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*Electrical Engineering and Computer
Science Practice*

Post-Construction EMF Measurements:

**Road Crossings of the
Sudbury to Hudson
Transmission Line in
Sudbury**

Post-Construction EMF Measurements:

Road Crossings of the Sudbury to Hudson Transmission Line in Sudbury, MA

Prepared for:

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Limitations

At the request of Eversource Energy (“Eversource”), Exponent measured electric and magnetic field levels at four road crossings in the town of Sudbury, MA after the construction of a new 115-kV transmission line between the Sudbury Substation in Sudbury, MA and the Hudson Light and Power Substation in Hudson, MA. This report summarizes work performed to date and presents the findings resulting from that work. Eversource has confirmed to Exponent that the data contained herein are not subject to Critical Energy Infrastructure Information restrictions. Although Exponent has exercised usual and customary care in the conduct of this analysis, the responsibility for the design and operation of the project remains fully with the client.

The findings presented herein are made to a reasonable degree of engineering and scientific certainty. Exponent reserves the right to supplement this report and to expand or modify opinions based on review of additional material as it becomes available, through any additional work, or review of additional work performed by others.

The scope of services performed during this investigation may not adequately address the needs of other users of this report, and any re-use of this report or its findings, conclusions, or recommendations presented herein for other than permitting of the project are at the sole risk of the user. The opinions and comments formulated during this assessment are based on observations and information available at the time of the investigation. No guarantee or warranty as to future life or performance of any reviewed condition is expressed or implied.

Executive Summary

The Sudbury to Hudson Transmission Line Reliability Project involved the construction of a new underground 115-kilovolt (kV) transmission line between Eversource's Sudbury Substation in Sudbury, and the Hudson Light and Power Substation in Hudson. The Project included approximately 9 miles of underground transmission line, including approximately 7.6 miles to be constructed within an existing Massachusetts Bay Transportation Authority right-of-way and 1.4 miles within city streets.

After completion and energization of the Project, Eversource requested that Exponent measure the levels of 60-Hertz electric and magnetic field (EMF) at locations where the new transmission line crosses public roads in the town of Sudbury. In addition to field measurements, Eversource requested that Exponent develop an "as-measured" model to calculate the magnetic field levels at 1 meter above ground for direct comparison with selected measurements.

Measurements were performed between approximately 10:30 AM and 3:30 PM EDT on August 26, 2025, and between approximately 12:00 PM and 4:00 PM EDT on August 28, 2025. Electric field levels were found to be near zero (< 0.1 kilovolts per meter (kV/m)) at all measurement locations, while the highest magnetic field level was measured to be 22 milligauss (mG). The "as-measured" model calculations were performed for a representative example road crossing at Peakham Road, accounting for both the as-built burial depth of the duct bank at that location and the loading on the transmission line at the time of measurements. The calculated magnetic-field levels from this model matched well with measured data.

All measured EMF levels were far below the reference levels published by the International Commission on Non-Ionizing Radiation Protection and the International Committee on Electromagnetic Safety. The reference levels for exposure of the general public published by those organizations are 2,000 mG and 9,040 mG, respectively for magnetic fields and 4.2 kV/m and 5 kV/m, respectively for electric fields.

Introduction

Background

The Sudbury to Hudson Transmission Line Reliability Project (Project) involved the construction of a new underground 115-kilovolt (kV) transmission line between Eversource's Sudbury Substation in Sudbury, and the Hudson Light and Power Substation in Hudson. The Project includes approximately 9 miles of underground transmission line including approximately 7.6 miles constructed within an existing Massachusetts Bay Transportation Authority (MBTA) right-of-way (ROW) and 1.4 miles within city streets.

Prior to the construction of the project, Eversource requested that Exponent measure the levels of 60-Hertz electric and magnetic fields (EMF) at locations where the proposed Project crosses public roads in the town of Sudbury. These measurements, taken on August 20, 2021, were meant to characterize the existing EMF levels at these locations and were previously reported in the report entitled "EMF Measurements: Road Crossings of the Sudbury to Hudson Transmission Line in Sudbury, MA, dated March 18, 2022. The magnetic field was measured to be less than 3.7 mG and electric fields were measured to be less than 0.1 kV/m. These EMF were primarily attributed to overhead distribution lines at the road crossings.

After construction and energization of the underground transmission line, Eversource requested that Exponent measure the levels of 60-Hertz EMF at the same locations as the pre-construction measurements. Two sets of post-construction measurements were taken, the first on August 26, 2025, and the second on August 28, 2025. In addition to field measurements, Eversource requested that Exponent develop an "as-measured" model incorporating the configuration and burial depth of the transmission line at the location of measurements as well as the loading of the transmission line at the time of measurements. This model was used to compare directly with magnetic-field measurements, recorded under the same conditions in order to evaluate the accuracy and efficacy of the modeling approach used in the permitting of the project.

Technical Background

All things connected to our electrical system—power lines; wiring in our homes, businesses, and schools; and all electric appliances and machines—are sources of electric and magnetic fields. In North America, most electricity is transmitted as alternating current (AC) at a frequency of 60 cycles per second measured in Hertz (Hz) (i.e., 60 Hz). The electric and magnetic fields from these AC sources are commonly referred to as power-frequency or extremely low frequency EMF.

Electric Fields

Electric fields from transmission and distribution lines result from the voltage on the conductors. Electric fields are measured in units of volts per meter (V/m) and for higher fields, in kilovolts per meter (kV/m), where 1,000 V/m is equal to 1 kV/m. In general, the level of an electric field diminishes with increasing distance from the source. Conducting objects such as walls, fences, and trees and the earth easily block electric fields. Thus, underground transmission lines (including the Sudbury – Hudson transmission line) are not a source of above-ground electric fields. Existing electric field sources include overhead distribution lines, but these contribute very little to electric fields indoors where the major sources are appliances, equipment, and machines within homes, offices, and factories.

