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October 5, 2020

Via Electronic Mail

Administrator of the N.H. Site Evaluation Committee
N.H. Site Evaluation Committee
21 South Fruit Street, Suite 10
Concord, NH 03301

Re: SEC Docket No. 2015-04: Public Service Company of New Hampshire d/b/a Eversource Energy ("Eversource"): Post-Construction Measurements of Electric and Magnetic Fields

Dear Administrator:

Enclosed for filing in the above-referenced docket, please find Eversource's Post-Construction Measurements of Electric and Magnetic Fields for the completed Seacoast Reliability Project.

Please do not hesitate to contact me with any questions.

Sincerely,

Adam Dumville

Adam M. Dumville

cc: Mr. Paul Kasper, NHPUC

Electrical Engineering and
Computer Science Practice

Exponent®

Seacoast Reliability Project

Post-Construction Measurements of Electric and Magnetic Fields

Seacoast Reliability Project

Post-Construction Measurements of Electric and Magnetic Fields

Prepared for

New Hampshire Site Evaluation Committee
New Hampshire Public Utilities Commission
21 South Fruit Street
Concord, NH 03301

On behalf of

Eversource Energy d/b/a
Public Service Company of New Hampshire
PSNH Energy Park
780 N Commercial Street
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October 5, 2020

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Acronyms and Abbreviations

Application	New Hampshire Site Evaluation Committee Docket No. 2015-04
EMF	Electric and magnetic fields
Eversource	Eversource Energy
ICES	International Committee on Electromagnetic Safety
IEEE	Institute of Electrical and Electronics Engineers
ICNIRP	International Commission on Non-Ionizing Radiation Protection
kV	Kilovolt
kV/m	Kilovolt per meter
mG	Milligauss
NHSEC	New Hampshire Site Evaluation Committee
PUC	Public Utilities Commission
ROW	Right-of-way
SRP or the Project	Seacoast Reliability Project
UNH	University of New Hampshire

Limitations

At the request of Eversource Energy d/b/a Public Service Company of New Hampshire, Exponent measured and modeled the levels of electric and magnetic fields associated with the post-construction configurations of transmission and distribution lines along the route of the Seacoast Reliability Project (SRP). This report summarizes work performed and presents the findings resulting from that work. In the analysis, we have relied on geometry, material data, usage conditions, specifications, and various other types of information provided by Eversource Energy. We cannot verify the correctness of this data and rely on the client for the data's accuracy. Eversource Energy has confirmed to Exponent that the data provided to Exponent and summary contained herein is 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 outside of the review of the SRP by the New Hampshire Public Utilities Commission or the New Hampshire Site Evaluation Committee, and any re-use of this report or its findings, conclusions, or recommendations presented herein 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 New Hampshire Site Evaluation Committee (NHSEC) reviewed the application of Eversource Energy d/b/a Public Service Company of New Hampshire (Eversource) for a new 115-kilovolt transmission line in Docket No. 2015-04 (Application) and approved the Application with conditions on January 31, 2019, in its Decision and Order granting a Certificate of Site and Facility. The Decision and Order included conditions for pre- and post-construction measurements of electric and magnetic fields (EMF) and required comparisons of the measured field levels to the guidelines for public exposure published by the International Committee on Electromagnetic Safety (ICES) or the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

This report summarizes post-construction EMF measurements to comply with the NHSEC order.

Exponent measured EMF levels from the configuration of post-construction transmission and distribution lines under conditions as near as possible to those assumed in the Application. Measurement locations were selected by Exponent and Eversource Energy in consultation with the New Hampshire Public Utilities Commission (PUC). These locations are located in the 11 Line Segments of the route proposed in the Application, based on the configurations of the new transmission line (designated F107).

Measured EMF levels and measured magnetic fields extrapolated to peak line loading were found to be well below health-based standards and guidelines developed by ICNIRP and ICES at all measurement sites. In addition, the demonstrated agreement between modeling and measurements confirmed both the reasonableness of the input data used to model EMF from the transmission lines and the accuracy of the modeling approach followed in the Application.

Introduction

The Seacoast Reliability Project (SRP or the Project) is a new 115-kilovolt (kV) transmission line (designated F107) between the Madbury and Portsmouth Substations. The SRP was constructed on existing rights-of-way (ROW) and is approximately 12.9 miles long. The F107 transmission line includes a combination of overhead, underground, and underwater components through portions of the towns of Madbury, Durham, and Newington, as well as the City of Portsmouth, including a submarine cable crossing from Durham to Newington under Little Bay.

The application for the Project was submitted on April 12, 2016, in New Hampshire Site Evaluation Committee (NHSEC) Docket No. 2015-04 (the Application) and was approved on January 31, 2019, by a Decision and Order granting a Certificate of Site and Facility, with conditions for determining pre- and post-construction measurements of electric and magnetic fields (EMF). The Decision and Order states:

> … Further Ordered that the Applicant, in consultation with the PUC [Public Utilities Commission] Safety Division, shall measure actual electromagnetic fields associated with operation of the Project both before and after construction of the Project during projected peak-load, and shall file with the Administrator the results of the measurements; and it is,
>
> Further Ordered that if the results of the electro-magnetic field measurements exceed the guidelines of the International Committee on Electromagnetic Safety (ICES) or the International Commission on Non-Ionizing Radiation Protection (ICNIRP), the Applicant shall file with the Administrator a mitigation plan designed to reduce the levels so that they are lower than the ICES or ICNIRP guidelines; and it is,
>
> Further Ordered that the Applicant shall measure the level of the electro-magnetic field at Mr. Fitch's property before and after construction of the Project; …

To comply with the NHSEC pre-project measurement requirements, Exponent performed measurements of EMF levels along the pre-project route and submitted a report titled *Seacoast Reliability Project Pre-Construction Measurements of Electric- and Magnetic-Field Levels* (the pre-project EMF Report) to the NHSEC and PUC on August 6, 2019 (Exponent, 2019). This pre-project EMF Report summarizes the results of measurements along 11 Line Segments of the Project that were selected in consultation with the PUC based upon the proposed transmission line configurations and the residential density along the route of the F107 transmission line. These same Line Segments were assessed during post-construction EMF measurements.

The goal of the measurements performed at the 11 representative sites on the Project route was to compare measured EMF levels to guidelines recommended by ICES and ICNIRP. Despite performing measurements during the time of expected peak loading (late July) the loading of transmission lines did not reach peak loading levels that had been projected by Eversource Energy in the Application, so Exponent adjusted site-specific models of the as-measured magnetic-field levels to account for peak-loading conditions (As-Measured – Adjusted for Peak Model). The results of this comparison between the EMF levels calculated from the As-Measured – Adjusted for Peak Model and guidelines from ICES and ICNIRP are provided in a tabular summary in Appendix A. This same methodology for adjusting the As-Measured model to peak loading was previously used in the pre-construction measurements of the SRP project. A substantially similar methodology was previously used for the analysis of pre- and post-construction measurements of the Merrimack Valley Reliability Project submitted to the NHSEC and PUC.[1] In addition, a graphical summary for each measurement location is provided in Appendix B. Aerial maps with annotations reflecting the specific locations of EMF measurements are provided in Appendix C, and loadings of power lines (as well as measured conductor heights) at the time of measurements are provided in Appendix D. The calibration certificates for each piece of equipment are included in Appendix E.

[1] Exponent, Inc. (Exponent). *Eversource / National Grid Merrimack Valley Reliability Project Pre-Construction Measurements of Electric and Magnetic Field Levels*, March 27, 2017.

Exponent, *Eversource / National Grid Merrimack Valley Reliability Project Post-Construction Measurements of Electric and Magnetic Field Levels*, October 18, 2018.

EMF Measurement and Calculation Methods

Measurement Methods

Prior to performing any measurements, Exponent and Eversource engineers jointly developed a measurement protocol, *Protocol for Post-energization Measurements of Electric and Magnetic Fields*, to ensure compliance with the NHSEC Order for making measurements of EMF levels from the existing lines before these lines were moved as part of the Project. This protocol, dated June 15, 2020, was sent to both the NHSEC and the PUC for review and comment (see Appendix F). The description below is based on the procedures described in this protocol.

Measurement Setup

At each measurement site, Exponent engineers photographed the conditions of the ROW and transmission or distribution lines and laid a long measuring tape on the ground beneath the lines to identify the horizontal location of the overhead line conductors. The vertical height of each conductor was measured and recorded using an acoustic line-height sensor (i.e., SupaRule T30).[2] Where a measurement transect other than perpendicular was required, the angle of the transect to the transmission or distribution lines was noted and measurement distances were adjusted accordingly.

Measurements

Exponent engineers measured both electric fields and magnetic fields as the total field computed as the resultant of field vectors measured along vertical, transverse, and longitudinal axes.[3] The magnetic field was measured in units of milligauss (mG) by orthogonally-mounted sensing coils whose output was recorded by a digital meter (EMDEX II) and attached to a survey wheel to simultaneously measure magnetic-field magnitude distance. The electric field was measured in units of kilovolts per meter (kV/m) with a single-axis sensor connected to the EMDEX II

[2] The heights of some shield wires were above the range of the line-height sensor. The heights of these shield wires were estimated using the as-measured phase conductor heights and design drawings.

[3] Measurements along the vertical, transverse, and longitudinal axes were recorded as root-mean-square magnitude, which refers to the common mathematical method of defining the effective voltage, current, or field of alternating-current power lines.

meter.[4] 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.

Magnetic-field measurements were recorded at intervals of approximately 1 to 3 feet using the measurement system of the EMDEX II and survey wheel, while electric-field measurements were performed at approximately 3- to 30-foot intervals with a minimum of five measurement locations performed in the immediate vicinity of each transmission or distribution line in accordance with IEEE Standard 644-2019.[5,6]

In addition, at each measurement site, an additional magnetic-field meter (EMDEX LITE) was placed at ground level beneath the center conductor of one of the power lines and set to continuously record fluctuations in the magnetic field that were due to changes in current flow on the lines above. The data from this sensor were used to evaluate if there was a large change in loading during the time that measurements were taken. The time and date of the field measurements were noted so that the loading on each of the lines at the time of field measurements could be matched.

These instruments meet the Institute of Electrical and Electronics Engineers (IEEE) instrumentation standard for obtaining accurate field measurements at power line frequencies (IEEE Std.1308-1994, R2010).[7] All meters and measurement accessories were calibrated by EMDEX, LLC, using methods like those described in IEEE Std. 644-2019. The calibration certificates for each piece of equipment are included in Appendix E.

Measurements at Little Bay Crossing

At the Little Bay Crossing, magnetic-field levels were modeled in the Application for a burial depth of 8 feet and a horizontal separation distance of 30 feet. The goal of the post-construction

[4] Measurement equipment was manufactured by Enertech Consultants, Cupertino, California.

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

[6] At locations far from the transmission lines, the distance between successive electric-field measurements was larger (approximately 15 to 30 feet). Nearer to the transmission lines, the distance between successive measurement locations was smaller (approximately 3 to 10 feet).

[7] Institute of Electrical and Electronics Engineers (IEEE). IEEE Recommended Practice for Instrumentation: Specifications for Magnetic Flux Density and Electric Field Strength Meters (IEEE Std. 1308-1994). New York: IEEE, 1994, R2010.

measurements was to evaluate the magnetic-field level for the configuration used in the Application. However, where the cables are separated by 30 feet from one another (as was modeled in the Application) the water depth is too great to allow for measurements even at low tide. Similarly, on land the cables are too close together to represent the configuration of the cables used in the Application. Magnetic-field modeling by Eversource, however, indicates that the highest magnetic-field level above the F107 transmission line for a 10-foot separation of cables is similar to the highest magnetic-field at a 30-foot separation. Measurements were therefore performed in the inter-tidal zone where the cables are far enough apart (approximately 12 to 16 feet) to be similar to the model in the Application but close enough to shore that measurements could be performed.

Prior to measurements in the intertidal zone, a surveyor identified the location of each cable of the F107 transmission line beneath steel-reinforced concrete mattresses, a location approximately 100 feet offshore where the buried cables were separated by approximately 12 to16 feet. When collecting data to either side of the concrete mattresses, the substrates in Little Bay were too soft to allow for measurements to be performed using a survey wheel on the substrate surface. To overcome this limitation, Exponent laid a series of 1 foot by 10 foot and 2 foot by 10 foot boards approximately perpendicular across the cables in order to allow the survey wheel to roll easily over the substrate surface and concrete mattresses. Since there will be no electric fields above ground from the transmission line, only magnetic-field levels were recorded at this location.

Pre-Measurement Calibration Procedure

One EMDEX II meter used in measurements was calibrated on December 27, 2019, and the other was calibrated on January 16, 2020, approximately 7 months before the scheduled measurement trip. In addition, to monitor the calibration status of the EMDEX II meters, the calibration was checked multiple times throughout the measurement campaign with a portable calibration coil; the maximum change in any calibration was approximately 4%, indicating that the EMDEX II maintained calibration throughout the measurement campaign.

Modeling Methods

At each measurement site, Exponent measured the conductor position and height of each transmission or distribution line and recorded the voltage and line loading data provided by Eversource to develop an As-Measured Model representing the operation of the lines at the site at the time of the measurement. This As-Measured Model also included information from the Application, such as the phasing configuration and conductor type for each line.

In addition to the As-Measured Model, Exponent also developed a model of each measurement site, evaluating the operation of the constructed lines at peak loading (As-Measured – Adjusted for Peak Model) in order to comply with the NHSEC Order. This adjustment was made by using the peak loading information provided in the Application.

EMF levels were calculated using computer algorithms developed by the Bonneville Power Administration, which also were used for the modeling of EMF levels in the Application.[8] The inputs to the program include data regarding voltage, current flow, phasing, and conductor positions measured on-site at each location.

In the model, simplifying assumptions were made in order to be able to use analytical solutions and to yield conservative values (i.e., higher than what might be measured). Each conductor was modeled as infinite in length at a fixed height above an infinite flat earth and was assumed to be parallel to all other conductors. All real-world conditions encountered in the measurements were not included in this simplified model. The assumptions used in the modeling are designed to generally overestimate the actual values. Measured values, however, are expected to differ slightly from calculated values because induced currents on the transmission or distribution line's shield wires, neutral return currents on distribution lines, and terrain irregularities not included in the model used to calculate EMF levels.

[8] Bonneville Power Administration (BPA). Corona and Field Effects Computer Program. Portland, OR: Bonneville Power Administration (BPA), 1991. These methods are functionally the same as Electric Power Research Institute's AC Transmission Line Reference Book – 200-kV and Above, Third Edition, referenced in the Application.

Measurement Locations

The locations of the measurement sites are shown in Figure 1 and were selected to cover the configurations of the F107 transmission line and accurately describe actual EMF levels for the entire route.

The location of the measurement sites were the same for both pre-construction and post-construction measurements. Each of the 11 specific measurement sites (1 within each of the 11 identified Line Segments) was selected to encompass as many of the following characteristics as possible to provide the best comparison with idealized models use for calculations in the Application:

1. Free of infrastructure (e.g., distribution lines, water or sewer pipes, gas or oil pipelines) or sources of EMF (e.g., other unrelated overhead lines or underground distribution lines; nearby equipment) that can alter or affect measured EMF levels;
2. Flat, level surface beneath the transmission or distribution lines that is away from structures (ideally near the mid-span of lines);
3. Free of underbrush, trees, or other conductive objects; and
4. Provide a measurement transect perpendicular to the power line conductors.

Locations for measurements in these 11 Line Segments were previously selected for pre-energization measurements and are described in Table 1 by the Line Segment in the Application, structure type, and municipality, and include additional information about specific measurement locations and date of measurements. In many (but not all) cases, the cross sections of shorter extent included measurement sites with some deficiencies (e.g., Site 1, Site 2, and Site 8); because there were not many potential options on those shorter sections, sub-optimal options were necessarily selected.

Spot measurements of magnetic-field levels also were performed beneath the F107 transmission line and at various points on the property of the Fitch residence at 291 Durham Point Road.

Table 1. EMF measurement location summary

Site	Line Section (Application Section)	Future F107 Structure Type	Pre-Construction Measurement Date	Municipality	Monitoring Location
1	Madbury Substation to Route 4 Crossing	Delta	6/6/2019	Madbury	North of Madbury Rd.
2	Underground through University of New Hampshire Parking Lot A	Underground	6/6/2019	Durham	University of New Hampshire Parking Lot A
3	University of New Hampshire to Durham Substation	Delta with underbuild	6/3/2019	Durham	Off Water Works Rd.
4	Packers Falls Substation to Newmarket Rd.	Delta with underbuild and adjacent line	6/3/2019	Durham	North of Bennett Rd.
5	Timber Brook Ln. to Sandy Brook Dr.	Delta with underbuild	6/3/2019	Durham	East of Sandy Brook Rd.
6†	Sandy Brook Dr. to Durham Point Rd.	Delta and adjacent line	6/3/2019	Durham	North of Durham Point Rd.
7*	Durham Point Rd. to Little Bay Launch	Delta	6/4/2019	Durham	South of Durham Point Rd.
8	Little Bay Crossing	Direct bury	6/4/2019	Durham	West side of Little Bay
9†	Underground through Frink Farm	Underground	6/4/2019	Newington	West of Nimble Hill Rd.
10	Fox Point Rd. to Spaulding Turnpike Crossing	Delta and adjacent line	6/4/2019	Newington	North of Fox Point Rd.
11	Crossing at Fox Run to Portsmouth Substation	Vertical and adjacent lines	4/29/2019	Newington	Mall Parking Lot

† Amended line section
* The Fitch property is located along this portion of the route.

