will be no external electric fields outside the HVDC cable bundle that are associated with their voltage (CSA Ocean Sciences Inc. and Exponent, 2019). This overview on electric and magnetic fields, as well as the EMF assessment generally, is thus focused on DC magnetic fields.

MFs from both DC and AC currents are similarly expressed as magnetic flux density (referred to as the "magnetic field") in units of gauss (G) or milligauss (mG) (1 G = 1,000 mG).[1] For a given configuration of current-carrying conductors, the size of MFs produced in both cases are directly

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[1] Another unit for MF levels is the microtesla (μT) (1 μT = 10 mG).

proportional to the size of the current in the cables in exactly the same way, and both DC and AC MFs similarly decrease with distance from the conductors.

There are a number of common natural and anthropogenic sources of static MFs, including, most notably, the Earth's geomagnetic field. The Earth's static geomagnetic field, which is associated with DC currents flowing in the Earth's liquid core, as well as metallic crustal elements, is the largest source of DC MFs for both marine and terrestrial environments (Normandeau Associates, Inc., and Exponent, Inc., 2011). The intensity of the background geomagnetic field at the Earth's surface varies between about 300 mG near the equator to the highest values of ~700 mG near the south and north poles. In the area of the Harlem River, the Earth's MF has a magnitude of about 510 mG.[2] DC magnetic fields from submarine cables can combine with the Earth's DC geomagnetic field to somewhat alter the direction and/or magnitude of the total DC magnetic field near the cables.

Besides DC submarine cables, perturbations to the Earth's geomagnetic field in coastal environments can also be caused by various types of ferromagnetic sources, including shore-based structures, such as docks, jetties, and bridges; sunken ships; pipelines; and ferromagnetic mineral deposits (Normandeau Associates, Inc., and Exponent, Inc., 2011; CSA Ocean Sciences Inc. and Exponent, 2019). Normandeau Associates, Inc., and Exponent, Inc., (2011) reported that MF impacts nearby to these sources can be on the order of tens of mG, while CSA Ocean Sciences Inc. and Exponent (2019) noted that undersea sources of DC MFs, including steel ships and bridges, can create DC MFs up to 100 times greater than MFs from DC submarine cables.

Anthropogenic sources of static MFs are also common in everyday life, including consumer products that use DC transmission or permanent magnets (*e.g.*, electric cars, trains for DC rail systems, loudspeakers, microphones, and toy magnets), as well as medical devices (*e.g.*, magnetic resonance imaging [MRI]) (Driessen *et al.*, 2020). Driessen *et al.* (2020) reported the measurement of static MFs up to about 10,000 mG inside both hybrid technology cars and the driver's cabins of DC trains. Driessen *et al.* (2020) also discussed how MRI workers are commonly exposed to static MFs on the order of several million mG, with even higher potential exposures in research environments (*e.g.*, 20,890,000 mG for a 7 Tesla scanner). ICNIRP (2009) observed that scanned patients and MRI operators can have static MF exposures between 1,500,000 and 30,000,000 mG for systems encountered in MRI clinics. Other workers who may be exposed to elevated levels of static MFs include welders, aluminum production workers, and workers at chloralkali plants. Typical small permanent magnets, such as those used in magnet clips and magnetic attachments in bags, buttons, magnetic necklaces and bracelets, magnetic belts, and magnetic toys, can generate local static MFs that exceed 5,000 mG (ICNIRP, 2009).