Magnetic Fields

As mentioned above, magnetic fields are produced by any source that generates, transmits, or uses electricity. Electricity travels as current from distant generating sources on high-voltage transmission lines to substations, then on to local distribution lines, and finally to our homes and workplaces for consumption. The strength of a magnetic field is expressed as magnetic flux density in units called gauss (G), or in milligauss (mG), where 1 G = 1,000 mG. In general, the strength of a magnetic field increases as the current increases, but the strength also depends on characteristics of the source—in the case of transmission lines, this includes the arrangement and separation of the conductors. Magnetic fields are not easily blocked by most common objects.

Like electric fields, the strength of magnetic fields diminishes with increasing distance from the source. Also, since the strength of magnetic fields associated with the transmission system varies depending on load conditions (i.e., the amount of current flowing in a conductor), the strength of magnetic fields from a particular source (such as transmission lines, distribution lines, and substation equipment) typically changes with time as the demand for electricity varies.

EMF Guidance

There are no federal standards for 60-Hz EMF attributable to utility infrastructure (or other sources). Similarly, the majority of states also do not have regulations applicable to 60-Hz EMF attributable to transmission or distribution lines or related infrastructure. In Massachusetts, the Massachusetts Energy Facilities Siting Board (EFSB) previously deemed magnetic-field levels of 85 mG at the edge of transmission line ROWs to be acceptable in the licensing of 345-kV transmission line facilities (Massachusetts Electric Company, 12 DOMSC 119, 228-242, 1985). More recently, the EFSB has assessed 60-Hz EMF levels from transmission lines on a case-by-case basis. In particular, the assessments focus on practical, no cost or low-cost options to reduce magnetic fields along transmission line ROWs, a practice consistent with the recommendations of the World Health Organization (WHO, 2007).

Levels of EMF are typically compared to standards and guidelines developed by national and international scientific and health agencies. Two international agencies that have published limits of exposure to EMF include the International Committee on Electromagnetic Safety (ICES) and the International Commission on Non-Ionizing Radiation Protection (ICNIRP). The assessment levels (reference levels) set by these organizations are summarized Table 1 below.

The reference values listed in Table 1 are commonly referenced as criteria for the evaluation of potential line designs and their potential effects on the electrical environment around transmission lines. These are not exposure limits, and exposures to higher EMF levels are allowed if the underlying basic restrictions on fields in the body are not exceeded.

Table 1. Reference levels for whole body exposure to 60-Hz fields: general public.

Organization	Magnetic Fields	Electric Fields
ICNIRP	2,000 mG	4.2 kV/m
ICES	9,040 mG	5 kV/m 10 kV/m*

*This is an exception within transmission line ROWs.

Measurements

Electric and magnetic-field measurements were taken on August 26, 2025 between approximately 10:30 AM and 3:30 PM EDT and repeated on August 28, 2025 between approximately 12:00 PM and 4:00 PM EDT. The temperature varied between approximately 70 and 76 degrees Fahrenheit during the time period of measurements taken on August 26th and approximately 74 and 76 degrees Fahrenheit during the time period of measurements taken on August 28th. Measurements were taken along transecting paths at four sites where the underground transmission line crosses roads in Sudbury: Dutton Road, Peakham Road, Horse Pond Road, and Union Avenue. An overview of these sites as it relates to the transmission line is shown in Figure 1.

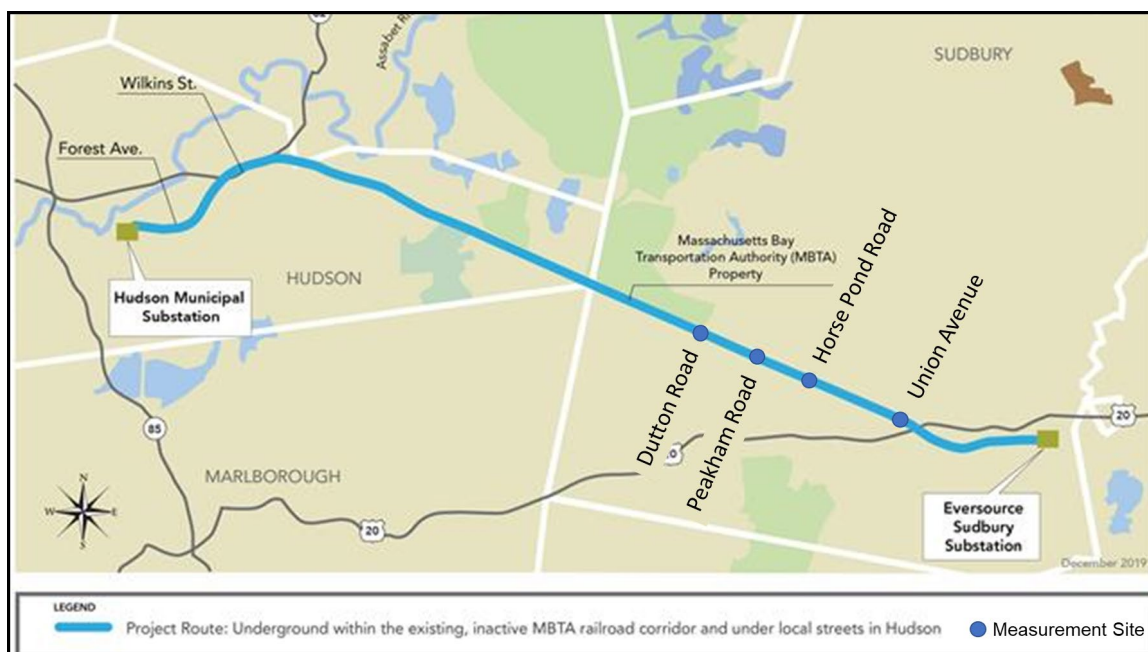


Figure 1. Sudbury to Hudson project route map with locations of road crossings in Sudbury.