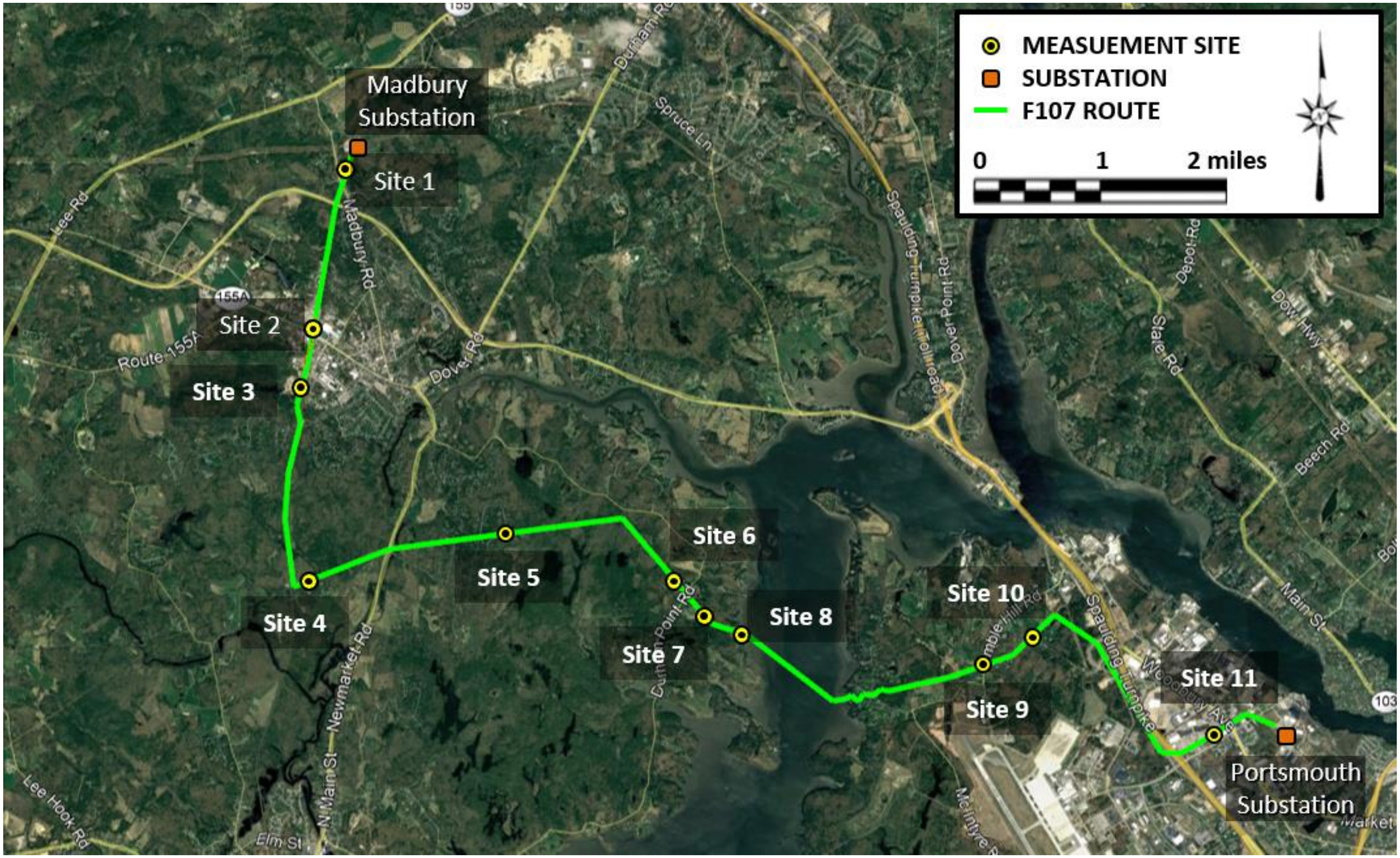

Figure 1. Route of the transmission line and locations of measurement sites.

Results

EMF measurements were scheduled and performed during the 2-week period between July 20 and July 31, 2020, when peak loading of transmission lines was expected (consistent with the NHSEC Order). Despite taking measurements in the summer season, measured loadings on the existing power lines did not always reach levels forecasted in the Application, so the magnetic-field measurements are summarized both in raw form and after adjustment to peak-loading levels. The following section presents a summary of the measurement results at each location, as well as a comparison of calculations with ICES and ICNIRP guidelines.

A direct comparison of the modeling provided in the Application to the measured and modeled levels from these analyses is provided in tabular form in Appendix A. EMF measurement results at each site are presented graphically in Appendix B and the locations of measurements are shown in annotated aerial photographs in Appendix C. Results of spot measurements at the Fitch property are summarized in Appendix B, Figure B-15. Appendices A and B also provide a comparison of the agreement between calculated EMF levels in the Application to EMF levels adjusted for peak-loading and site-specific conditions and discusses the reasons for some observed differences.

Comparison of Measured and Calculated Magnetic-Field Levels

To confirm the accuracy of modeling methods, Exponent compared the measured magnetic-field values with the values calculated from the As-Measured Model at each site. These comparisons use the same software algorithms used in the Application, but in this case, the model accounts for transmission-line conductor heights at the time measurements were taken, and the magnetic fields are calculated from recorded line currents provided by Eversource.

As described in the previous section, detailing the measurement locations and conditions of measurements, it was rarely possible to identify a single location that encompassed all of the desirable characteristics of a measurement site, so the results below reflect the deviations between modeled and measured levels expected when comparing calculations from an idealized model with measurements from a real-world transmission line ROW.

Example Comparison: Site 6 (Sandy Brook Dr. to Durham Point Rd)

This example is presented below in Figure 2 for reference and discussion while the results for the remaining sites are presented in Appendix B. Site 6 was selected because the site conditions were among the most consistent with the conditions assumed in the calculation model described in the Application.[9]

Figure 2 shows magnetic-field levels (left side) and electric-field levels (right side) separately. Actual measurement values are shown by a series of '+' markers while the magnetic fields calculated by the As-Measured Model are superimposed with a dark blue solid line. Magnetic-field measurements were taken every 1 to 3 feet using a survey wheel in conjunction with the magnetic-field meter. The '+' markers sometimes appear as a thick, jagged line due to the close spacing of the measurement locations.

In contrast, electric-field measurements were performed at individual measurement locations separated by approximately 4 to 15 feet (with closer spacing near the transmission or distribution lines and at greater spacing on more distant portions of the ROW), so generally appear as discrete '+' symbols indicating the measured value.

The results illustrated in this figure indicate that calculated and measured levels were generally in good agreement and that all measured and modeled field levels are far below the ICNIRP or ICES limits.

[9] Site 3 was presented in the pre-construction measurements as an example. However, post-construction measurements at the same location were not possible because the new F107 transmission line had an angle tower at one end of the span. The Site 3 measurement location was therefore moved one span to the north, which had UNH [University of New Hampshire] Circuit 6 crossing the ROW at an oblique angle and UNH Circuit 12 near the ROW edge. These circuits were lightly loaded and did not appreciably affect magnetic-field measurements, but did affect electric-field measurements.

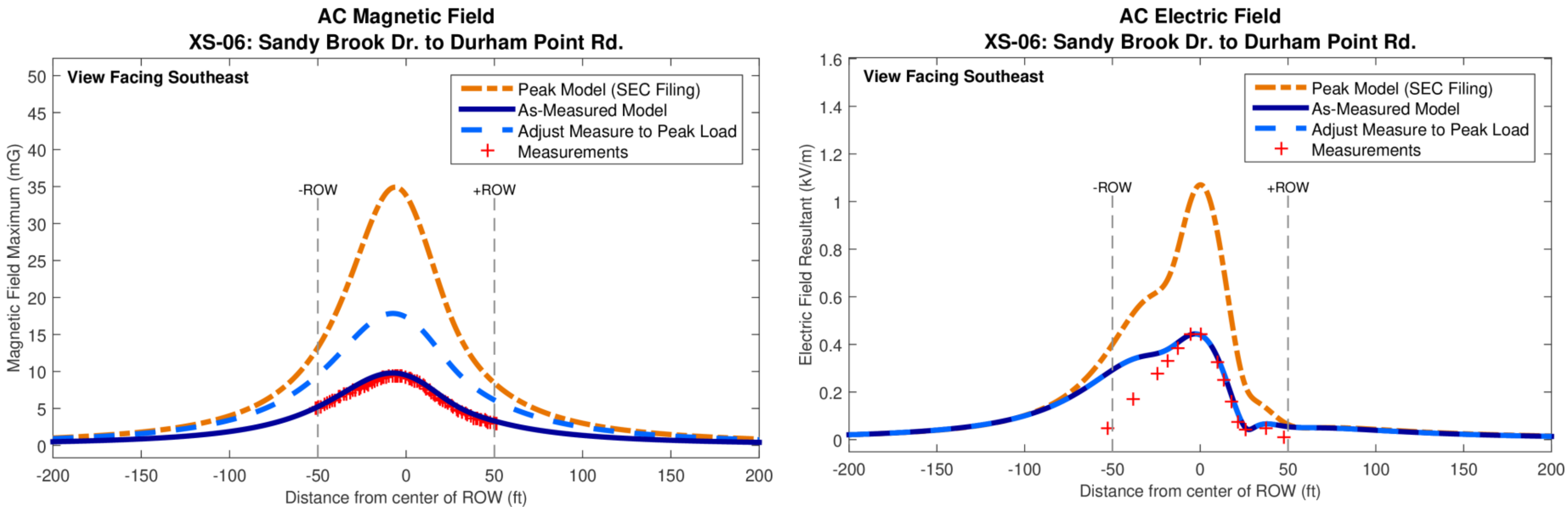

Figure 2. Comparison of measurements at Site 6 (Sandy Brook Dr. to Durham Point Rd.) with calculations from the As-Measured Model, As Measured - Adjusted for Peak Model, and the Peak Model from the Application for comparison.

Magnetic-field levels (left) and electric field levels (right) are shown. For comparison, the ICNIRP magnetic-field reference level is 2,000 mG and the electric-field reference level is 4.2 kV/m.

The agreement between the calculated- and measured-field profiles at Site 6 was evaluated by calculating the mean deviation between the measured and calculated magnetic-field values, which was approximately 6% for the magnetic field, with the measured magnetic-field values generally lower than the calculated magnetic-field levels. The deviation between measured and modeled electric fields is larger (a mean deviation of 27%) due to the presence of large trees at the ROW edge that shielded the electric field from the line on portions of the ROW. These figures also serve to demonstrate the conservative nature of the modeling approach with the results showing that the measured EMF levels are consistently similar to, or lower than, the modeled levels.

The degree of match between measurements and modeling at other locations depended on the characteristics of the measurement site and the extent to which each site meets (or does not meet) the selection criteria discussed above. Measurement Sites 5, 6, 7, and 11 all had a mean deviation between measurements and magnetic-field modeling of approximately 10% or less. Measurement Sites 1 to 4 and 10 had a mean deviation between measurements and magnetic-field modeling of approximately 12% to 19%, and Measurement Sites 8 and 9 had a larger mean deviation >40%.

Magnetic-field levels near the ROW edge

In addition to comparing the EMF levels across the ROW, it also is useful to compare the modeled and measured magnetic-field levels at the edges of the ROW. Since it was not always possible to take measurements precisely at the ROW edges due to limited brush and tree clearing, terrain, or other factors, the comparison below uses the measurements that were made closest to the ROW edge and compares those values to the as-built model of the field levels at that same measurement location (often not precisely at the ROW edge).[10] This comparison is shown in a bar graph (Figure 3) in which the measured field level closest to the ROW edge is shown in a blue bar and the modeled field level at the same measurement point closest to the ROW edge is shown in a yellow bar. Using Site 6 as an example and comparing to Figure 2, and Appendix A, Table A-1 it can be seen that on the '–' ROW edge, the measured magnetic-

[10] The results presented in Figure 3 therefore differ slightly from those presented in Tables A-1 and A-2 in Appendix A.

field level of 5.1 mG matches well with the modeled level of 5.2 mG at the same location. Likewise, on the '+' ROW edge, the measured magnetic-field level of 3.1 mG matches well with the modeled level of 3.3 mG.

Comparisons of EMF levels at the edges of the ROW in other sections show the measured field levels are generally similar to or lower than the modeled level.[11] The ROW-edge electric-field levels also are shown, but generally provide less information because the trees ubiquitous at the ROW edges significantly attenuated the electric field at these locations.

Figure 4 also shows that although there are some small deviations between measured and calculated magnetic-field values at a few of the sites, the calculated values are generally higher than the measured EMF levels at the edges of the ROW.

[11] At Site 8 (Little Bay Launch), the concrete mattresses covering the cables appear to have provided substantial shielding of the magnetic fields compared to calculations. As a result, measured levels were far below modeled levels. At Site 9, the very low measured magnetic-field levels mean that the fractional mean deviation is much larger than at other sites, even though the absolute difference between measurements and modeling is within approximately ±2 mG.

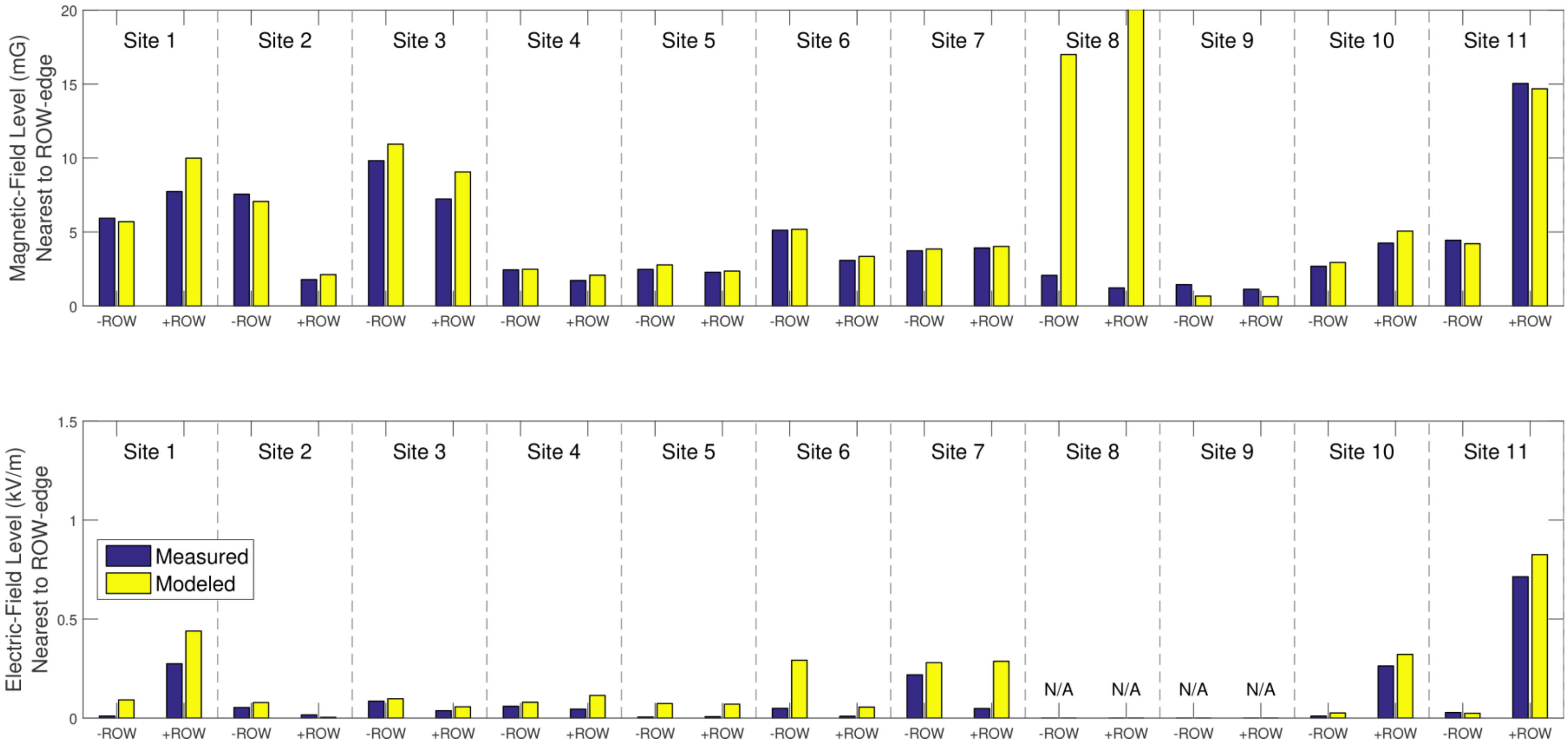

Figure 3. Comparison of measured and modeled EMF levels near the ROW edges.

Comparison of Measured and Calculated EMF Levels to ICES and ICNIRP Guidelines

Levels of EMF are often assessed by comparison to standards and guidelines developed by scientific and health agencies. Several scientific organizations, including ICNIRP and ICES, have published limits of exposure to 60-Hertz EMF. As discussed in greater detail in the Application (e.g., Appendix 40) both ICNIRP and ICES have developed limits for exposure, as well as screening levels below which compliance with the standards are ensured. The ICNIRP screening levels are 2,000 mG and 4.2 kV/m for magnetic fields and electric fields, respectively. The guidelines for ICES are somewhat higher, 9,040 mG and 5 kV/m for magnetic fields and electric fields, respectively.[12]

All measured magnetic-field levels on the route were found to be far below the ICNIRP or ICES limits (less than 2% of the limits). Even when adjusted to peak loading, these maximum levels were less than 5% of the ICNIRP or ICES limits.[13] All measured electric-field levels on the route were similarly found to be below the ICNIRP or ICES limits. The highest electric-field levels were measured at Site 11 beneath the existing 345-kV transmission line and also were approximately one-half or less of the ICNIRP or ICES limits.

[12] There is an exception for transmission line ROWs for electric fields where 10 kV/m levels are permitted.

[13] This does not include the modeling of Site 8 when adjusted to peak loading because of the shielding of the concrete mattresses that is not included in the modeling and so is not indicative of actual magnetic-field levels expected under peak loading.

Conclusion

The measurements and analysis in this report comply with the NHSEC Decision and Order issued January 31, 2019, to provide measured actual electric- and magnetic-field levels pre-construction along the route of the Project and to compare the measured field levels to those published by ICES and ICNIRP. The measurement sites were determined in consultation with the PUC and were selected to describe all the proposed configurations of the F107 transmission line for the entire route. All measurements discussed herein were performed under conditions as near as possible to conditions assumed for the post-construction configurations in the original modeling.

Measured magnetic-field levels were very similar to or lower than modeled levels and measured electric-field levels were consistently lower than modeled levels due to the shielding effect of trees, brush, terrain, and structures found on the ROW and beyond.

All measured magnetic-field levels on the route were found to be less than 5% of the ICNIRP or ICES limit, even when adjusted to peak-loading levels. Similarly, all measured electric-field levels on the route were found to be approximately one-half of the ICNIRP or ICES limits or less. In addition, the demonstrated agreement between modeling and measurements confirmed the reasonableness of the input data used to model EMF from the transmission lines and accuracy of the modeling approach followed in the Application.