There are no United States (US) Federal Standards limiting general public or occupational exposure to EMFs from HVDC transmission lines. Scientists have not reported any confirmable chronic health risks for the weak steady EMFs associated with HVDC power transmission; this is

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[2] https://www.ngdc.noaa.gov/geomag/calculators/magcalc.shtml?#igrfwmm

consistent with the fact that humans have lived for tens of thousands of years in the presence of the Earth's DC geomagnetic field, which is not known to adversely interact with biological processes or directly affect human health. As summarized in Table 1, international health and safety organizations have established health-based exposure guidelines for DC MFs applicable to both the general public and occupational populations based on preventing transient sensory effects including vertigo and nausea. In particular, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) has established a general public exposure guideline of 4,000,000 mG for static MFs (ICNIRP, 2009). This exposure guideline encompasses safety factors in order to be sufficiently protective of the general public. To avoid potential harm to individuals with implantable medical devices possibly containing ferromagnetic materials (*e.g.*, pacemakers and cardiac defibrillators), ICNIRP recommends that such individuals not be exposed to static MFs above 5,000 mG (ICNIRP, 2009). More recently, the International Committee on Electromagnetic Safety (ICES) within the Institute of Electrical and Electronics Engineers (IEEE) conducted an updated review of the scientific and medical research literature and retained its safety guidelines for general public exposure to static MFs of 1,180,000 mG and 3,530,000 mG for head and trunk exposure and limb exposure, respectively (IEEE, 2019).

Table 1. DC MF Guidelines Established by Health and Safety Organizations

Organization	MF Guideline
General Public	
International Commission on Non-Ionizing Radiation Protection (ICNIRP) (exposure to any part of the body)	4,000,000 mG[(a)]
Institute of Electrical and Electronics Engineers (IEEE) Standard C95.6	1,180,000 mG[(b)] 3,530,000 mG[(c)]
Occupational	
International Commission on Non-Ionizing Radiation Protection (ICNIRP)	20,000,000 mG[(d)] 80,000,000 mG[(e)]
American Conference of Governmental and Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs)	20,000,000 mG[(f)] 200,000,000 mG[(g)] 5,000 mG[(h)]

Notes:
DC = Direct Current; MF = Magnetic Field; kV/m = Kilovolts Per Meter; mG = Milligauss.
(a) Applies to exposures to any part of the body (ICNIRP, 2009).
(b) Applies to head and of trunk exposure (IEEE, 2019).
(c) Applies to exposure of limbs (IEEE, 2019).
(d) Applies to head and of trunk exposure (ICNIRP, 2009).
(e) Applies to exposure of limbs (ICNIRP, 2009).
(f) ACGIH TLV for general workplace whole body exposure (ACGIH, 2024).
(g) ACGIH TLV for general workplace limb exposure (ACGIH, 2024).
(h) ACGIH TLV for workers with implanted ferromagnetic or electronic medical devices (ACGIH, 2024).

NEW YORK STATE PUBLIC SERVICE COMMISSION MAGNETIC FIELD AND ELECTRIC FIELD INTERIM STANDARDS FOR RIGHT-OF-WAY EDGES

For 60-Hz AC electricity transmission, the NYSPSC has an edge-of-ROW MF interim standard of 200 mG and an edge-of-ROW EF interim standard of 1.6 kV/m (NYSPSC, 1990, 1978). As discussed briefly below, these edge-of-ROW interim standards were developed for 60-Hz AC electric and magnetic fields, but they have also been applied to static (0 Hz) DC magnetic fields (*e.g.*, TRC, 2010; Exponent, 2021). As defined in NYSPSC's "Statement of Interim Policy on Magnetic Fields of Major Electric Transmission Facilities," which was issued on September 11, 1990 (NYSPSC, 1990), the MF interim standard is to be applied to MFs at 1 meter above the ground surface for line loading conditions corresponding to winter normal conductor ratings. This interim standard is not health-based and is instead based on modeled average edge-of-ROW MFs for a large sample of 345 kV transmission lines in New York State for assumed line loading conditions at the winter normal conductor ratings (NYSPSC, 1990). Opinion 78-13 issued by NYSPSC on June 19, 1978 (NYSPSC, 1978), established the edge-of-ROW EF interim standard of 1.6 kV/m, and stated that it is applicable to a height of one meter above ground level and with the line at the rated voltage. Similar to the MF interim standard, this EF interim standard is also not health-based.