At each of these road crossings, the 60-Hz EMF levels from all existing sources were measured in transects along both sides of the road, approximately perpendicular to the path of the transmission line. The strength of the magnetic field was measured in units of mG with a data-logging EMDEX II,¹ 3-axis magnetic-field meter with survey wheel (the calibration certificate

¹ Measurement equipment was manufactured by Energetech Consultants, Cupertino, California.

for the EMDEX II is included in Appendix A). This meter recorded the total (resultant) root-mean-square magnetic field and the magnetic field along the x, y, and z axes. This meter meets the IEEE instrumentation standard for obtaining accurate field measurements at power-line frequencies and measurements were performed in general accordance with industry standards.² Although the underground transmission line is not expected to be a source of above-ground electric fields, the electric field was nevertheless measured. Electric fields were measured in units of kV/m with a single-axis sensor accessory for the EMDEX II meter. The single-axis sensor was aligned sequentially along vertical, transverse, and longitudinal axes to capture the value of the electric-field vector along each axis.

At the location of the four road crossings there are one or more existing distribution lines running along the side of the road. These distribution lines (along with the electrical service they provide to nearby customers) contributed to the measured EMF levels at the road crossings.

- Dutton Road: one distribution line (342-H8) runs along the west side of the road.
- Peakham Road: one distribution line (342-H2) runs along the east side of the road.
- Horse Pond Road: two distribution lines (342-H2 and 342-H8) run along the west side of the road.
- Union Avenue: two distribution lines (342-H2 and 342-H5) run along the east side of the road.

Aerial maps of the measurement paths at each road crossing are provided in Figure 2 to Figure 5.

² Institute of Electrical and Electronics Engineers (IEEE). Standard Procedures for Measurement of Power Frequency Electric and Magnetic Fields from AC Power Lines (ANSI/IEEE Std. 644- 2019). New York: IEEE, 2019.

Institute of Electrical and Electronics Engineers (IEEE). IEEE Recommended Practice for Instrumentation: Specifications for Magnetic Flux Density and Electric Field Strength Meters—10 Hz to 3 kHz. New York: IEEE: Standard 1308-2023.



Figure 2. Approximate measurement paths along Dutton Road.



Figure 3. Approximate measurement paths along Peakham Road.

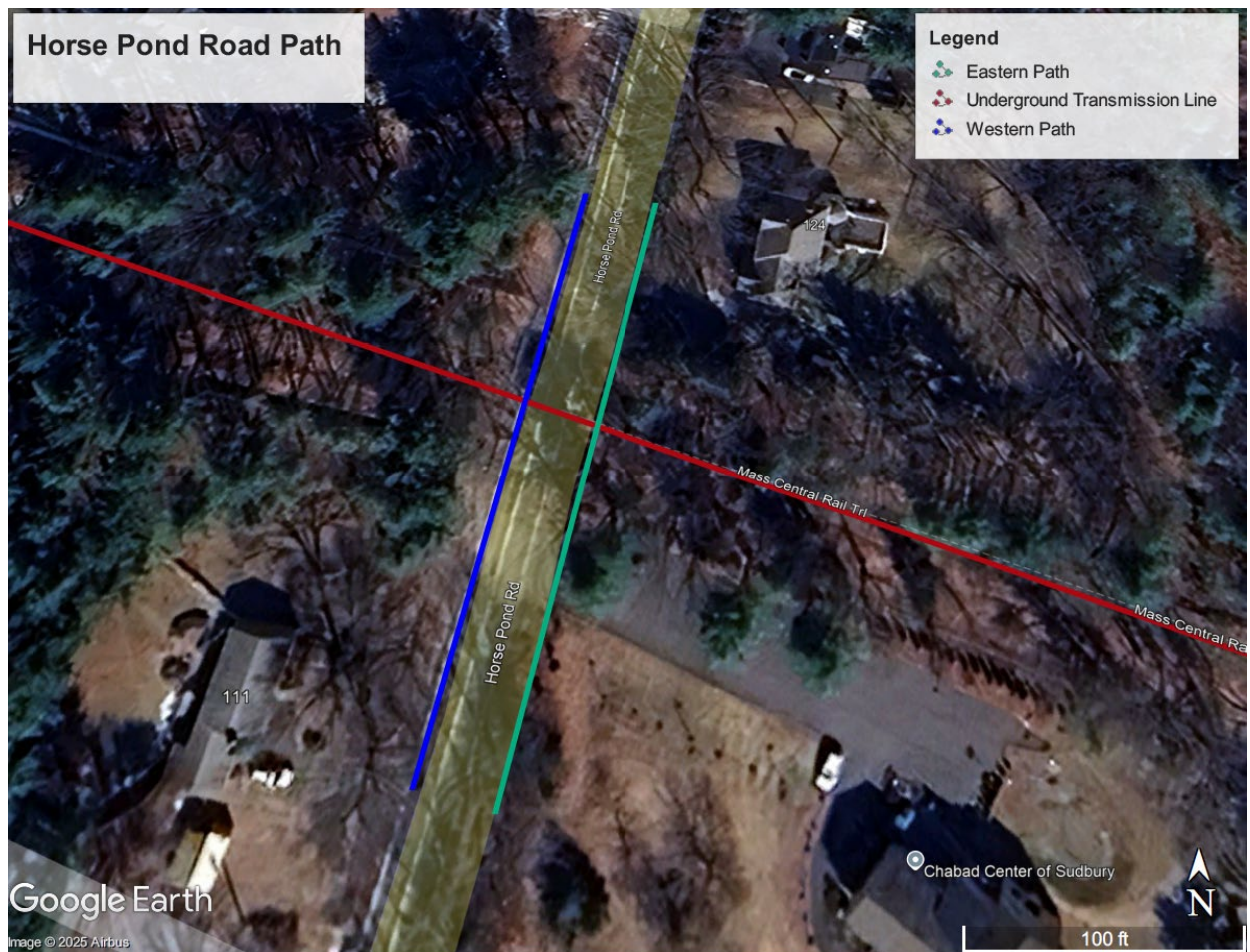


Figure 4. Approximate measurement paths along Horse Pond Road.



Figure 5. Approximate measurement paths along Union Avenue.