Appendix A

Summary of Measured and Calculated EMF Levels

The ROW edge was not accessible at all measurement sites, nor was it always possible to determine exactly where the ROW edge was located. As a result, EMF measurements (and electric-field measurements in particular) often were measured near to the ROW edge, but not precisely at the ROW edge. Reported measurement values in the tables below are therefore reported at the location where the electric- and magnetic-field measurements were made closest to the –ROW and +ROW edges. In addition, to make the most meaningful comparison to these measured values, all modeled values are reported at these same locations, not at the precise ROW edge. As a result, the ROW-edge field values reported in the tables below may differ slightly from those presented in the Application.

In the tables below EMF levels are reported for four scenarios:

- Magnetic-field levels:
    1. Peak Model used in the Application Filing
    2. Modeled Field (for measured line height and load at time of measurements)
    3. Modeled Field (for measured line height, and load adjusted to peak level)
    4. Measured Field
- Electric-field levels:
    1. Peak Model used in the Application Filing
    2. Modeled Field (for measured line height at time of measurements)
    3. Modeled Field (for measured line height; no adjustment for peak loading needed)[1]
    4. Measured Field

To comply with the NHSEC Order issued January 31, 2019 the measurements below are provided to enable a direct comparison between actual electric- and magnetic-field levels measured along the route of the Project those published by the ICES and ICNIRP.

The ICNIRP screening levels are 2,000 mG and 4.2 kV/m for magnetic and electric fields, respectively. The guidelines for ICES are somewhat higher, 9,040 mG and 5 kV/m for magnetic and electric fields, respectively.[2]

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[1] The loading on the transmission and distribution lines is low enough that a negligible change in conductor height is expected for average compared to peak loading. Therefore, the electric-field model adjusted to peak conditions is identical to that for average load conditions.

[2] There is an exception for transmission line ROWs for electric fields where 10 kV/m are permitted.

Table A-1. Measured and calculated magnetic-field levels (mG). Levels can be compared to screening levels for ICNIRP (2,000 mG) and ICES (9,040 mG)

Site # / Date	Condition	Value at Measurement Point: Nearest −ROW Edge	Max on ROW	Nearest +ROW Edge
Site 1 **July 21, 2020**	Peak Model (Application Filing)*	3.4	52	13
	Modeled Field (for measured line height and load at time of measurements)	5.7	26	10
	Modeled Field (for measured line height, and load adjusted to peak level)	8.1	36	18
	Measured Field	5.9	24	7.7
Site 2 **July 21, 2020**	Peak Model (Application Filing)	15	49	4.6
	Modeled Field (for measured line height and load at time of measurements)	7.1	33	2.1
	Modeled Field (for measured line height, and load adjusted to peak level)	8.9	67	2.2
	Measured Field	7.6	38	1.8
Site 3 **July 21, 2020**	Peak Model (Application Filing)*	9.3	24	5.5
	Modeled Field (for measured line height and load at time of measurements)	11	22	9.1
	Modeled Field (for measured line height, and load adjusted to peak level)	6.7	10	4.3
	Measured Field	9.8	18	7.2
Site 4 **July 21, 2022**	Peak Model (Application Filing)†	9.6	29	21
	Modeled Field (for measured line height and load at time of measurements)	2.5	3.2	2.1
	Modeled Field (for measured line height, and load adjusted to peak level)	6.0	20	15
	Measured Field	2.4	2.9	1.7
Site 5 **July 24, 2020**	Peak Model (Application Filing)	11	18	9.0
	Modeled Field (for measured line height and load at time of measurements)	2.8	3.5	2.4
	Modeled Field (for measured line height, and load adjusted to peak level)	6.2	7.7	5.2
	Measured Field	2.5	3.2	2.3
Site 6 **July 20, 2020**	Peak Model (Application Filing)‡	13	35	8.5
	Modeled Field (for measured line height and load at time of measurements)	5.2	10	3.3
	Modeled Field (for measured line height, and load adjusted to peak level)	9.4	18	6.2
	Measured Field	5.1	9.5	3.1

Site # Date	Condition	Value at Measurement Point: Nearest −ROW Edge	Max on ROW	Nearest +ROW Edge
Site 7 **July 22, 2020**	Peak Model (Application Filing)*	10	35	12
	Modeled Field (for measured line height and load at time of measurements)	3.8	9.1	4.0
	Modeled Field (for measured line height, and load adjusted to peak level)	9.0	21	9.4
	Measured Field	3.7	8.0	3.9
Site 8 **July 23, 2020**	Peak Model (Application Filing)	143	193	165
	Modeled Field (for measured line height and load at time of measurements)	17	196	30
	Modeled Field (for measured line height, and load adjusted to peak level)	40	455	69
	Measured Field	2.1	11	1.2
Site 9 **July 20, 2020**	Peak Model (Application Filing)‡	1.0	48	0.9
	Modeled Field (for measured line height and load at time of measurements)	0.7	29	0.6
	Modeled Field (for measured line height, and load adjusted to peak level)	1.2	54	1.2
	Measured Field	1.4	40	1.1
Site 10 **July 20, 2020**	Peak Model (Application Filing)	12	52	11
	Modeled Field (for measured line height and load at time of measurements)	2.9	8.1	5.1
	Modeled Field (for measured line height, and load adjusted to peak level)	13	19	12
	Measured Field	2.7	6.8	4.3
Site 11 **July 20, 2020**	Peak Model (Application Filing)	5.6	140	38
	Modeled Field (for measured line height and load at time of measurements)	4.2	30	15
	Modeled Field (for measured line height, and load adjusted to peak level)	6.1	59	28
	Measured Field	4.4	32	15

* During post-construction modeling small typographical errors in the phase information input data of the F107 transmission line model were identified. Values may therefore differ slightly from those presented in the Application.

† A typographical error in the Application resulted in incorrect values being inserted into the Peak results summary table. Values therefore differ from those presented in the Application.

‡ Magnetic-field levels for peak loading were not presented in the Application for the Amended sections. No values are therefore available for comparison in the Application.

Table A-2. Measured and calculated electric-field levels (kV/mG). Levels can be compared to screening levels for ICNIRP (4.2 kV/m) and ICES (5 kV/m or 10 kV/m on a ROW)

Site # / Date	Condition	Value at Measurement Point: Nearest −ROW Edge	Max on ROW	Nearest +ROW Edge
Site 1 **July 21, 2020**	Peak Model (Application Filing)	<0.1	1.1	0.5
	Modeled Field (for measured line height at time of measurements)	0.1	1.0	0.5
	Modeled Field (for measured line height; no adjustment for peak loading needed)	0.1	1.0	0.5
	Measured Field	<0.1	0.8	0.3
Site 2 **July 21, 2020**	Peak Model (Application Filing)*	0.1	0.3	<0.1
	Modeled Field (for measured line height at time of measurements)	0.1	0.1	<0.1
	Modeled Field (for measured line height; no adjustment for peak loading needed)	0.1	0.1	<0.1
	Measured Field	0.1	0.1	<0.1
Site 3 **July 21, 2020**	Peak Model (Application Filing)	0.2	0.2	0.1
	Modeled Field (for measured line height at time of measurements)	0.1	0.1	0.1
	Modeled Field (for measured line height; no adjustment for peak loading needed)	0.1	0.1	0.1
	Measured Field	0.1	0.1	<0.1
Site 4 **July 21, 2022**	Peak Model (Application Filing)	0.2	0.2	0.2
	Modeled Field (for measured line height at time of measurements)	0.1	0.1	0.1
	Modeled Field (for measured line height; no adjustment for peak loading needed)	0.1	0.1	0.1
	Measured Field	0.1	0.1	<0.1
Site 5 **July 24, 2020**	Peak Model (Application Filing)	0.2	0.2	0.2
	Modeled Field (for measured line height at time of measurements)	0.1	0.1	0.1
	Modeled Field (for measured line height; no adjustment for peak loading needed)	0.1	0.1	0.1
	Measured Field	<0.1	<0.1	<0.1
Site 6 **July 20, 2020**	Peak Model (Application Filing)	0.4	1.1	0.1
	Modeled Field (for measured line height at time of measurements)	0.3	0.4	0.1
	Modeled Field (for measured line height; no adjustment for peak loading needed)	0.3	0.4	0.1
	Measured Field	<0.1	0.4	<0.1

Site # / Date	Condition	Value at Measurement Point: Nearest −ROW Edge	Max on ROW	Nearest +ROW Edge
Site 7 **July 22, 2020**	Peak Model (Application Filing)	0.3	1.1	0.3
	Modeled Field (for measured line height at time of measurements)	0.3	0.4	0.3
	Modeled Field (for measured line height; no adjustment for peak loading needed)	0.3	0.4	0.3
	Measured Field	0.2	0.3	<0.1
Site 8† **July 23, 2020**	Peak Model (Application Filing)	N/A	N/A	N/A
	Modeled Field (for measured line height at time of measurements)	N/A	N/A	N/A
	Modeled Field (for measured line height; no adjustment for peak loading needed)	N/A	N/A	N/A
	Measured Field	N/A	N/A	N/A
Site 9† **July 20, 2020**	Peak Model (Application Filing)	N/A	N/A	N/A
	Modeled Field (for measured line height at time of measurements)	N/A	N/A	N/A
	Modeled Field (for measured line height; no adjustment for peak loading needed)	N/A	N/A	N/A
	Measured Field	N/A	N/A	N/A
Site 10 **July 20, 2020**	Peak Model (Application Filing)	0.2	1.0	0.4
	Modeled Field (for measured line height at time of measurements)	<0.1	0.5	0.3
	Modeled Field (for measured line height; no adjustment for peak loading needed)	<0.1	0.5	0.3
	Measured Field	<0.1	0.4	0.3
Site 11 **July 20, 2020**	Peak Model (Application Filing)	<0.1	4.2	0.9
	Modeled Field (for measured line height at time of measurements)	<0.1	1.8	0.8
	Modeled Field (for measured line height; no adjustment for peak loading needed)	<0.1	1.8	0.8
	Measured Field	<0.1	1.6	0.7

* The Peak Model (Application Filing) did not account for existing distribution lines in this portion of the route. These distribution lines are not often included in modeling, but are included herein because they affected measured field levels. Reported levels in this table may therefore differ slightly from the Application.

† There are no electric fields above ground from underground transmission lines. Therefore, no measurements or modeling of electric fields was performed at these Sites.

Agreement between Calculated EMF Levels in the Application to EMF Levels Adjusted for Peak-Loading and Site-Specific Conditions

Figure A-1 provides a graphical summary of the ROW-edge magnetic-field levels (left) and electric-field levels (right). The ROW-edge values reported in the Application[3,4] are shown on the horizontal axis ("Application Model") and the ROW-edge values calculated in the model adjusted for peak-loading are shown on the vertical axis ("Adjusted Model") with circles representing the –ROW and triangles representing the +ROW. Values above the gray dashed line show where the measured field levels are higher in the Adjusted Model than in the values obtained in the Application Model. Conversely, values below the gray dashed line show locations where the measured values in the Adjusted Model were lower at that site than those in the Application Model.

The results shown in Figure A-1 indicate that modeled magnetic-field levels (adjusted to peak conditions) are the same or less than those submitted in the Application (Appendix 41 and 41a) when adjusted to peak-loading conditions. This serves to show that the modeling assumptions and calculations used in the Application were generally conservative so as to overestimate actual magnetic-field levels. The exceptions to this observation are Site 3 in which the loading of the underbuilt 380 line at the time of measurements exceeded that from the projected peak loading, and at Sites 2 and 9 in which the configuration of the duct bank and burial of the cables differ from that of the Application (See Table D-1).

Some calculation levels projected to peak loading are slightly higher than in the Application due to slight variations in the actual configuration of the line compared to that assumed in the Application. At locations where this occurs the figures in Appendix C provide additional context around differences between the Application model ("Peak Model (SEC Filing)") and the model of the configuration of the lines at the adjusted to peak loading ("Adjust Measure to Peak Load")

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3 Some modeling results herein reflect corrections to typographical errors identified in the output tables of the Application. The values in Table A-1 and A-2 reflect these corrected values.

4 Magnetic-field results for Site 8 have been excluded from this plot because the shielding effect of the mattresses renders projection results to be uninformative and would adversely affect the scale of the axis. Full results are found in Table A-1 and A-2.

and why those differences were likely observed. For example, at Site 1 the only viable measurement location occurred at a transition span of the distribution line and at Site 10 the orientation of the F107 transmission line (two conductors toward the edge of the ROW and one conductor toward the center off the ROW) was flipped compared to the configuration used in the Application. As a result, the measured field levels in these sections were slightly different than what was used for modeling.

Modeled electric-field levels (adjusted to peak conditions) are generally similar to those submitted in the Application with *de minimus* variations within the range of 0.05 to 0.1 kV/m. Tables A-1 and A-2, above, contain similar comparisons for all measured cross sections, with graphical comparisons provided in Appendix B.

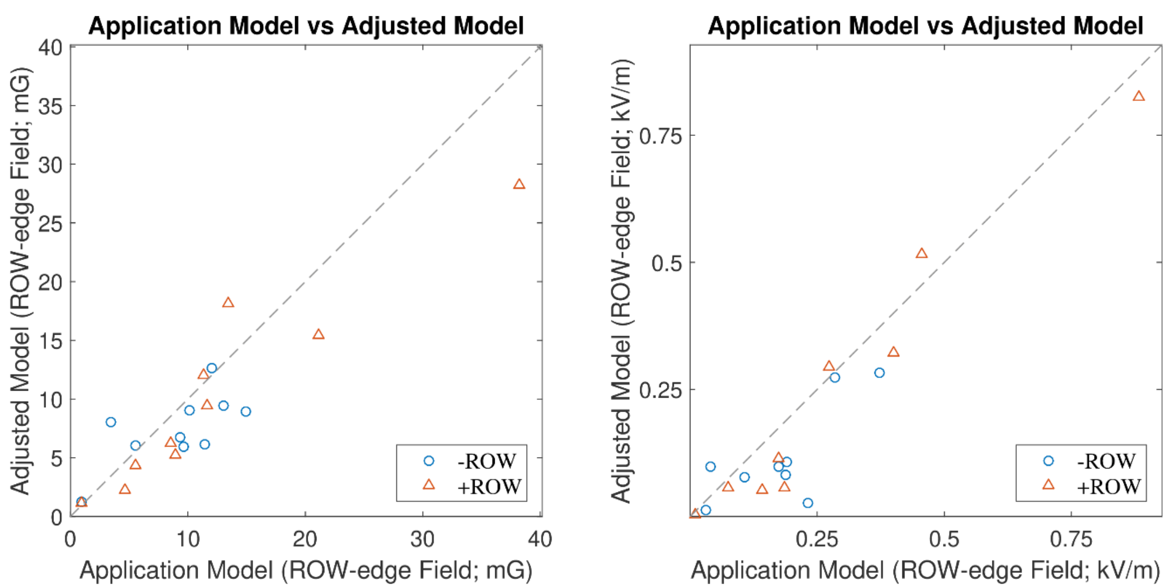

Figure A-1. Comparison of modeled EMF levels at peak loading from the Application (Application Model) and those for the model field, adjusted to peak load conditions (Adjusted Model).

ROW-edge magnetic-field levels (left) and electric-field levels (right).

Appendix B

Graphical Profiles of Measured and Calculated EMF Levels at Measurement Sites

Results for each of the 11 measurement sites are presented below. Both electric fields and magnetic fields were measured at each site, except at Site 8 (Little Bay Crossing), and at Site 9 (through the Frink Farm) where only magnetic-field levels were measured because the F107 transmission line was constructed underground). For each measurement site, an aerial photograph showing the approximate location of the ROW edges and measurement locations is included in Appendix C.

Electric- and magnetic-field levels are presented in separate figures. In each of these figures, actual measurement values are shown by a series of red '+' markers. Magnetic-field levels were measured every 1 to 3 feet using a survey wheel in conjunction with the magnetic-field meter. The series of '+' markers sometimes appear as a thick, jagged line due to the density of measurements. In contrast, electric-field measurements were performed at individual measurement locations separated by approximately 3 to 30 feet, so generally appear as discrete '+' symbols indicating the measured value. In each figure, three separate models are included. An orange 'dash-dot' line shows the peak-loading model submitted in the Application, a solid dark blue line shows the model developed using the As-Measured configuration (and loading) at the time of measurements, a dashed light blue line shows the model developed by adjusting the As-Measured Model to peak loading conditions, while individual measurements are shown in corresponding red '+' markers.

Note the vertical scale is different in each of the figures.

Site 1

Measurements at Site 1 (north of Madbury Rd.) were performed on July 21, 2020.

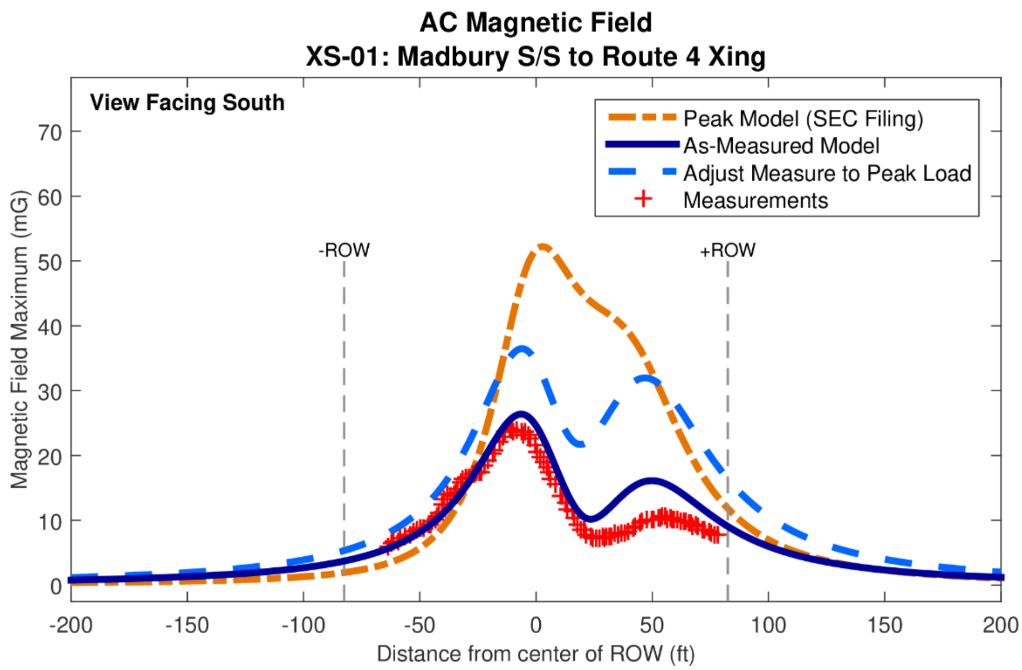

Figure B-1. Measured and modeled magnetic-field levels at Site 1.