CHPE HVDC CABLE BUNDLE PROPERTIES

B&B modeled the CHPE HVDC cables using cable bundle specifications and electrical properties provided by TDI-USA. The geometry of the CHPE HVDC cable bundle was interpreted from Lankhorst (2024) (Figure 1). As illustrated in Figure 1, the HVDC cable bundle will consist of two single-core submarine cables – one positively charged and the other negatively charged – bundled together in a horizontal arrangement (*i.e.*, touching side-by-side during installation, with a separation distance of 138 mm for the conductor centers). The single-core cables will consist of a copper conductor that is surrounded by a number of different layers that include insulation, metal sheath, metal armor, and an outer serving consisting of two layers of black polypropylene yarn with the inner layer impregnated with bitumen (NKT HV Cables AB, 2022). As compared to the total external cable diameter of 138 mm, the conductors will have an outer diameter of 57.8 mm. The submarine cables will be encased by the UraGUARD Cable Protection System (CPS), which will have a nominal thickness of 25 mm. Under the installation conditions, the HVDC cables have a rated continuous current of 1,638 amps, which is representative of a maximum loading case consistent with the loading of an overhead transmission line at its winter normal conductor rating, as specified by NYSPSC for MF calculations in its interim policy (NYSPSC, 1990). Table 2 summarizes these cable dimensions and electrical properties used for the magnetic field modeling analysis.

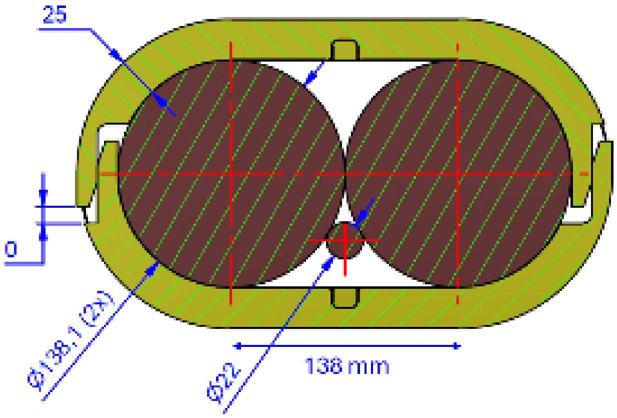

Figure 1. UraGUARD CPS Cross-Section (dimensions in mm) (Lankhorst, 2024). Note that the cross section does not show the different cable components discussed above. As discussed above and indicated in Table 2, the copper conductors will have a diameter of 57.8 mm, as compared to the total external cable diameter of 138 mm.

Table 2. Summary of CHPE HVDC Cable Bundle Specifications and Electrical Properties Used as Inputs to DC Magnetic Field Calculations

Cable Parameters	Value/Range	Source
Cable Dimensions and Electrical Properties		
External cable diameter	138.1 mm	NKT HV Cables AB (2022)
Conductor diameter	57.8 mm	NKT HV Cables AB (2022)
Nominal line voltage	±400 kV	NKT HV Cables AB (2022)
Rated continuous current under the installation conditions	1,638 amps	NKT HV Cables AB (2022)
UraGUARD Cable Protection System (CPS)[a]		
UraGUARD thickness	25 mm	Lankhorst (2024)
Horizontal Cable Bundle		
Horizontal conductor separation (center-to-center)	138.1 mm	Lankhorst (2024)

Notes:
CHPE: Champlain Hudson Power Express®
CPS: Cable Protection System
HVDC: High voltage direct current
(a) UraGUARD material properties and dimensions may change upon receipt of additional or updated information from Lankhorst.