Results and Discussion

The magnetic-field levels measured along the transects of each road crossing (Figure 2 to Figure 5) are shown graphically in Figure 6 to Figure 13 and summarized in Table 2 and Table 3. Each measurement shows a clear peak in the magnetic field above the underground Sudbury – Hudson transmission line. The maximum magnetic field measured at any of the sites on either day was 22 mG.

The burial depth of the underground transmission line differs among the different road crossings and also between the eastern and western sides of each individual road crossing, resulting in differences in measured values on different sides of the street for each crossing. For example, on Union Ave, the approximate burial depth changes from around 7 ft on the west side to 5 ft on the east side, resulting in slightly higher measured magnetic field values on the east side compared to the west side. All measurements were performed approximately parallel to the existing overhead distribution lines running along the east or west sides of the road. Thus, the measured magnetic-field levels include contributions both from the underground Sudbury – Hudson transmission line as well as the overhead distribution lines. All measured electric-field levels were <0.1 kV/m, consistent with the very low levels expected in the vicinity of overhead distribution lines. All measured magnetic-field levels were low, far below the ICNIRP reference level of 2,000 mG and the ICES exposure reference level of 9,040 mG.

Table 2. Summary of magnetic fields measured at road crossings in Sudbury on August 26.

Location	Side of Road	Magnetic Field (mG) on August 26						
		-15 ft	-10 ft	-5 ft	Max	5 ft	10 ft	15 ft
Dutton Road	West	4.6	6.7	8.9	10	9.4	6.6	4.6
	East	4.4	7.4	12	15	13	8.8	5.7
Peakham Road	West	5.6	9.1	16	22	18	8.7	5.1
	East	4.6	6.9	10	12	10	7.4	5.0
Horse Pond Road	West	4.8	8.0	13	16	12	7.4	4.6
	East	4.4	6.3	9.4	12	9.7	6.7	4.6
Union Avenue	West	4.2	6.5	9.6	11	9.1	5.9	3.9
	East	4.1	6.6	11	16	12	7.6	4.7

Table 3. Summary of magnetic fields measured at road crossings in Sudbury on August 28.

Location	Side of Road	Magnetic Field (mG) on August 28						
		-15 ft	-10 ft	-5 ft	Max	5 ft	10 ft	15 ft
Dutton Road	West	1.7	2.1	2.6	2.9	2.6	2.1	1.7
	East	1.3	1.9	3.0	3.7	2.9	1.9	1.4
Peakham Road	West	1.4	2.4	4.2	6.2	5.1	2.7	1.5
	East	1.6	2.2	3.0	4.2	3.9	2.9	2.1
Horse Pond Road	West	2.6	3.7	6.2	8.1	6.4	3.7	2.3
	East	2.8	3.9	5.8	6.9	6.0	3.8	2.6
Union Avenue	West	2.0	3.1	4.9	6.0	5.1	3.6	2.5
	East	3.1	4.6	7.1	8.9	6.7	4.1	2.6

Additionally, magnetic-field levels scale linearly with the loading on the transmission line and magnetic-field levels measured on August 26 were higher than those recorded on August 28. This observation is expected since loading on the transmission line was higher on August 26 compared to August 28, as shown in Table 4. This table shows the minimum, average and maximum loading (in units of Amperes [A]) on the transmission line at the time of measurements on August 26, and 28 as compared to the average and peak loading used in permitting of the project.³ Loading on the transmission line during measurements on August 26 was higher than in pre-construction calculations, while the loading on the transmission line during measurements on August 28 was lower than in pre-construction calculations. Despite higher loading at the time of measurements, the maximum measured magnetic-field (22 mG) was lower than the 24 mG calculated during pre-construction modeling for average loading. The greater burial depth at the location of measurements (>4.6 ft) is deeper than that used for pre-construction modeling (39 inches to the top-most conductor), explaining why a lower magnetic-field level was measured despite higher loading at the time of measurements.

³ “Sudbury to Hudson Transmission Line Reliability Project Electric Field and Magnetic Field Assessment,” dated March 27, 2017

Table 4 Minimum, average and maximum loading at each location during the time of measurements as compared to the average (128 A) and peak (461 A) loading used in the pre-construction filing.

Road Crossing	Date and Time	Loading at Time of Measurements (A)		
		Minimum	Maximum	Average
Dutton Road	8/26 2:47PM – 3:01PM	154	169	161
	8/28 3:10PM – 3:24PM	64	68	66
Peakham Road	8/26 1:43PM – 1:57PM	154	171	162
	8/28 2:08PM – 2:21PM	70	78	74
Horse Pond Road	8/26 12:02PM – 12:20PM	152	161	156
	8/28 1:10PM – 1:25PM	79	97	89
Union Avenue	8/26 10:45AM – 10:58AM	146	157	152
	8/28 12:06PM – 12:20PM	82	92	85