Magnetic-field levels from measurements adjusted to peak loading (dashed blue line) were slightly higher than those reported for peak loading in the Application. This is primarily due to the fact that the measurement location was performed on a transition span of the distribution line (slightly to the left of the centerline) so the as-built model and Application model have slightly different assumptions which affect results at both ROW edges (due to the mutual cancellation of magnetic fields from adjacent power lines). The phasing of the adjacent distribution line (determined from EMF measurements) differed from that used in the Application model.

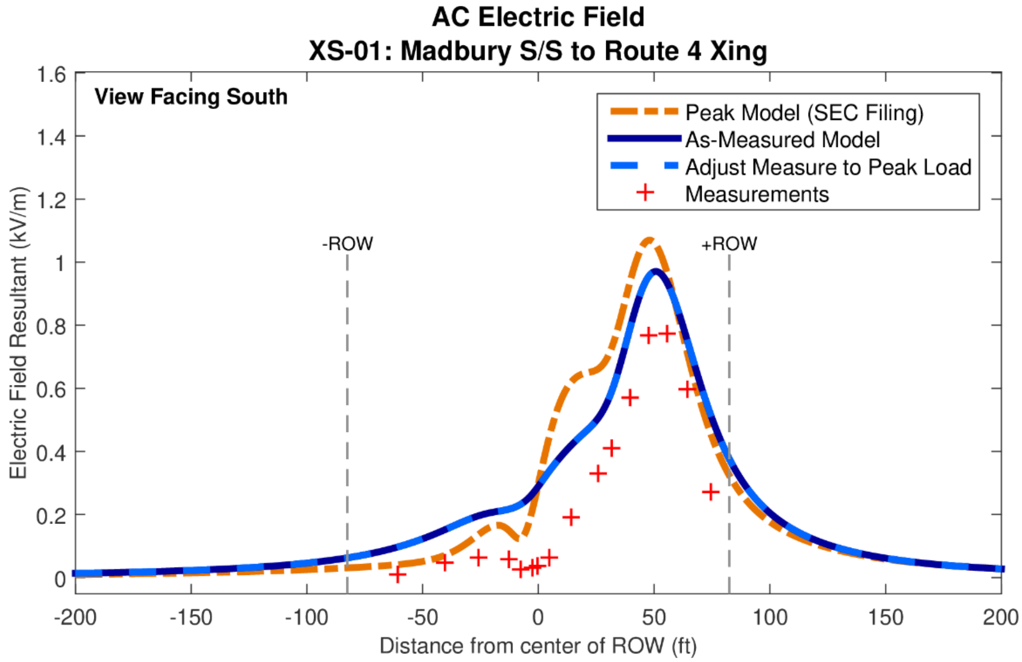

Figure B-2. Measured and modeled electric-field levels at Site 1.

Site 2

Measurements at Site 2 (in UNH parking lot A) were performed on July 21, 2020.

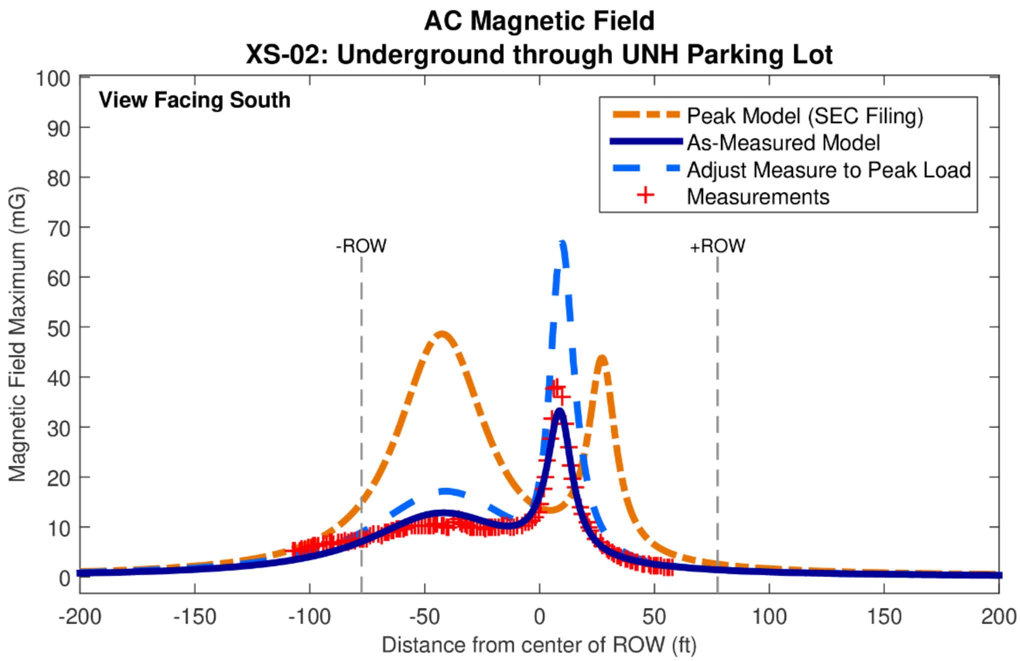

Figure B-3. Measured and modeled magnetic-field levels at Site 2.

Magnetic-field levels from measurements adjusted to peak loading (dashed blue line) directly above the duct bank were higher than in the Application because of a shallower burial depth at the location of measurements than was assumed in the Application. Field levels, however, at the edge of the ROW and beyond are similar to or lower than in the Application.

The measured magnetic field above the F107 duct bank was higher than the modeled value for this measurement site and is based upon the as-built drawings indicating a burial depth of approximately 2.25 feet (to the top of the duct bank). The best match between measurements and modeling occurred for a burial depth of approximately 1.5 feet (to the top of the duct bank). However, modeling does not include the effects of ground continuity conductors which could explain the apparent difference.

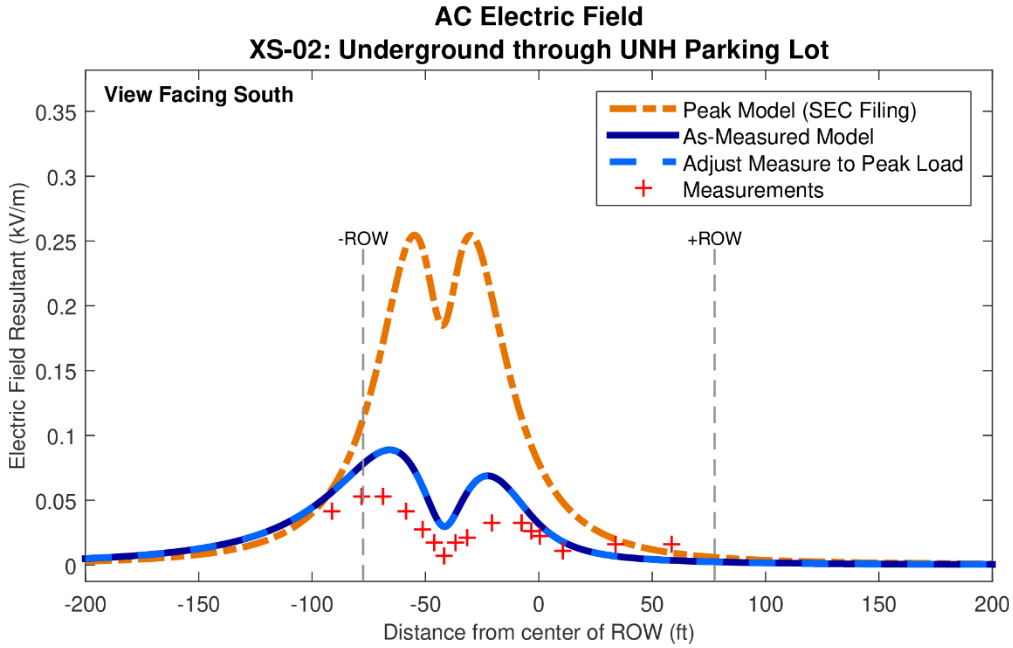

Figure B-4. Measured and modeled electric-field levels at Site 2.

Site 3

Measurements at Site 3 (off Water Works Rd.) were performed on July 21, 2020.

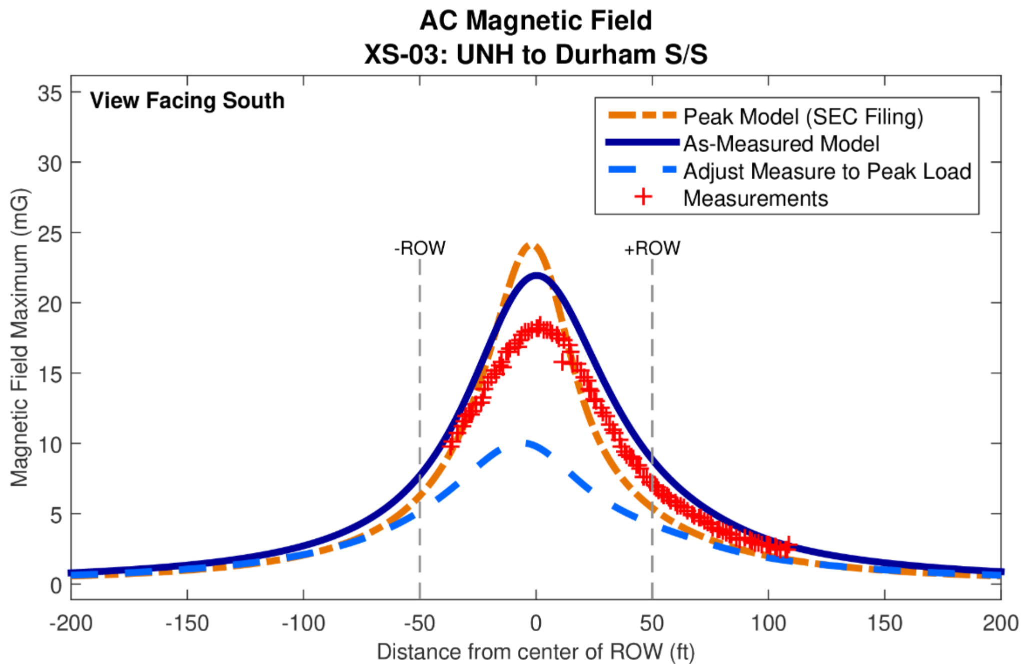

Figure B-5. Measured and modeled magnetic-field levels at Site 3.

Magnetic-field levels at the time of measurements (red '+' symbols) as well as the As-Measured Model (solid blue line) were higher than reported in the Application because the loading of the underbuilt 380 distribution line at the time of measurements exceeded the level assumed in the Application. The calculations are therefore dominated by the higher currents (and lower clearance height) of the distribution line.

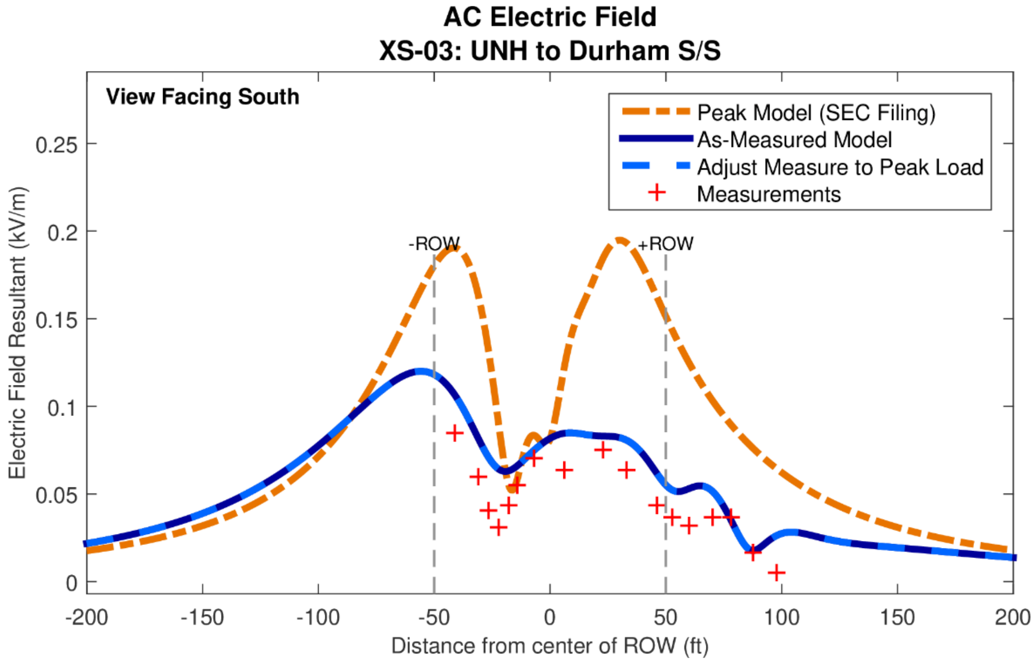

Figure B-6. Measured and modeled electric-field levels at Site 3.

Site 4

Measurements at Site 4 (north of Bennett Rd.) were performed on July 22, 2020.

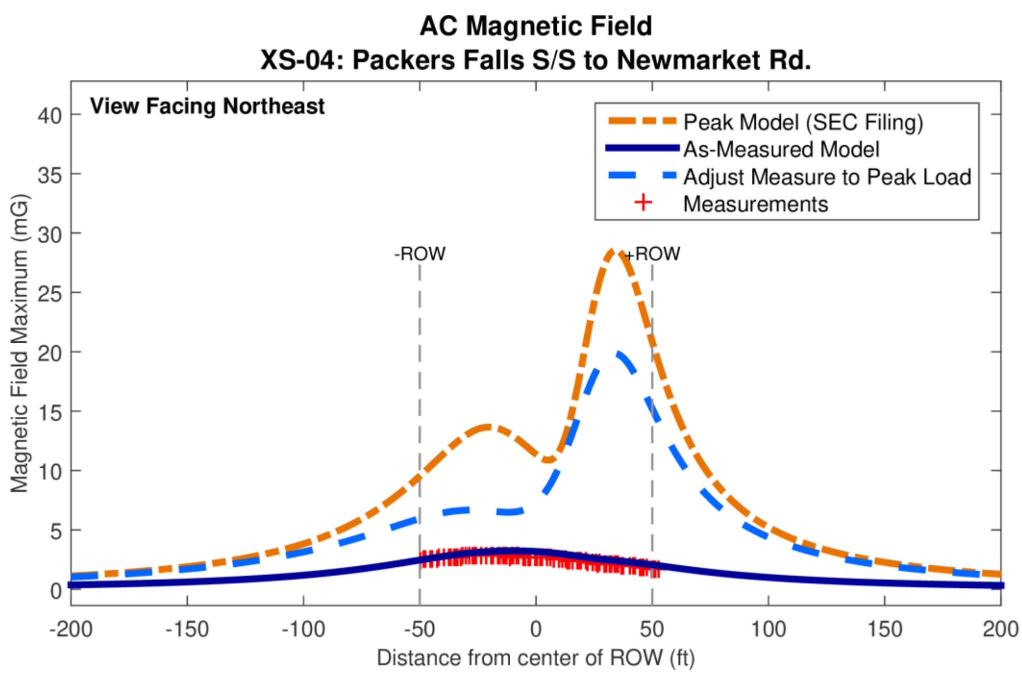

Figure B-7. Measured and modeled magnetic-field levels at Site 4.

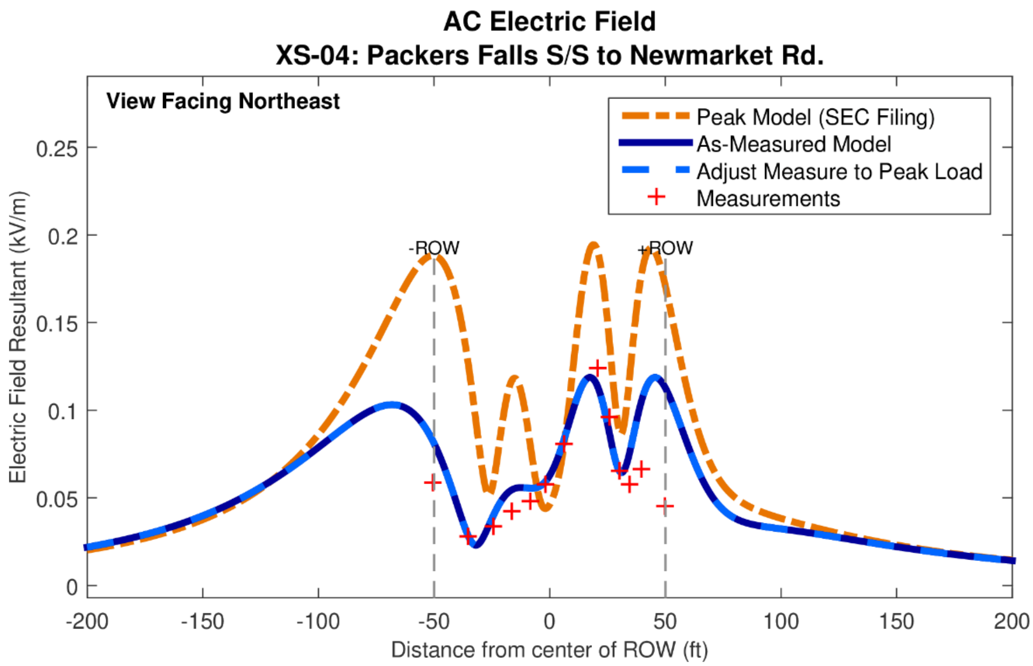

Figure B-8. Measured and modeled electric-field levels at Site 4.

Site 5

Measurements at Site 5 (east of Sandy Brook Rd.) were performed on July 24, 2020.