MAGNETIC FIELD MODELING ANALYSIS

The "EMF and Corona Effects Analysis" calculation program, designed by the Bonneville Power Administration (BPA) of the US Department of Energy, was used to calculate MFs above the Harlem River surface from the CHPE HVDC cable bundle. The calculations in this program are based on Maxwell's equations, which apply the laws of physics as related to electricity and magnetism, and magnetic fields are calculated *via* the application of the Biot-Savart law. Modeled magnetic fields using this program are both precise and accurate for the input data used. The results of the model have been checked against results from other software (*e.g.*, Southern California Edison's FIELDS program), confirming that the implementation of the laws of physics in this program is consistent. Modeled DC magnetic field levels from the BPA program are reported as the root mean square (RMS) values of the real "maximum" rotating magnetic fields, *i.e.*, the RMS values of the semi-major axis magnitudes of the field ellipse that are known as $B_{Maximum}$ or B_{Max}. These results are thus consistent with the NYSPSC interim policy statement that specifically refer to the calculation of the "maximum rms flux density" magnetic fields (NYSPSC, 1990).

Consistent with prior MF modeling analyses (*e.g.*, TRC, 2010; Exponent, 2021), DC magnetic fields were predicted at a height of 1 meter (3.28 feet) above the water surface of the Harlem River for a cross section across the submarine HVDC cable bundle. DC magnetic fields were modeled as a function of horizontal distance from the centerline of the horizontal cable bundle, perpendicular to the direction of current flow, for 1-foot intervals out to 50 feet on either side of the cable bundle centerline. Because magnetic field levels above the river will depend on the distance from the cable bundle, modeling was conducted for three different representative water depths− an average water depth of 25 feet, a minimum water depth of 14 feet, and a maximum water depth of 27 feet. As discussed previously, conductor loadings equal to the rated continuous current under the installation conditions were used, since these maximum loadings are consistent with the loading of an overhead transmission line at its winter normal conductor rating, as specified by NYSPSC for MF calculations in its interim policy statement (NYSPSC, 1990). Comparisons with the NYSPSC edge-of-ROW MF interim standard were conservatively made for a short distance of 10 feet (3 meters) from the centerline of the cable bundle due to the lack of a defined ROW width for the submarine route segment within the Harlem River.

Table 3 below provides magnetic field modeling results for selected locations along the cross section across the cable bundle, including directly above the centerline of the cable bundle where the maximum modeled MF levels were observed, and at distances of ±10 feet, ±25 feet, and ±50 feet from the cable bundle centerline; while Appendix A provides a complete summary of MF modeling results for one-foot intervals along the 100-foot cross sections that were modeled. Figure 2 shows the MF modeling results in graphical form, further illustrating how the model-predicted MF levels vary with water depth, and how they rapidly decrease with increased distance from the cable centerlines. As indicated in the table and figure, for each of the representative water depths, model-predicted MFs at ±10 feet were well below the NYSPSC edge-of-ROW MF interim standard of 200 mG. In addition, all modeled MF levels above the Harlem River for the HVDC cable bundle were well below the Earth’s geomagnetic field of approximately 510 mG.

Table 3. Calculated Direct Current (DC) Magnetic Field (MF) Levels at 3.28 Feet (1 Meter) Above the Water Surface in the Harlem River for HVDC Cable Installation on the Riverbed

River Depth	**Calculated DC Magnetic Field Levels (mG) at Horizontal Distances from the Cable Bundle Centerline**						
	-50 ft	**-25 ft**	**-10 ft**	**0 ft (Max)**	**+10 ft**	**+25 ft**	**+50 ft**
Minimum (14 ft)	1.8	5.4	12.7	17.2	12.7	5.4	1.8
Average (25 ft)	1.5	3.5	5.6	6.3	5.6	3.5	1.5
Maximum (27 ft)	1.5	3.2	5.0	5.5	5.0	3.2	1.5

Notes:
DC: Direct current
ft: Feet
HVDC: High voltage direct current
mG: Milligauss
max: Maximum