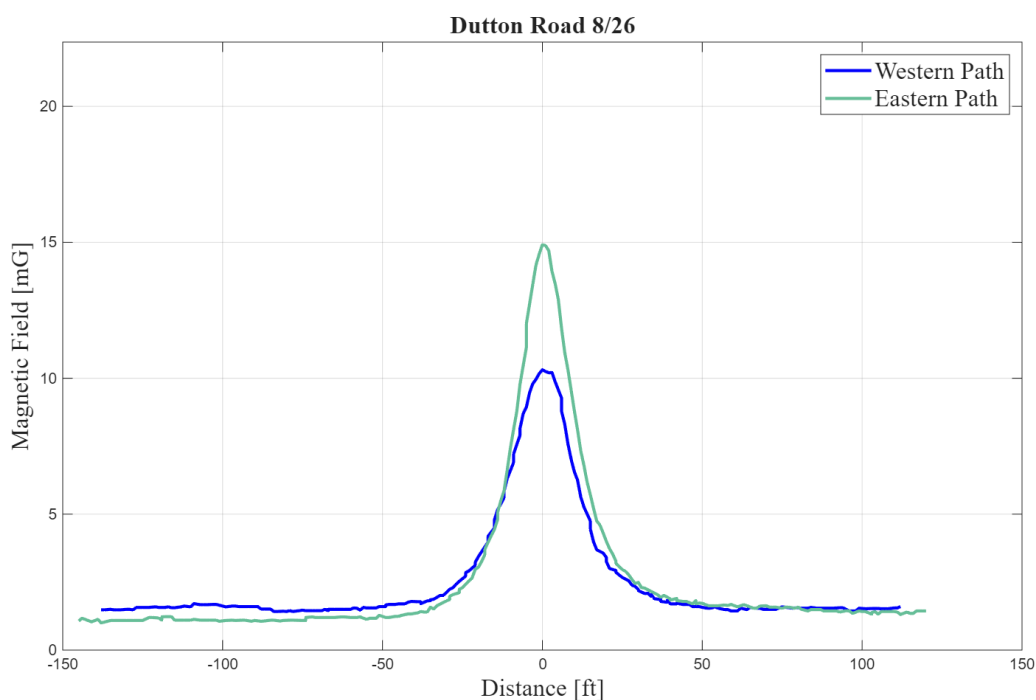


Figure 6. Magnetic field (mG) measured along Dutton Road on August 26.

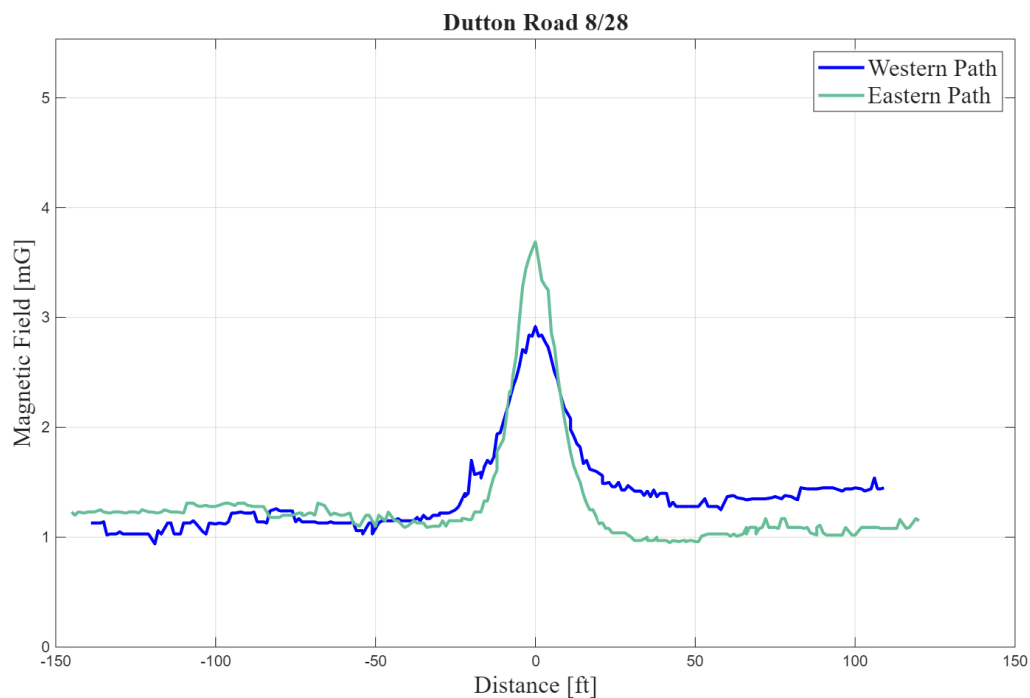


Figure 7. Magnetic field (mG) measured along Dutton Road on August 28.

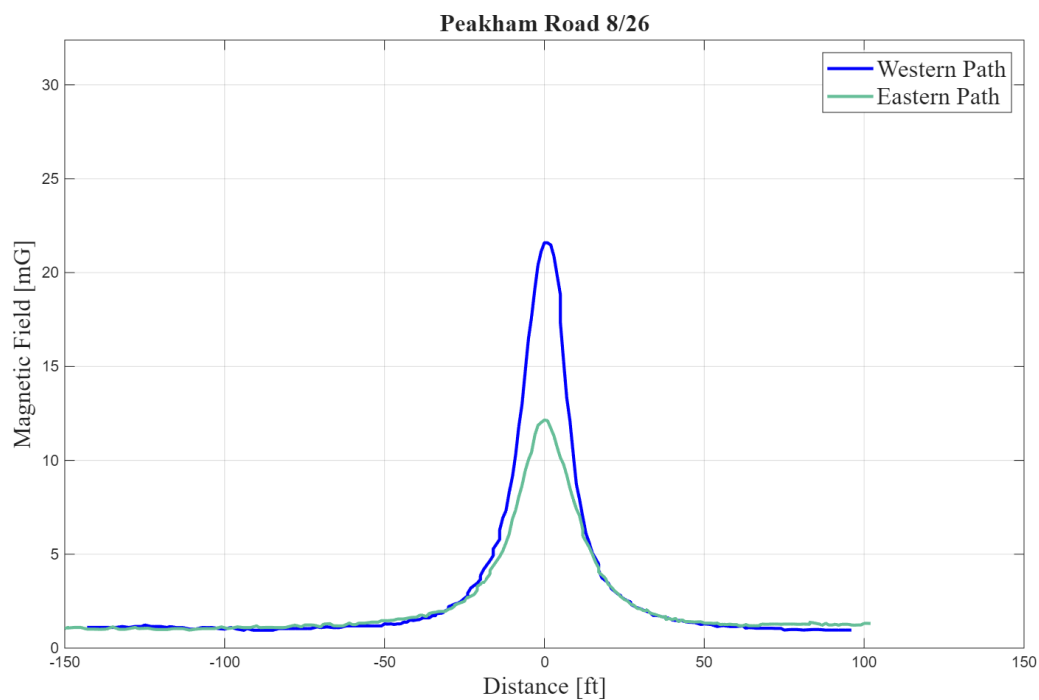


Figure 8. Magnetic field (mG) measured along Peakham Road on August 26.