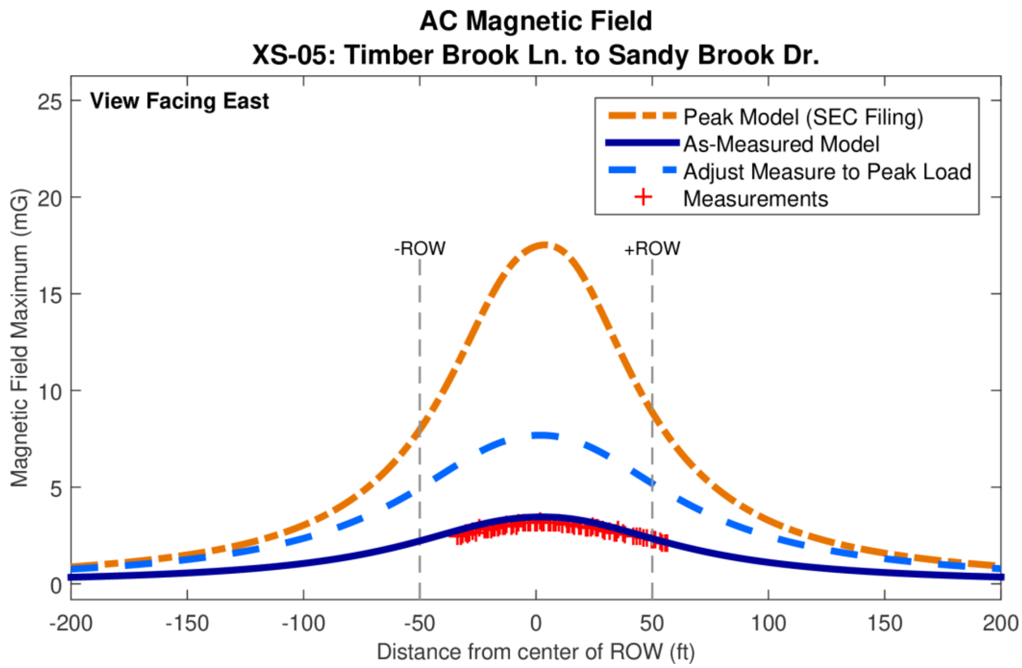

Figure B-9. Measured and modeled magnetic-field levels at Site 5.

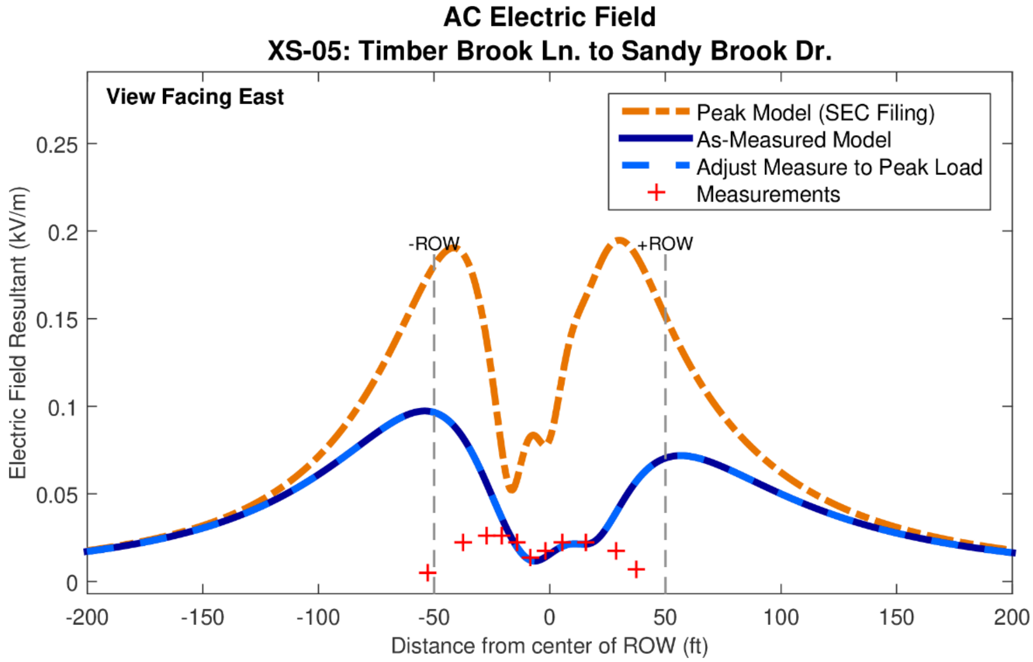

Figure B-10. Measured and modeled electric-field levels at Site 5.

Site 6

Measurements at Site 6 (north of Durham Point Rd.) were performed on July 20, 2020.

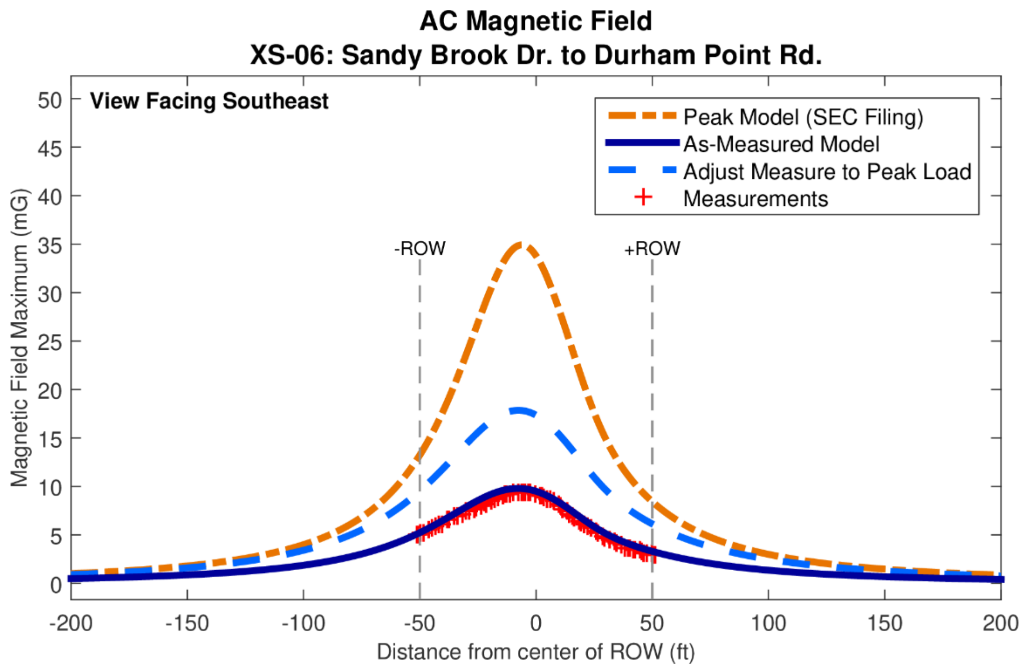

Figure B-11. Measured and modeled magnetic-field levels at Site 6.

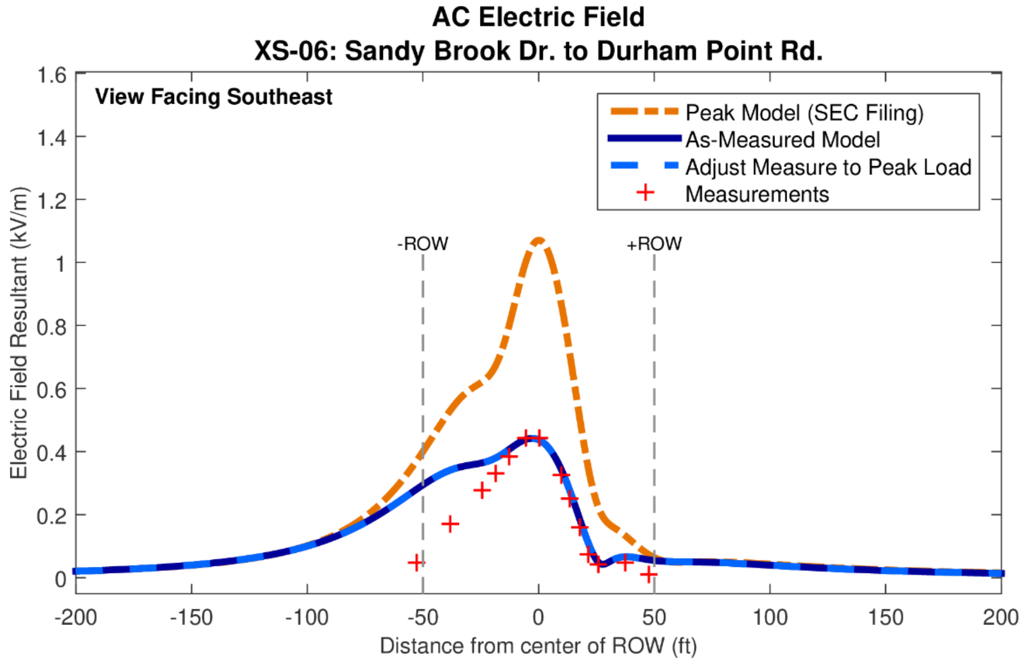

Figure B-12. Measured and modeled electric-field levels at Site 6.

Site 7

Measurements at Site 7 (south of Durham Point Rd.) were performed on July 22, 2020.

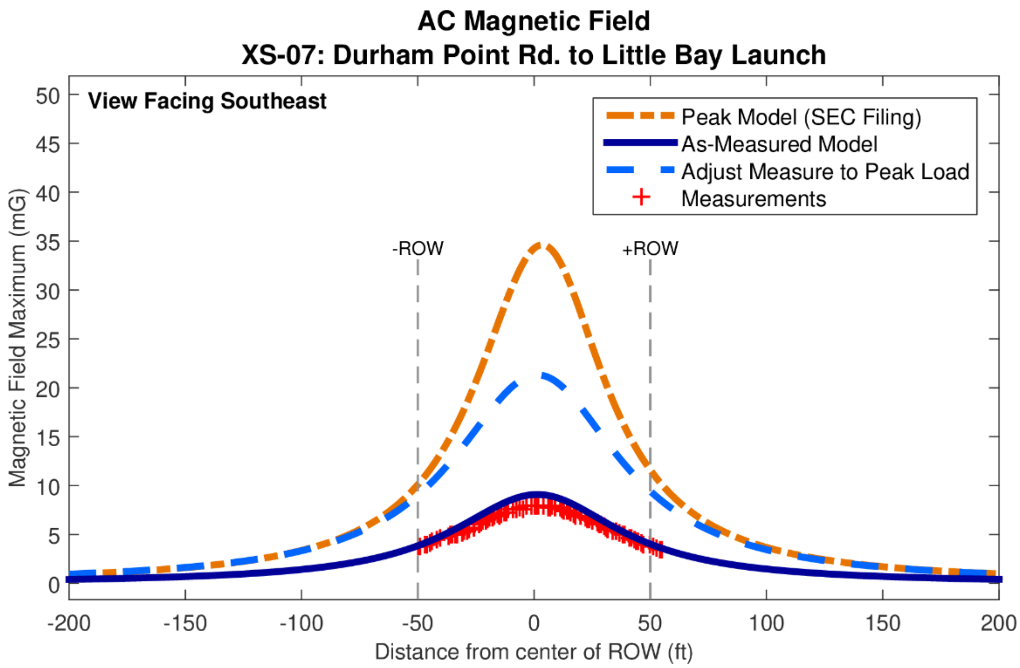

Figure B-13. Measured and modeled magnetic-field levels at Site 7.

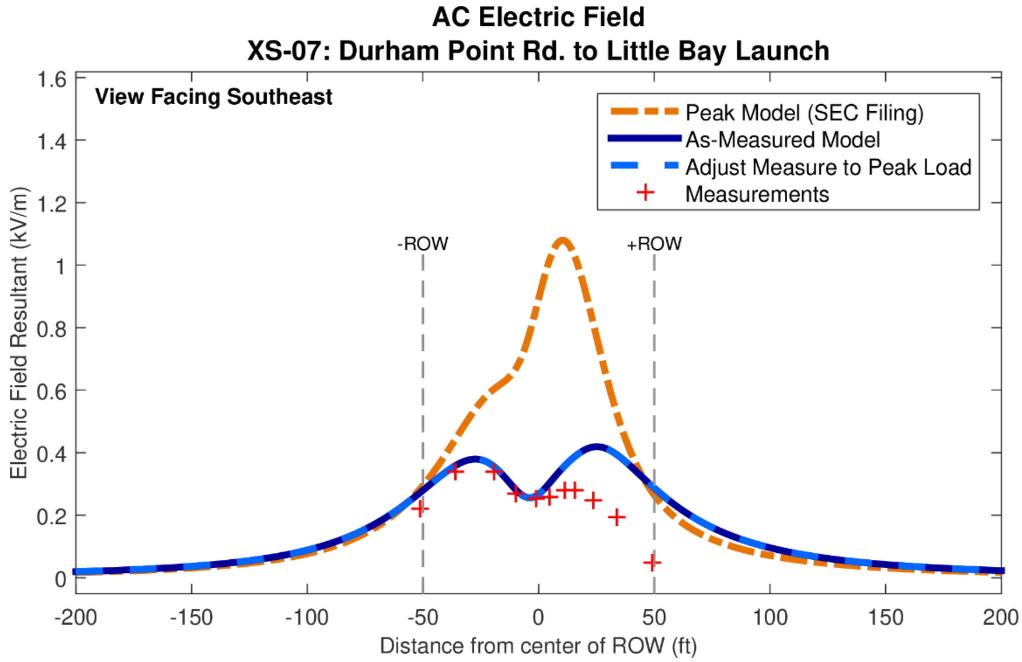

Figure B-14. Measured and modeled electric-field levels at Site 7.

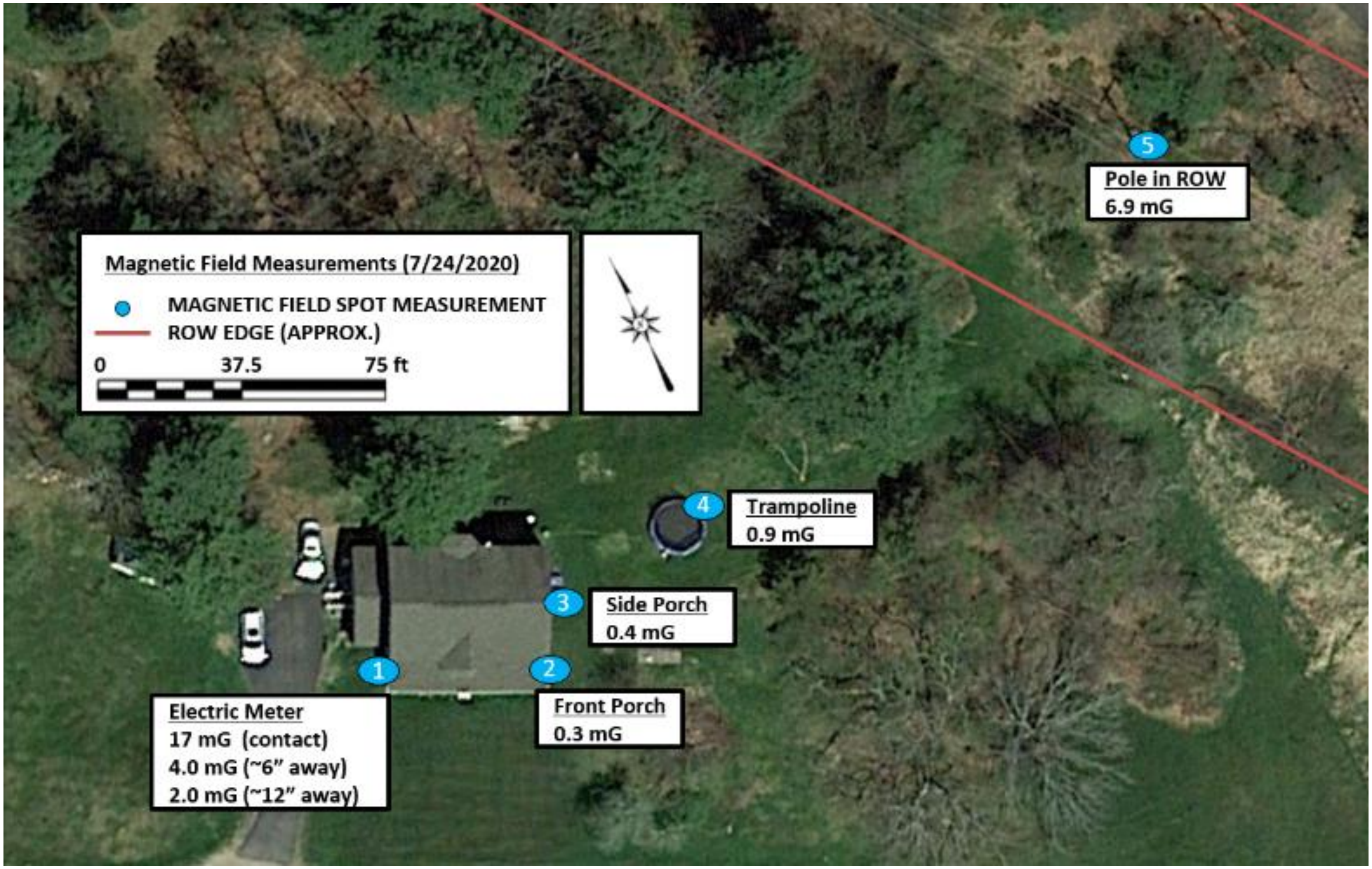

Figure B-15. Measurements of magnetic field levels on Fitch Property (along the same Line Segment as Site 7)

Pre-construction magnetic field levels at the electric meter were slightly higher while at all other measurement locations field levels were similar to or slightly lower than Post-construction measurements.

Site 8

Measurements at Site 8 (west side of Little Bay) were performed on July 23, 2020.