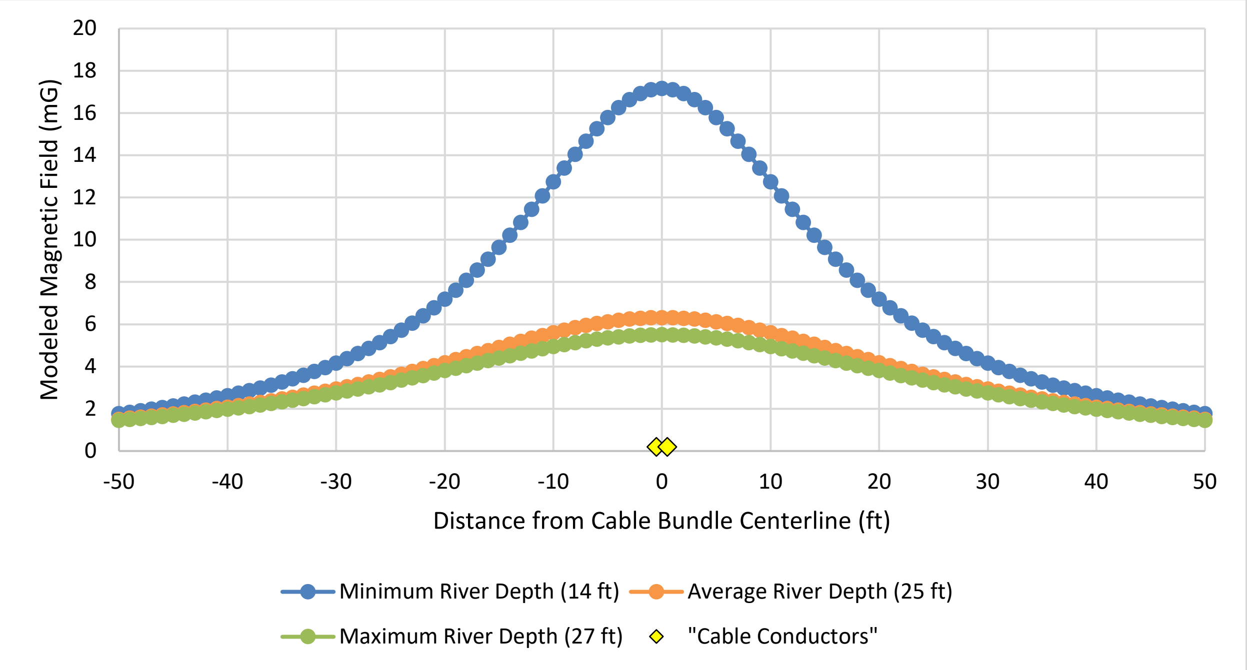

Figure 2. Calculated Direct Current (DC) Magnetic Field (MF) Levels at 3.28 Feet (1 Meter) Above the Water Surface in the Harlem River for HVDC Cable Installation on the Riverbed. HVDC = High Voltage Direct Current; mG = Milligauss; ft = Feet. It is assumed that the horizontal cable bundle is installed on the riverbed and covered by the UraGUARD Cable System. Calculated MFs are shown for representative river depths of 14 ft (minimum), 25 ft (average), and 27 ft (maximum). Conductor locations on the graph are not to scale and are provided to show relative locations.

CONCLUSIONS

Based on the magnetic field modeling results and the lack of any external electric fields, B&B concluded that electric and magnetic fields above the Harlem River surface for the installation of the CHPE HVDC cables directly on the riverbed will comply with the NYSPSC edge-of-ROW electric and magnetic field interim standards.

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Attachment A

Summary of Calculated DC Magnetic Fields

Table A.1 Tabular Summary of Calculated DC Magnetic Field (MF) Levels at 3.28 Feet (1 Meter) Above the Water Surface in the Harlem River for HVDC Cable Installation on the Riverbed and Representative Water Depths