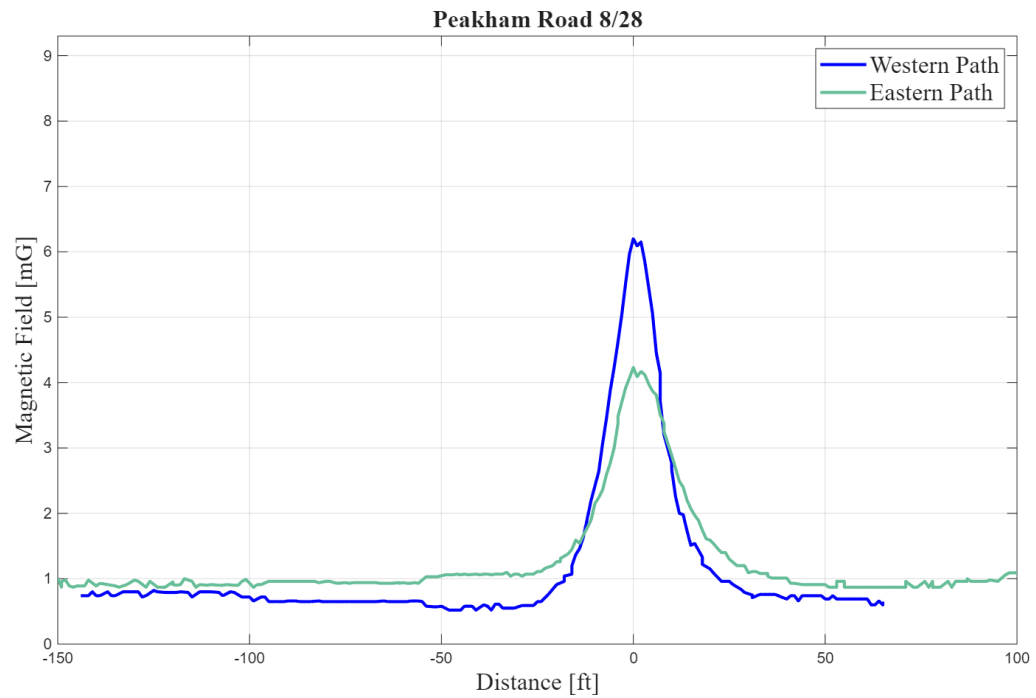


Figure 9 Magnetic field (mG) measured along Peakham Road on August 28.

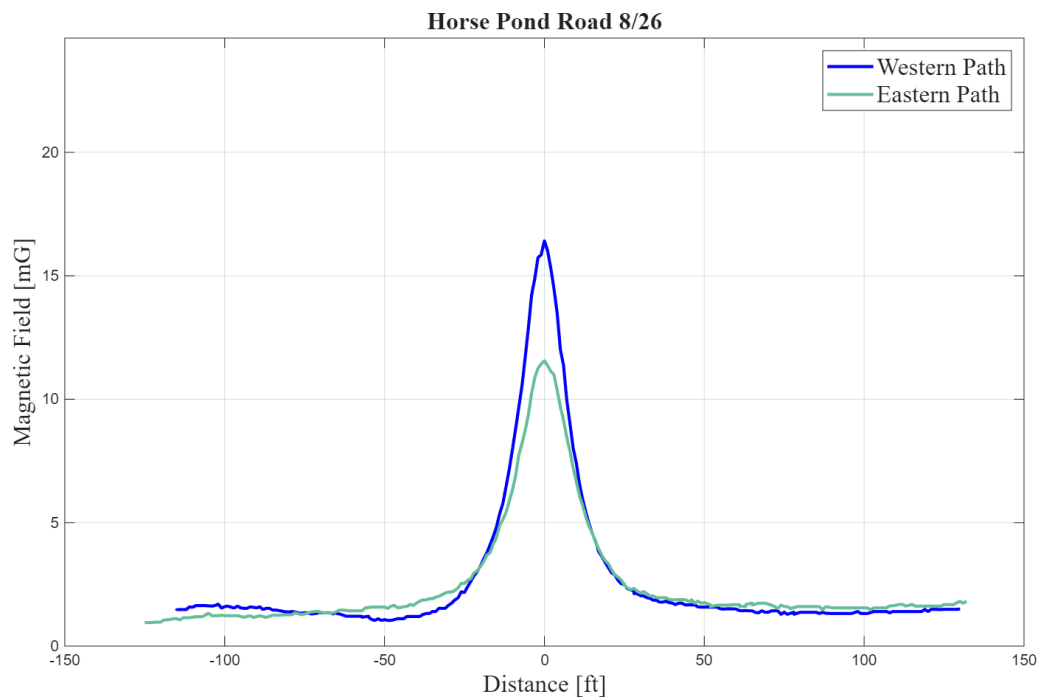


Figure 10. Magnetic field (mG) measured along Horse Pond Road on August 26.