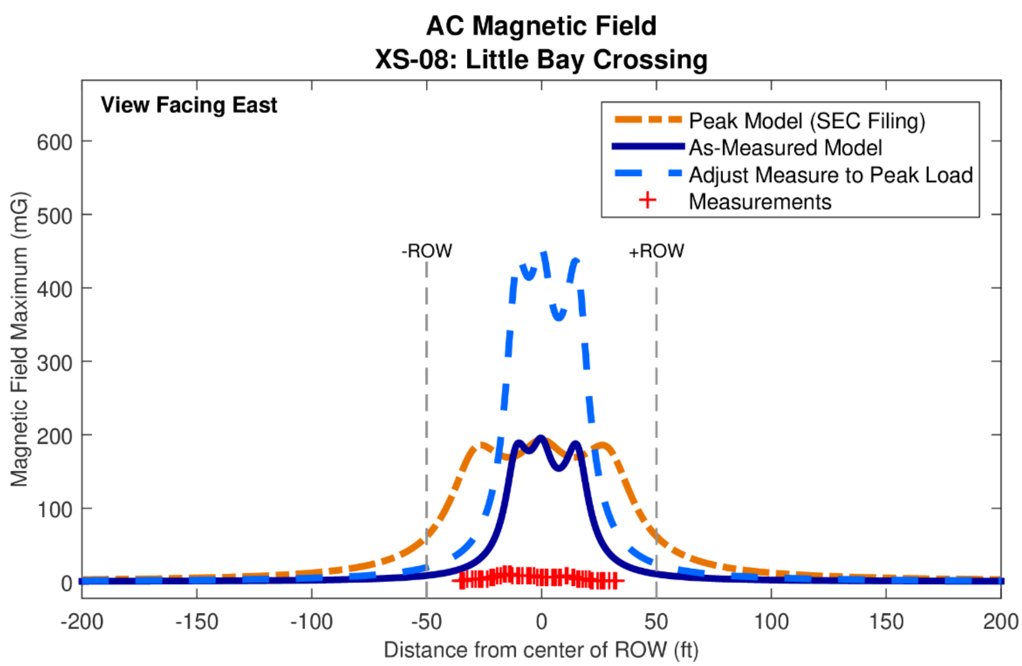

Figure B-16. Measured and modeled magnetic-field levels at Site 8.

Cables are covered by concrete mattresses. Despite shallower burial at the location of measurements than was assumed in the Application, the magnetic field levels above ground were far lower than predicted, likely due to shielding from the rebar in the concrete mattresses.

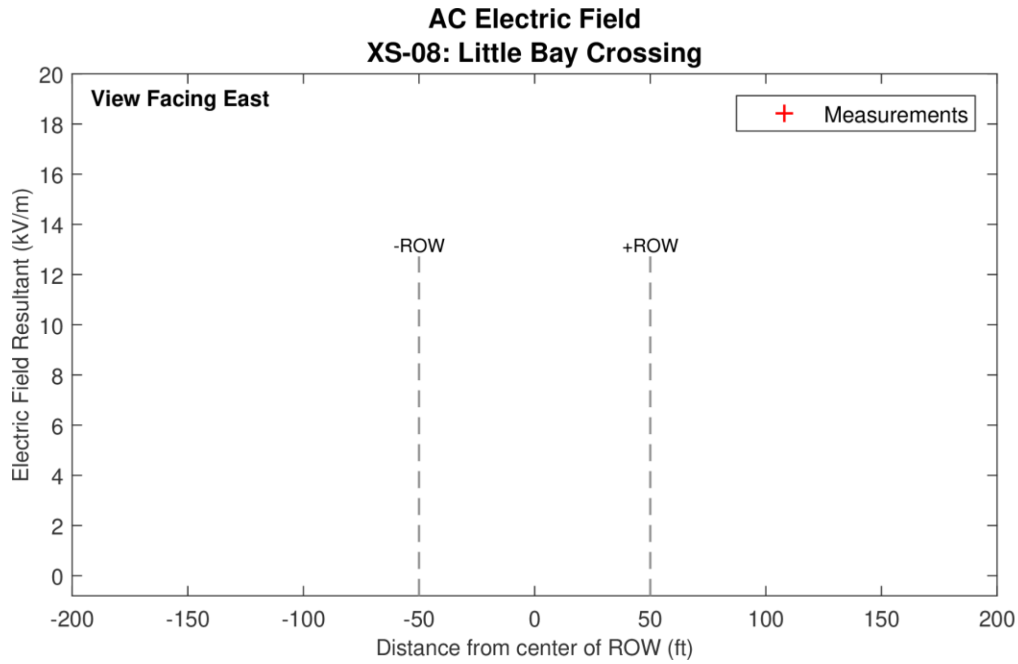

Figure B-17. No electric-field measurements were performed at Site 8.

There is no direct source of electric field above ground or above the bottom of the crossing. No electric field was calculated post-construction because the voltage on the conductors of the F107 transmission line will not produce a direct electric field outside the cable.

Site 9

Measurements at Site 9 (west of Nimble Hill Rd.) were performed on July 23, 2020.

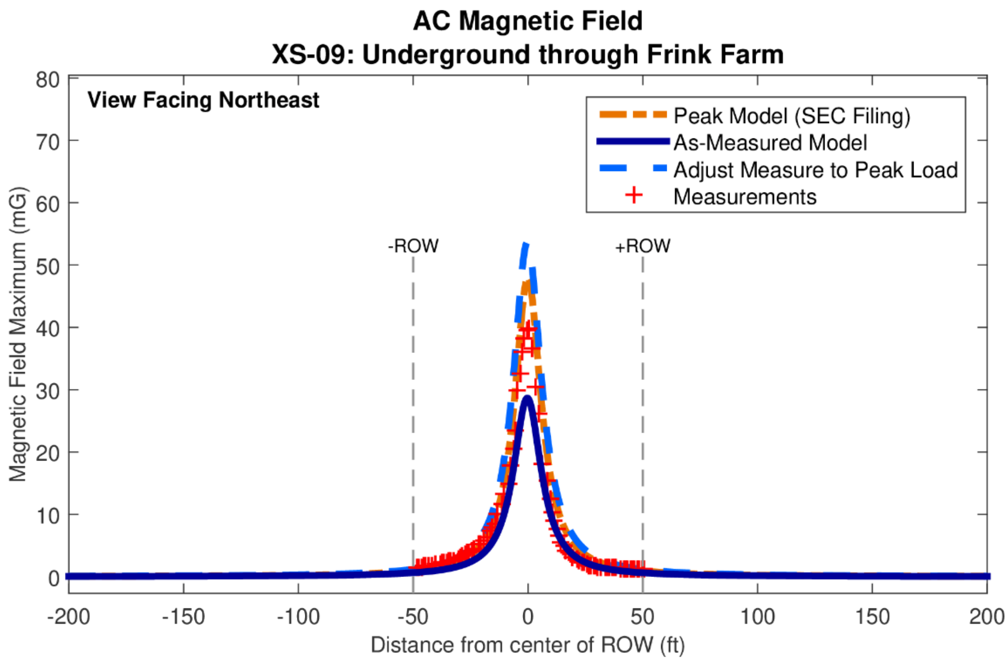

Figure B-18. Measured and modeled magnetic-field levels at Site 9.

Magnetic-field levels from measurements adjusted to peak loading (dashed blue line) directly above the duct bank were higher than those modeled in the Application because of a shallower burial depth than was assumed in the Application. At the ROW edges, magnetic-field levels from measurements adjusted to peak loading are slightly higher than reported in the Application, but the difference between the two is *de minimus*.

The measured magnetic field above the F107 duct bank was higher than the modeled value for this measurement site and is based upon the as-built drawings indicating a burial depth of approximately 3 feet (to the top of the duct bank). The best match between measurements and modeling occurred for a burial depth of approximately 1.75 feet (to the top of the duct bank). However, modeling does not include the effects of ground continuity conductors which could explain the apparent difference.

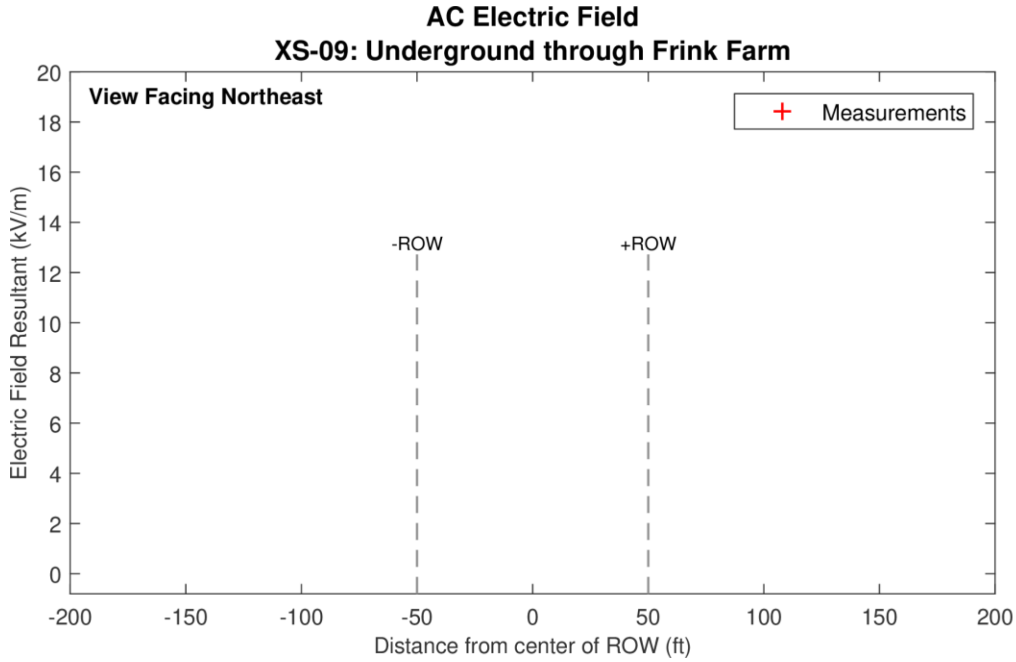

Figure B-19. No electric fields measurements were performed at Site 9.

The F107 transmission line is constructed underground in this section of the route and will therefore not be a direct source of electric fields above ground.

Site 10

Measurements at Site 10 (north of Fox Point Rd.) were performed on July 20, 2020.

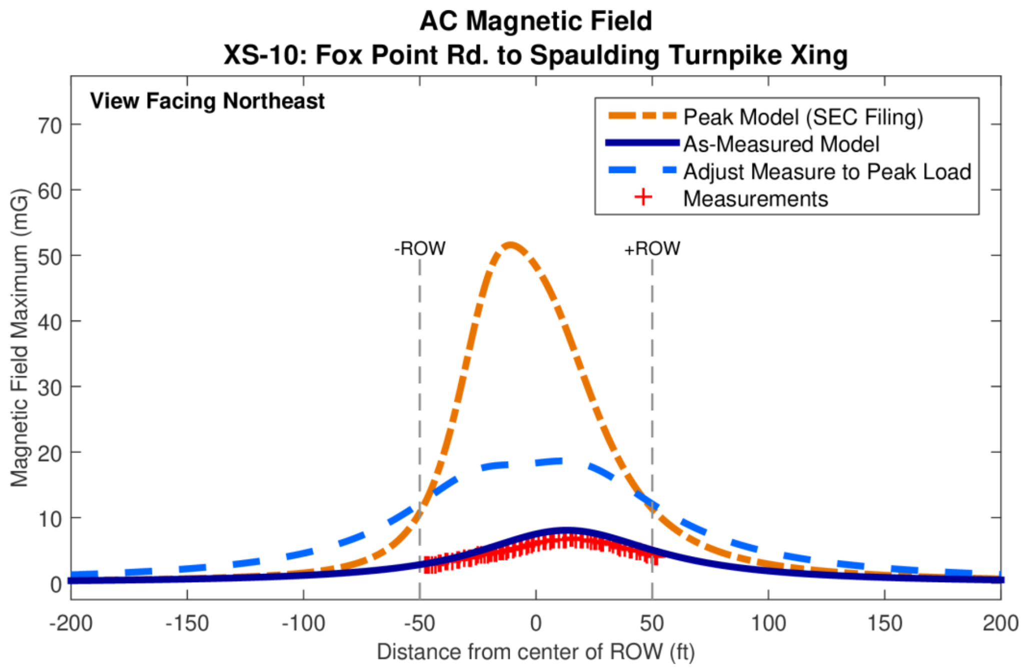

Figure B-20. Measured and modeled magnetic-field levels at Site 10.

Magnetic-field levels from measurements adjusted to peak loading at the ROW edges were slightly higher than in the Application because on the span at which measurements were performed the orientation of the F107 transmission line (two conductors toward the edge of the ROW and one conductor toward the center off the ROW) was flipped compared to the configuration assumed in the Application.

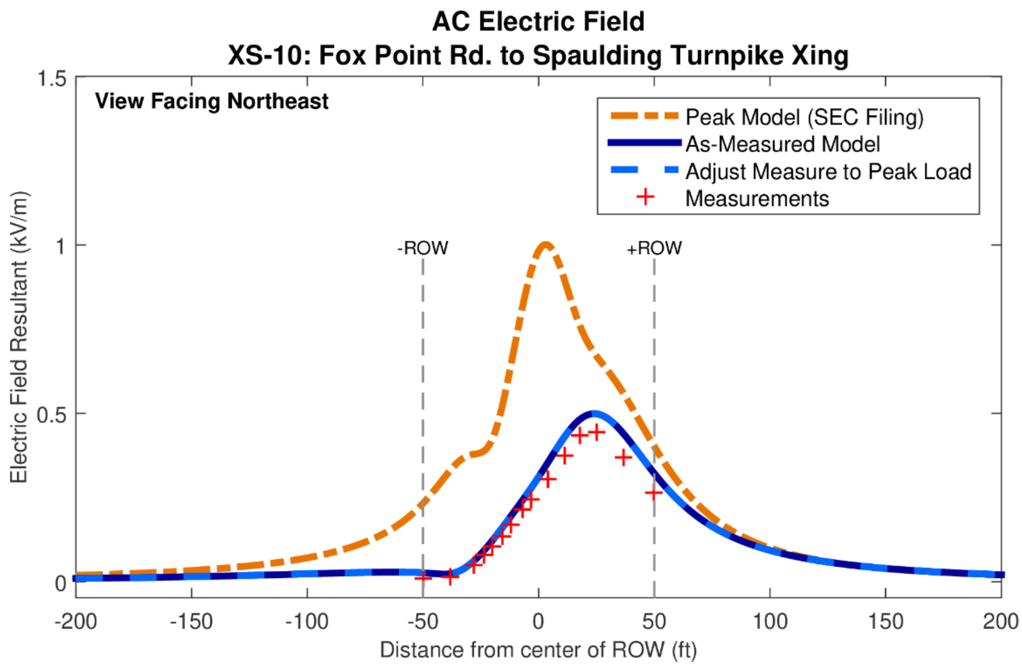

Figure B-21. Measured and modeled electric-field levels at Site 10.

Site 11

Measurements at Site 11 (in the Mall parking lot) were performed on July 20, 2020.

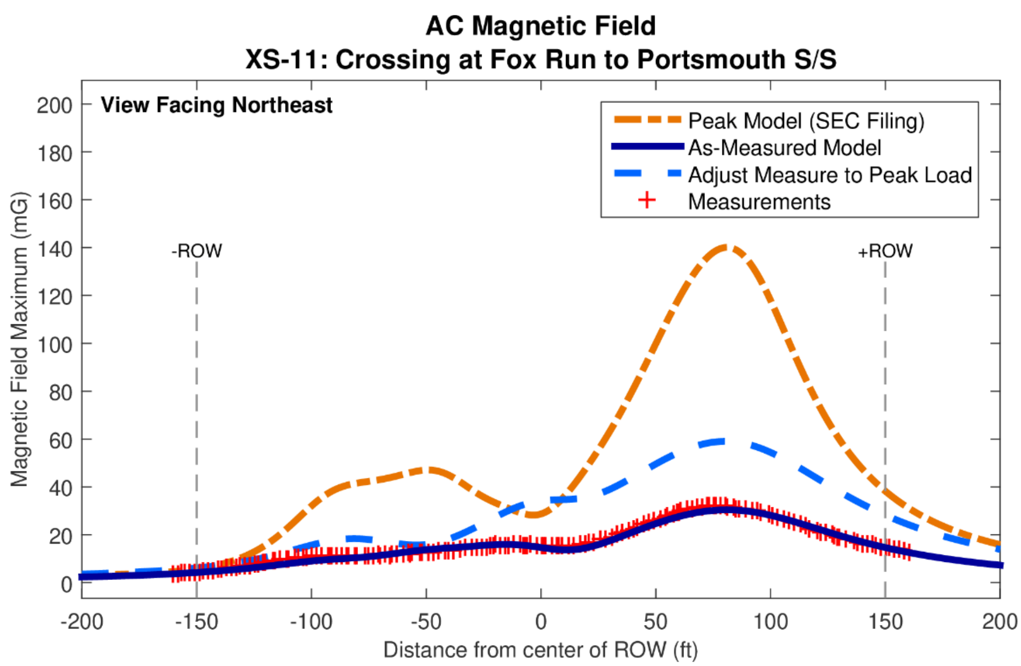

Figure B-22. Measured and modeled magnetic-field levels at Site 11.

Magnetic-field levels from measurements adjusted to peak loading at the −ROW edge were slightly higher than in the Application because (as indicated in the Application) the spacing between the E194 and F107 transmission lines varies along this portion of the route. The Application model assumed that the horizontal spacing between the conductors was 55 feet while the spacing between structures at the location of the measurements was approximately 39 feet. The phasing of the E194 and 3135 transmission lines (determined from EMF measurements) differed from that used in the Application model.

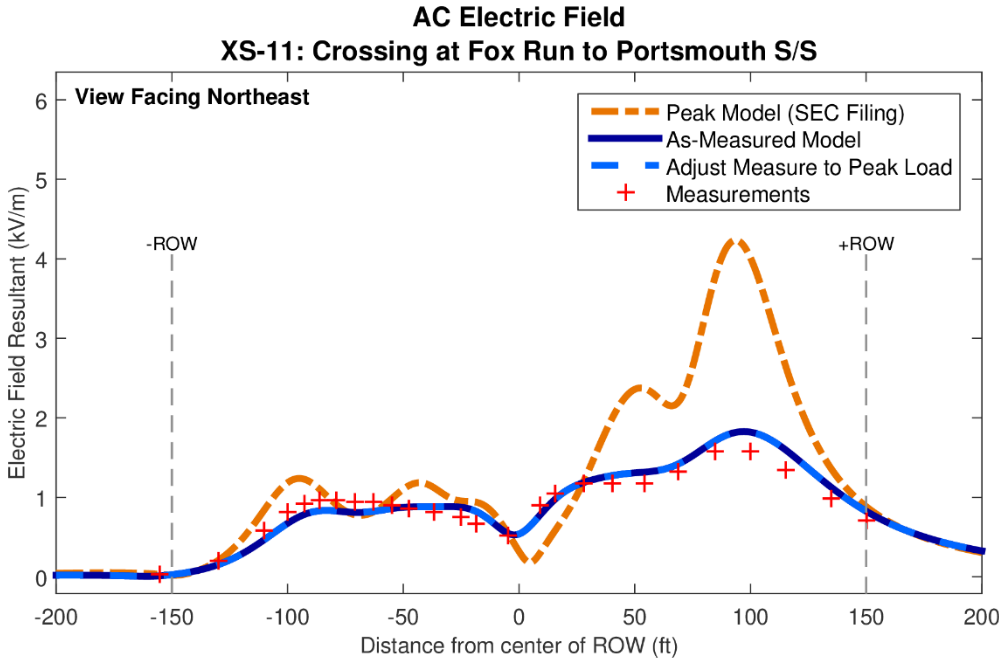

Figure B-23. Measured and modeled electric-field levels at Site 11.