Distance from Centerline (ft)	Magnetic Field (mG) at 3.28 Feet (1 Meter) Above the Water Surface		
	Minimum Water Depth (14 ft)	Average Water Depth (25 ft)	Maximum Water Depth (27 ft)
-50	1.77	1.51	1.45
-49	1.84	1.55	1.50
-48	1.91	1.60	1.54
-47	1.98	1.65	1.59
-46	2.06	1.71	1.64
-45	2.14	1.76	1.69
-44	2.22	1.82	1.74
-43	2.31	1.88	1.80
-42	2.41	1.94	1.86
-41	2.51	2.01	1.92
-40	2.62	2.07	1.98
-39	2.73	2.15	2.04
-38	2.85	2.22	2.11
-37	2.98	2.30	2.18
-36	3.12	2.38	2.25
-35	3.27	2.46	2.33
-34	3.42	2.55	2.41
-33	3.59	2.64	2.49
-32	3.77	2.74	2.57
-31	3.96	2.84	2.66
-30	4.16	2.94	2.75
-29	4.38	3.04	2.84
-28	4.61	3.16	2.94
-27	4.86	3.27	3.04
-26	5.13	3.39	3.14
-25	5.41	3.51	3.25
-24	5.72	3.64	3.35
-23	6.05	3.77	3.46
-22	6.40	3.90	3.58
-21	6.78	4.04	3.69
-20	7.18	4.18	3.81
-19	7.62	4.32	3.93
-18	8.08	4.47	4.04

Distance from Centerline (ft)	**Magnetic Field (mG) at 3.28 Feet (1 Meter) Above the Water Surface**		
	Minimum Water Depth (14 ft)	**Average Water Depth (25 ft)**	**Maximum Water Depth (27 ft)**
-17	8.57	4.61	4.16
-16	9.09	4.76	4.28
-15	9.64	4.91	4.40
-14	10.21	5.05	4.52
-13	10.82	5.20	4.63
-12	11.44	5.34	4.74
-11	12.09	5.47	4.85
-10	12.74	5.60	4.95
-9	13.39	5.73	5.05
-8	14.04	5.84	5.14
-7	14.67	5.95	5.22
-6	15.25	6.04	5.29
-5	15.79	6.12	5.35
-4	16.26	6.19	5.41
-3	16.64	6.25	5.45
-2	16.93	6.29	5.48
-1	17.10	6.31	5.50
0	17.16	6.32	5.50
1	17.10	6.31	5.50
2	16.93	6.29	5.48
3	16.64	6.25	5.45
4	16.26	6.19	5.41
5	15.79	6.12	5.35
6	15.25	6.04	5.29
7	14.67	5.95	5.22
8	14.04	5.84	5.14
9	13.39	5.73	5.05
10	12.74	5.60	4.95
11	12.09	5.47	4.85
12	11.44	5.34	4.74
13	10.82	5.20	4.63
14	10.21	5.05	4.52
15	9.64	4.91	4.40
16	9.09	4.76	4.28
17	8.57	4.61	4.16
18	8.08	4.47	4.04
19	7.62	4.32	3.93
20	7.18	4.18	3.81

Distance from Centerline (ft)	Magnetic Field (mG) at 3.28 Feet (1 Meter) Above the Water Surface		
	Minimum Water Depth (14 ft)	Average Water Depth (25 ft)	Maximum Water Depth (27 ft)
21	6.78	4.04	3.69
22	6.40	3.90	3.58
23	6.05	3.77	3.46
24	5.72	3.64	3.35
25	5.41	3.51	3.25
26	5.13	3.39	3.14
27	4.86	3.27	3.04
28	4.61	3.16	2.94
29	4.38	3.04	2.84
30	4.16	2.94	2.75
31	3.96	2.84	2.66
32	3.77	2.74	2.57
33	3.59	2.64	2.49
34	3.42	2.55	2.41
35	3.27	2.46	2.33
36	3.12	2.38	2.25
37	2.98	2.30	2.18
38	2.85	2.22	2.11
39	2.73	2.15	2.04
40	2.62	2.07	1.98
41	2.51	2.01	1.92
42	2.41	1.94	1.86
43	2.31	1.88	1.80
44	2.22	1.82	1.74
45	2.14	1.76	1.69
46	2.06	1.71	1.64
47	1.98	1.65	1.59
48	1.91	1.60	1.54
49	1.84	1.55	1.50
50	1.77	1.51	1.45