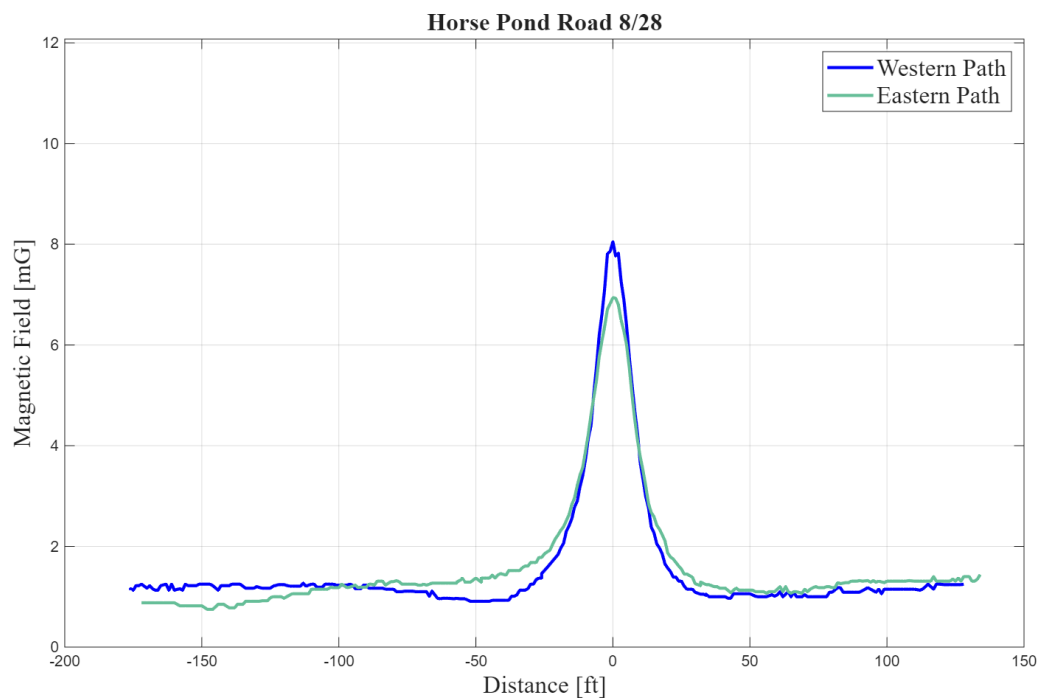


Figure 11 Magnetic field (mG) measured along Horse Pond Road on August 28.

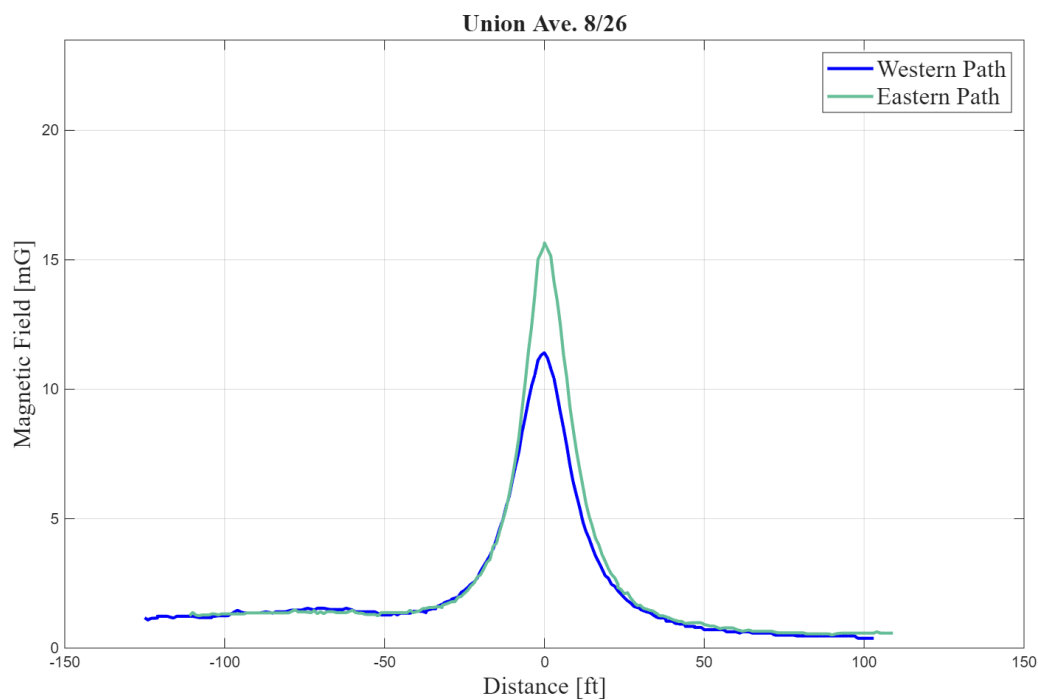


Figure 12. Magnetic field (mG) measured along Union Avenue on August 26.

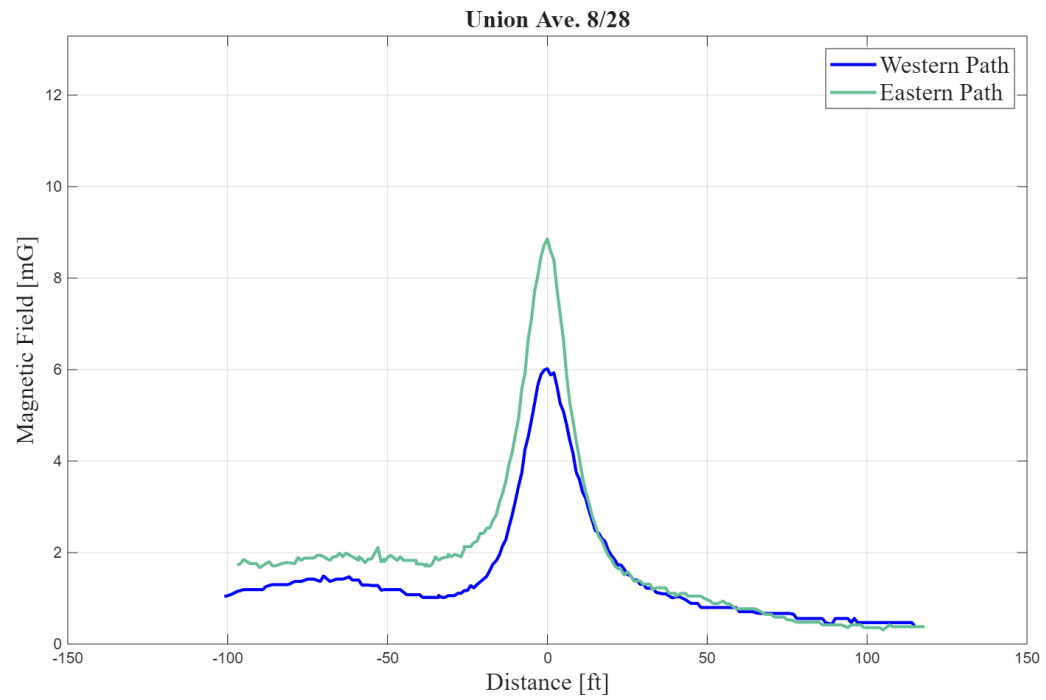


Figure 13. Magnetic field (mG) measured along Union Avenue on August 28.