Appendix C

Aerial Maps of Measurement Sites

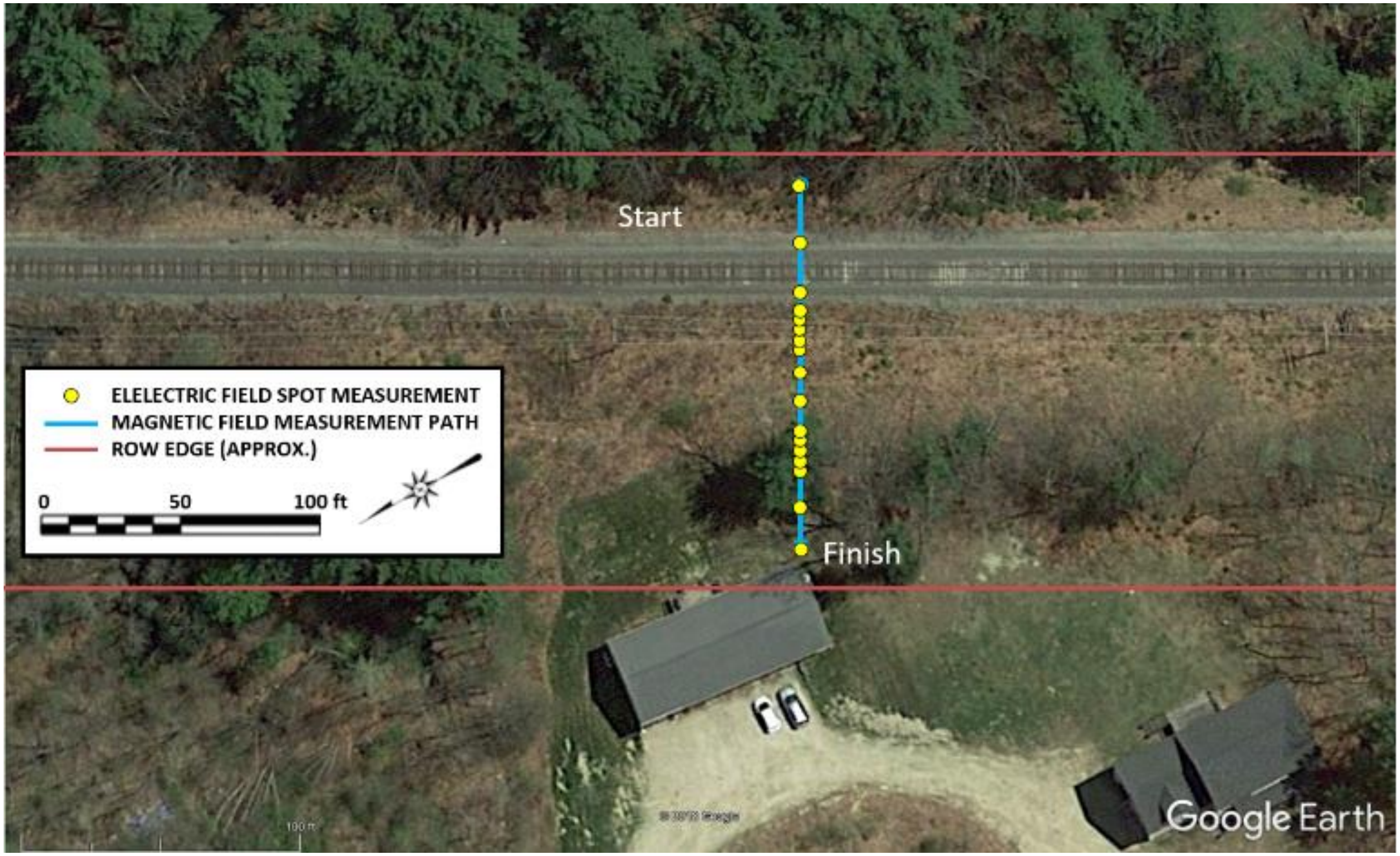

Figure C-1. Aerial photograph of Measurement Site 1 (north of Madbury Rd.) showing the approximate location of the magnetic-field measurement path and electric-field spot measurements performed on July 21, 2020.

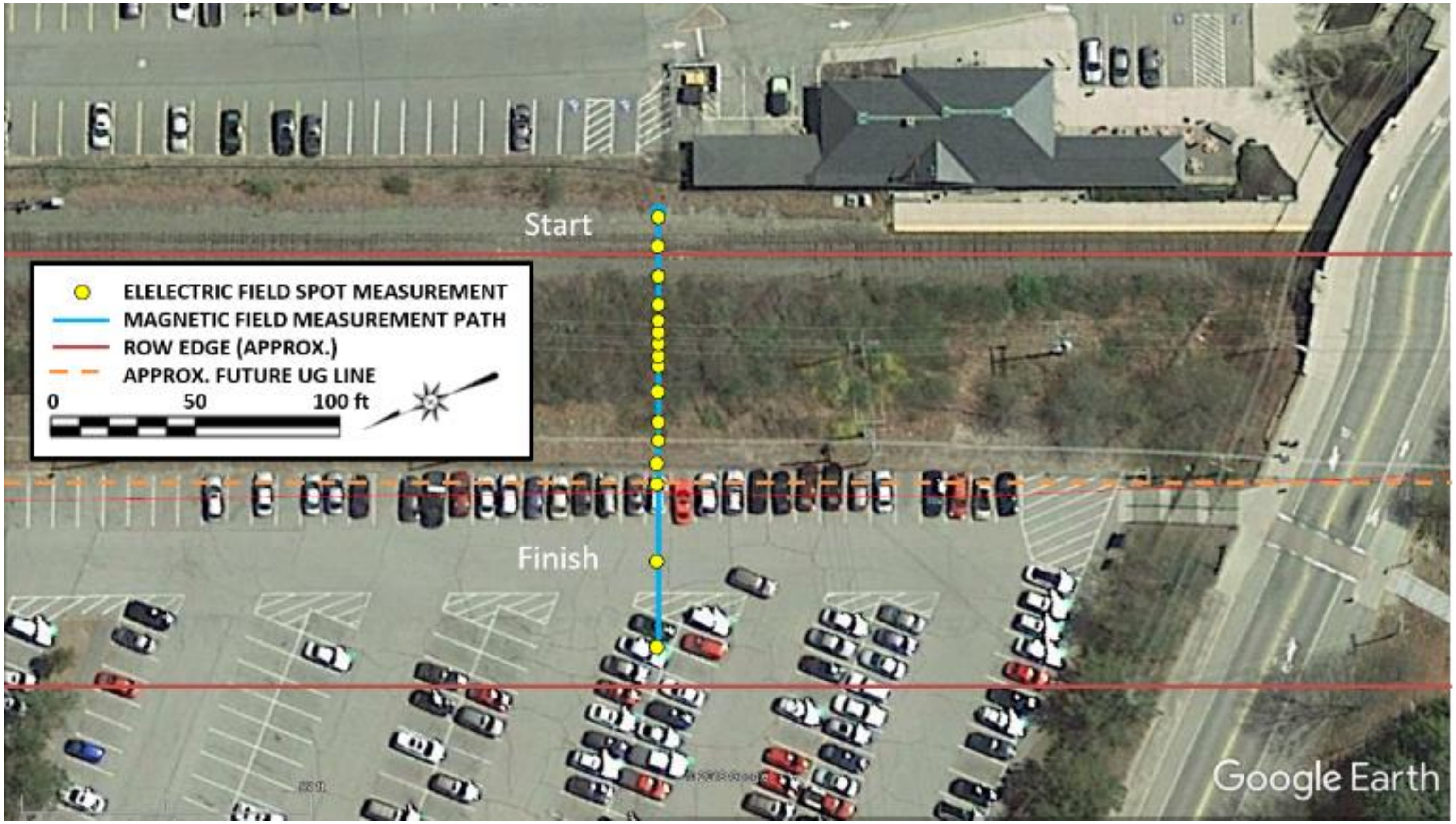

Figure C-2. Aerial photograph of measurement Site 2 (UNH Parking Lot A) showing the approximate location of the magnetic-field measurement path and electric-field spot measurements performed on July 21, 2020.

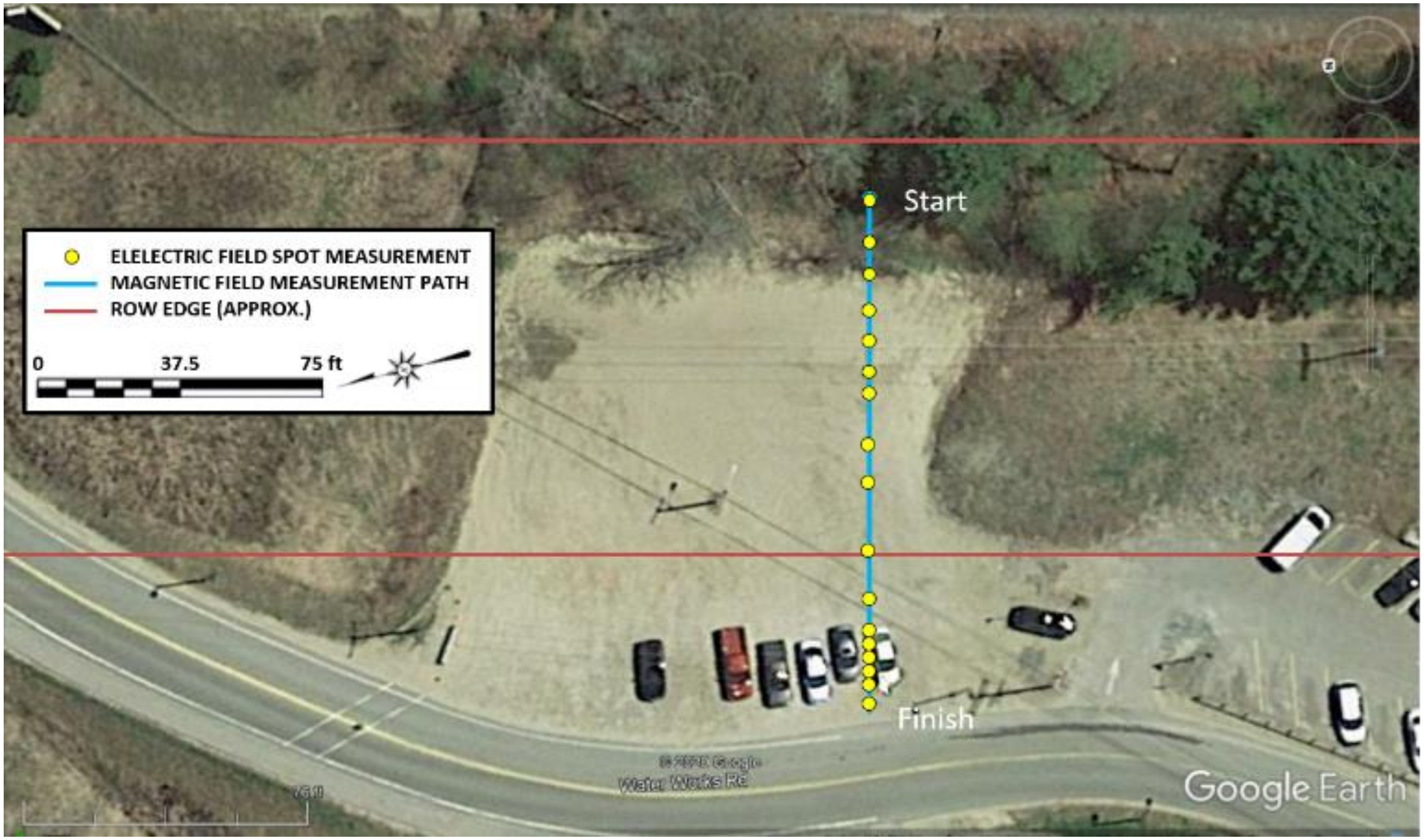

Figure C-3. Aerial photograph of measurement Site 3 (off Waterworks Rd.) showing the approximate location of the magnetic-field measurement path and electric-field spot measurements performed on July 21, 2020.

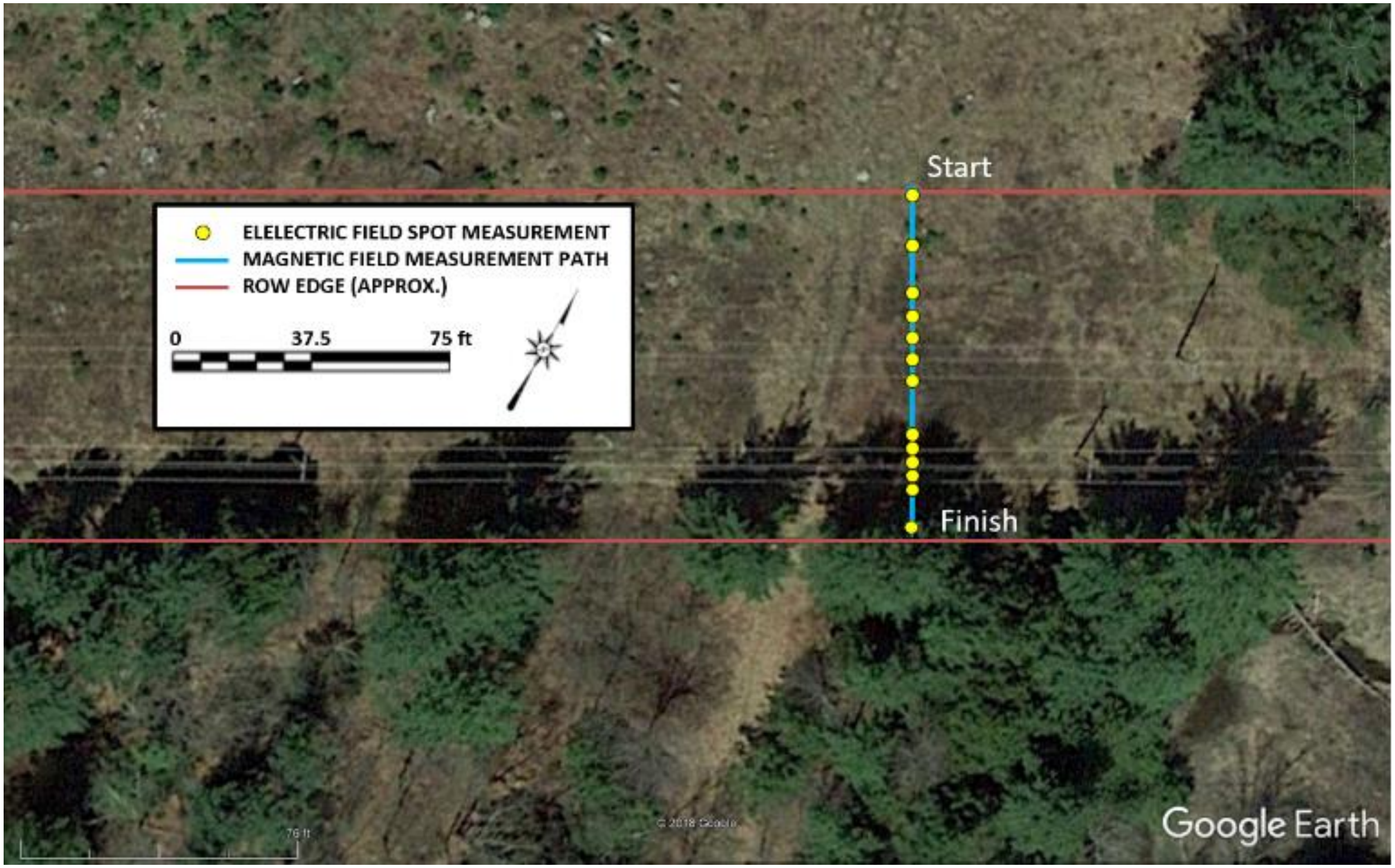

Figure C-4. Aerial photograph of measurement Site 4 (north of Bennett Rd.) showing the approximate location of the magnetic-field measurement path and electric-field spot measurements performed on July 22, 2020.