Comparison of Model to Measurements

Models can be used to predict the magnetic fields, due to an underground transmission line, under different loading conditions and at different locations along the transmission line without the need for measurements in the field. To confirm the accuracy of such models, they can be compared to field measurements accounting for significant factors that may affect the calculated fields. As such, Exponent developed a model which utilizes specific factors at the time and location of the measurements including:

- 1) the as-built duct bank configuration and geometry, including locations of the phase conductors and the ground continuity conductor (GCC),
- 2) the as-built burial depth of the duct bank,
- 3) power transmission data at the time of the measurement in order to calculate the current flowing through the transmission line.

The calculations were performed using COMSOL MultiPhysics Version 6.2, which uses finite-element methods to solve the time-harmonic Maxwell-Ampere's Law that determines the magnetic field. Note that this model only accounts for magnetic fields generated by the transmission line while the measurement will contain contributions from other sources, such as overhead distribution lines. To minimize these confounding factors, the west side of the Peakham Road was chosen for the comparison between the model and the measurements on August 28, as shown in Figure 14.

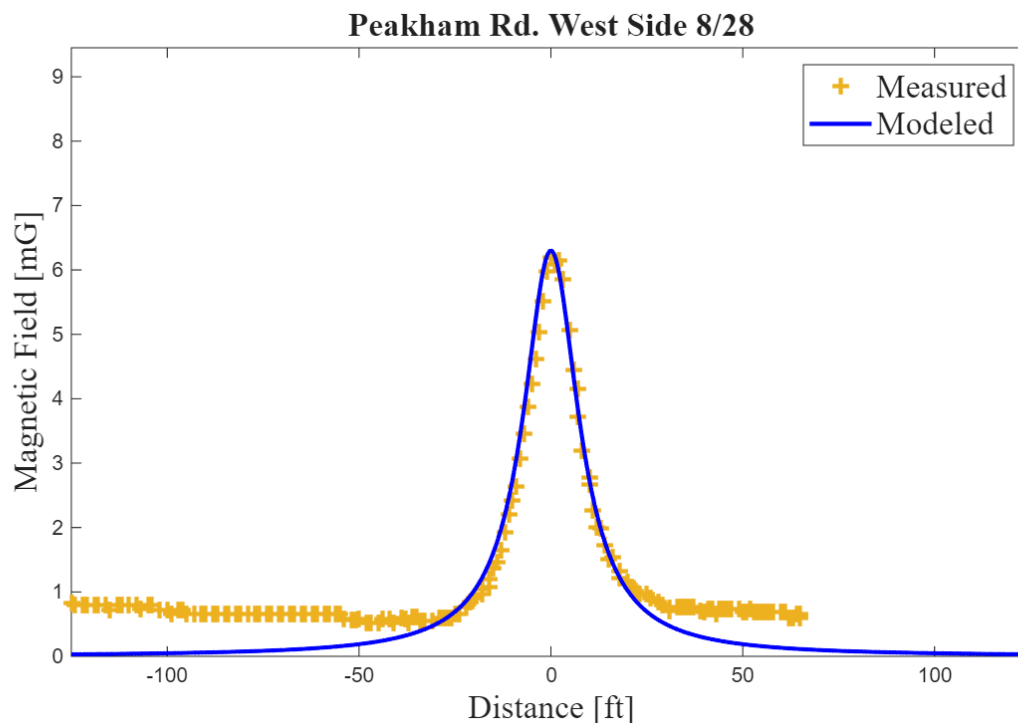


Figure 14 Comparison of modeled magnetic field with the measured magnetic field at Peakham Road on August 28.

The model accurately predicts the magnetic field near the transmission line with a maximum calculated value within 2% of the measured value. Magnetic-field levels from the transmission line decrease rapidly with distance from the source and at distances away from the transmission line (e.g., beyond approximately 25 feet from the transmission line centerline), the contribution of the local distribution line (342-H2) to magnetic-field levels is greater than that of the Sudbury – Hudson transmission line. This is shown by the relatively constant magnetic-field level of ~0.9 mG at distances greater than approximately 25 feet from the transmission line.

Conclusion

After the construction of the Sudbury to Hudson underground transmission line, Eversource requested that Exponent measure the EMF levels from the Sudbury – Hudson transmission line at locations of public road crossings in the town of Sudbury. EMF were measured along both sides of Dutton Road, Peakham Road, Horse Pond Road and Union Avenue. Electric field levels were found to be very low (< 0.1 kV/m) at all measurement locations, while the highest magnetic field level was measured to be 22 milligauss (mG). Additionally, an ‘as-measured’ model of the transmission line was developed, which incorporates the as-built geometry and burial depth of the transmission line at the location of measurements along the west side of Peakham Road as well as the loading on the transmission line at the time of measurements. The close agreement between measured and magnetic-field levels confirms the accuracy and validity of the modeling approach used to calculate magnetic-field levels presented during permitting of the transmission line.

All measured EMF levels were far below the reference levels published by the International Commission on Non-Ionizing Radiation Protection and the International Committee on Electromagnetic Safety. The reference levels for exposure of the general public published by those organizations are 2,000 mG and 9,040 mG, respectively for magnetic fields and 4.2 kV/m or 5 kV/m, respectively for electric fields.

Appendix A

EMDEX II Calibration Certificate

Certificate of Calibration

The calibration of this instrument was controlled by documented procedures as outlined on the Certificate of Testing Operations and Accuracy Report using equipment traceable to N.I.S.T., ISO/IEC 17025:2017(E), and ANIZ540-1 COMPLIANT.

Instrument Model: EMDEX II - Standard

Frequency: 60 Hz

Serial Number: 3830

Date of Calibration: 05/07/2025

Re-calibration suggested at one year from above date.

EMDEX
LLC

Calibration Inspector: *H. Christopher Hooper*

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