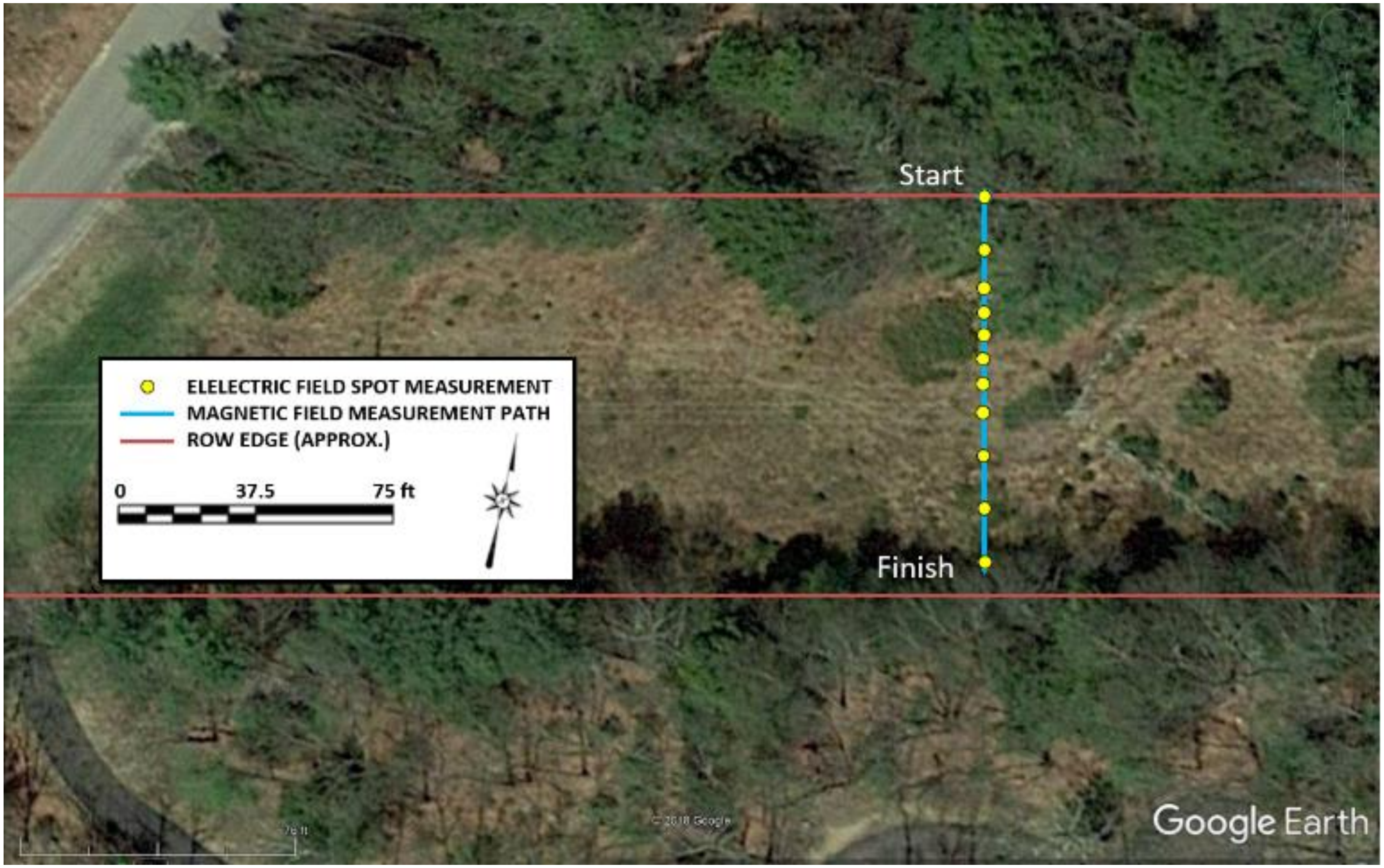

Figure C-5. Aerial photograph of measurement Site 5 (east of Sandy Brook Rd.) showing the approximate location of the magnetic-field measurement path and electric-field spot measurements performed on July 24, 2020.

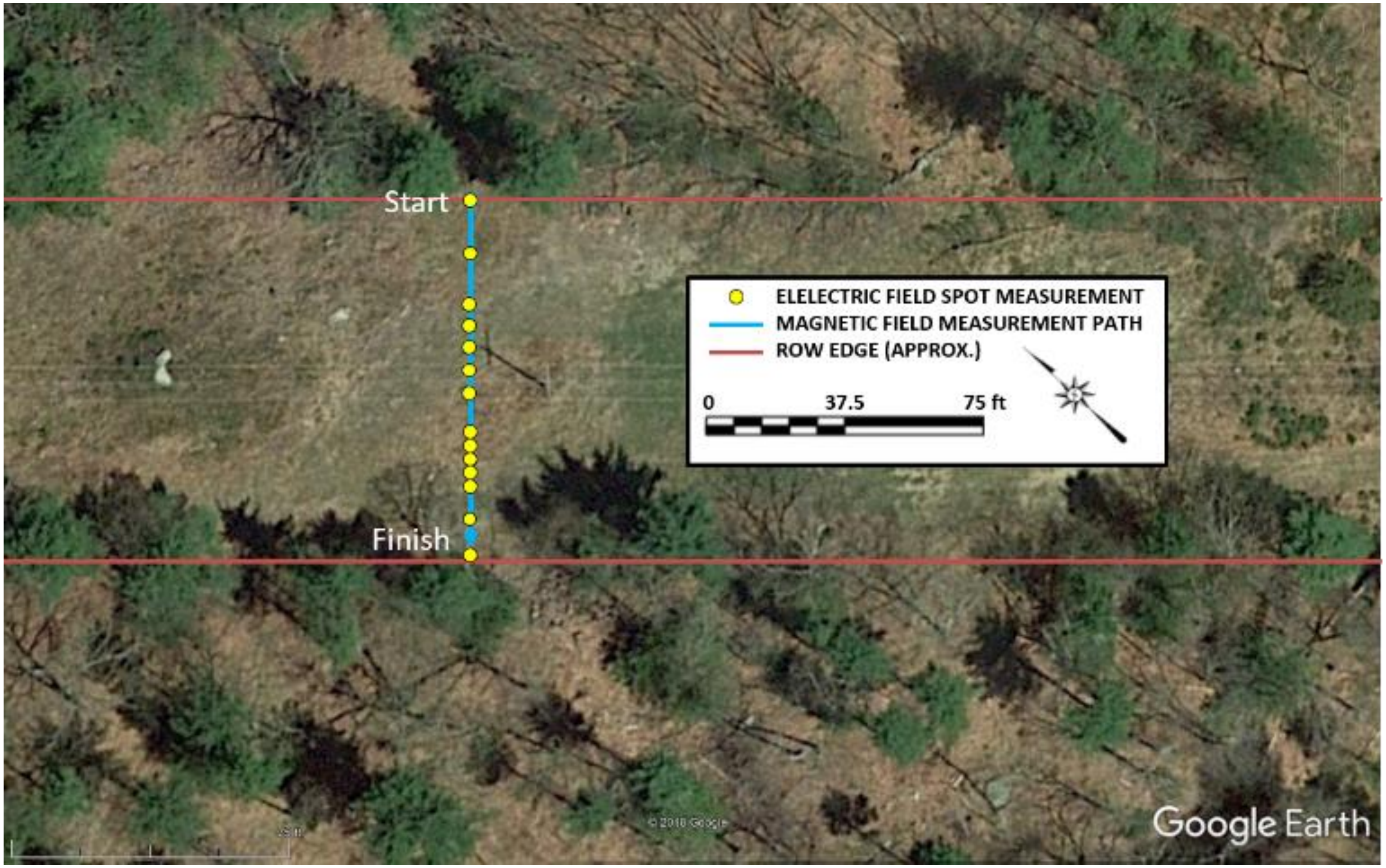

Figure C-6. Aerial photograph of measurement Site 6 (north of Durham Point Rd.) showing the approximate location of the magnetic-field measurement path and electric-field spot measurements performed on July 20, 2020.

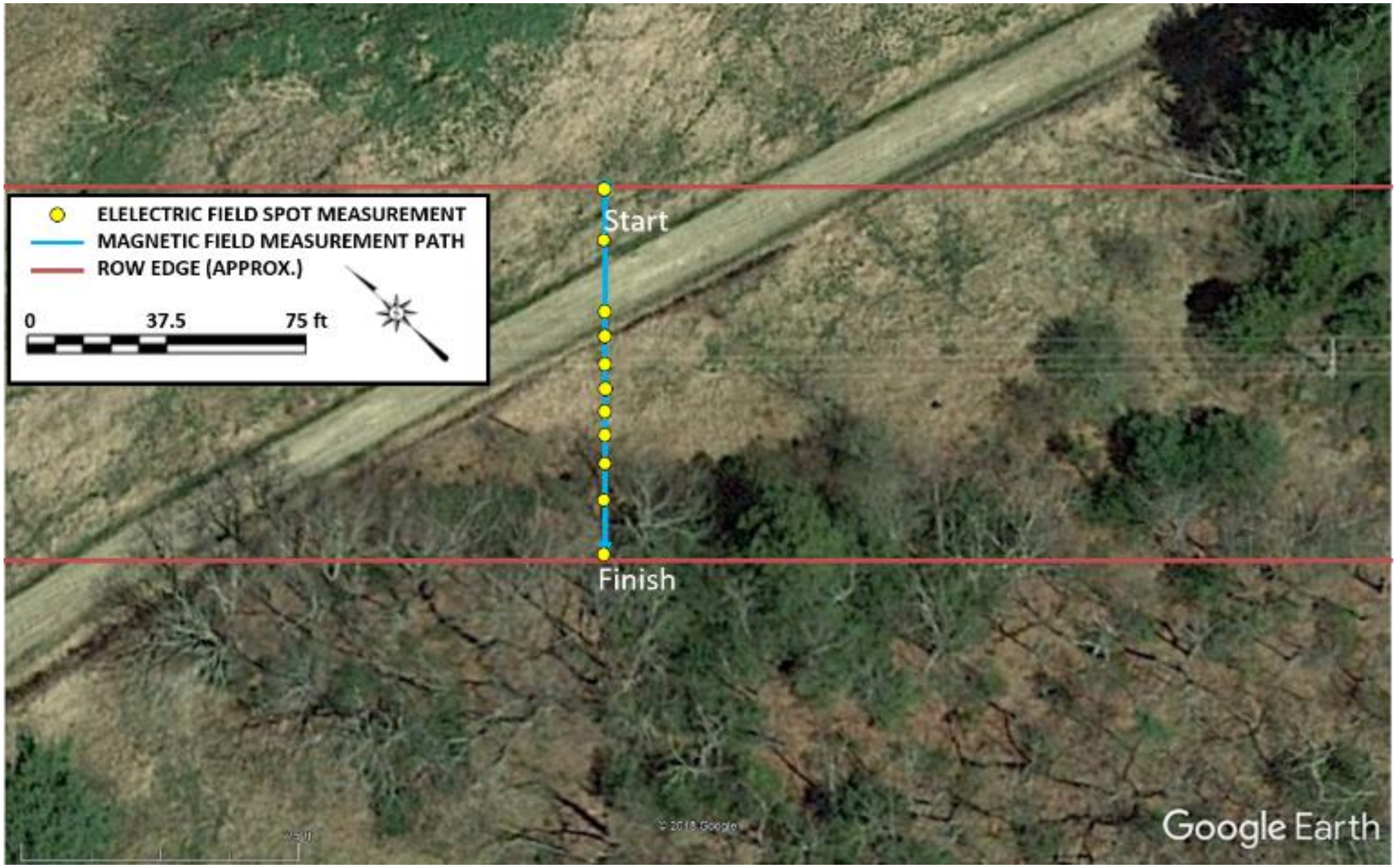

Figure C-7. Aerial photograph of measurement Site 7 (south of Durham Point Rd.) showing the approximate location of the magnetic-field measurement path and electric-field spot measurements performed on July 22, 2020.

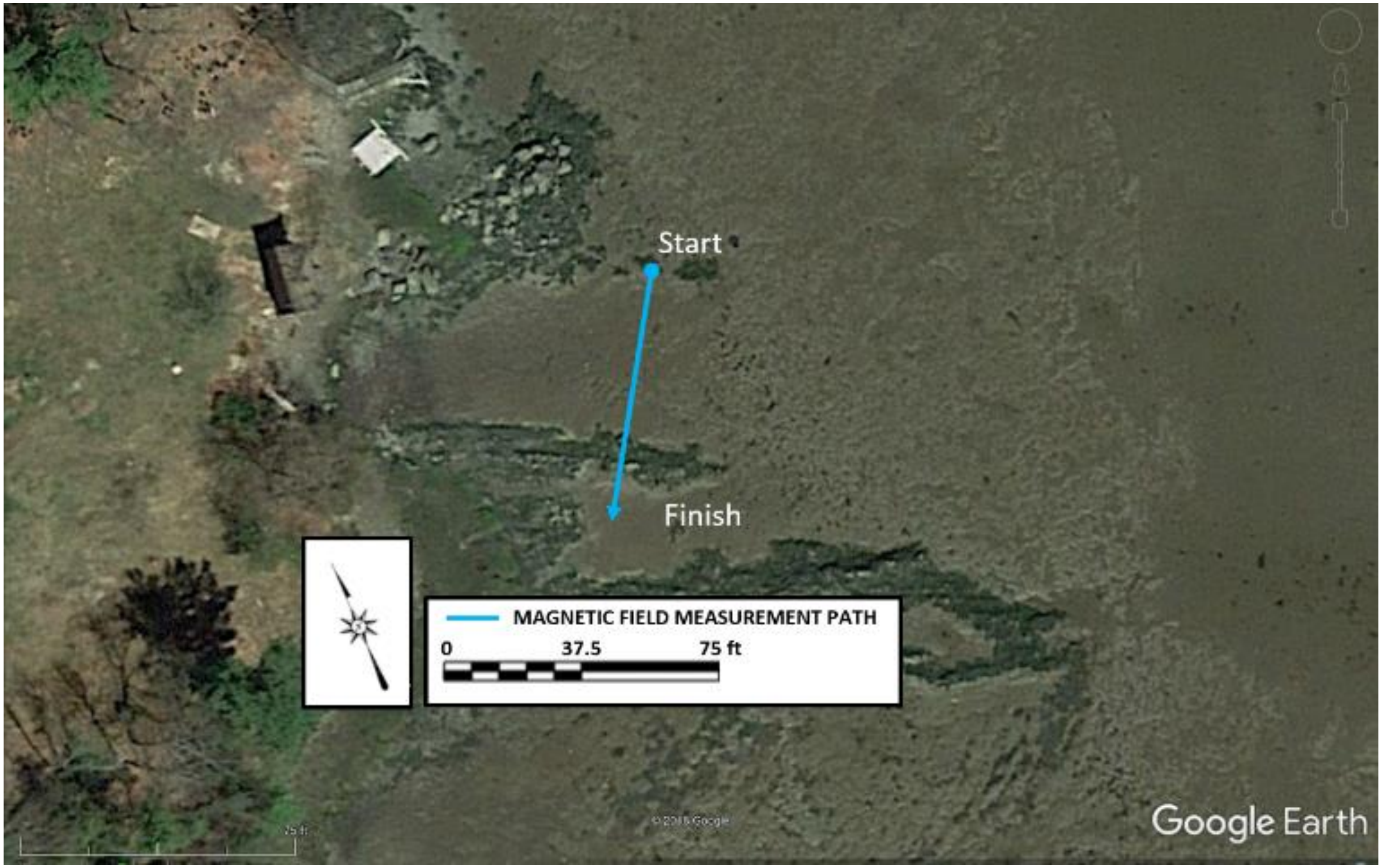

Figure C-8. Aerial photograph of measurement Site 8 (west side of Little Bay) showing the approximate location of the magnetic-field measurement path performed on July 23, 2020.

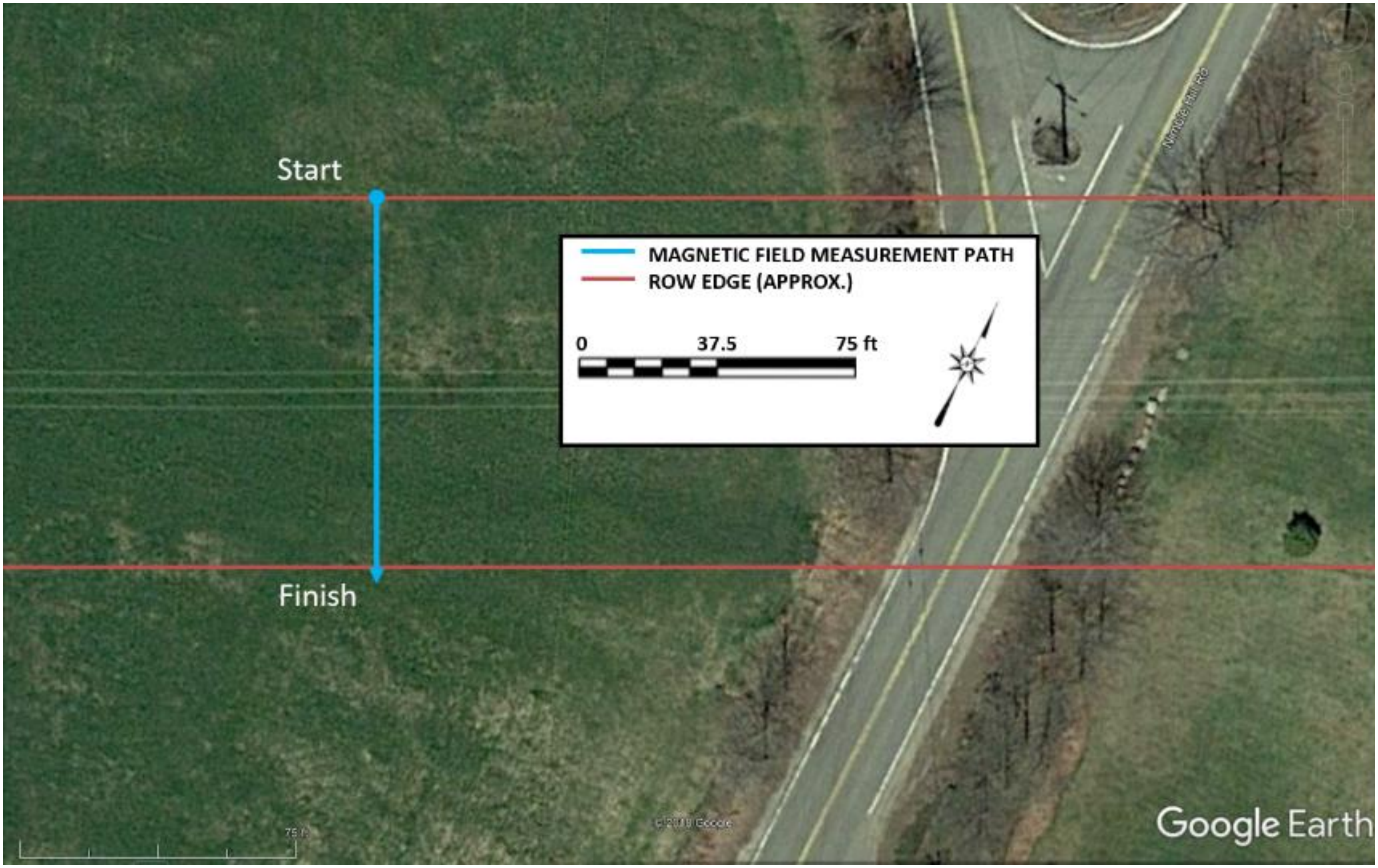

Figure C-9. Aerial photograph of measurement Site 9 (west of Nimble Hill Rd.) showing the approximate location of the magnetic-field measurement path performed on July 20, 2020.

Figure C-10. Aerial photograph of measurement Site 10 (north of Fox Point Rd.) showing the approximate location of the magnetic-field measurement path and electric-field spot measurements performed on July 20, 2020.

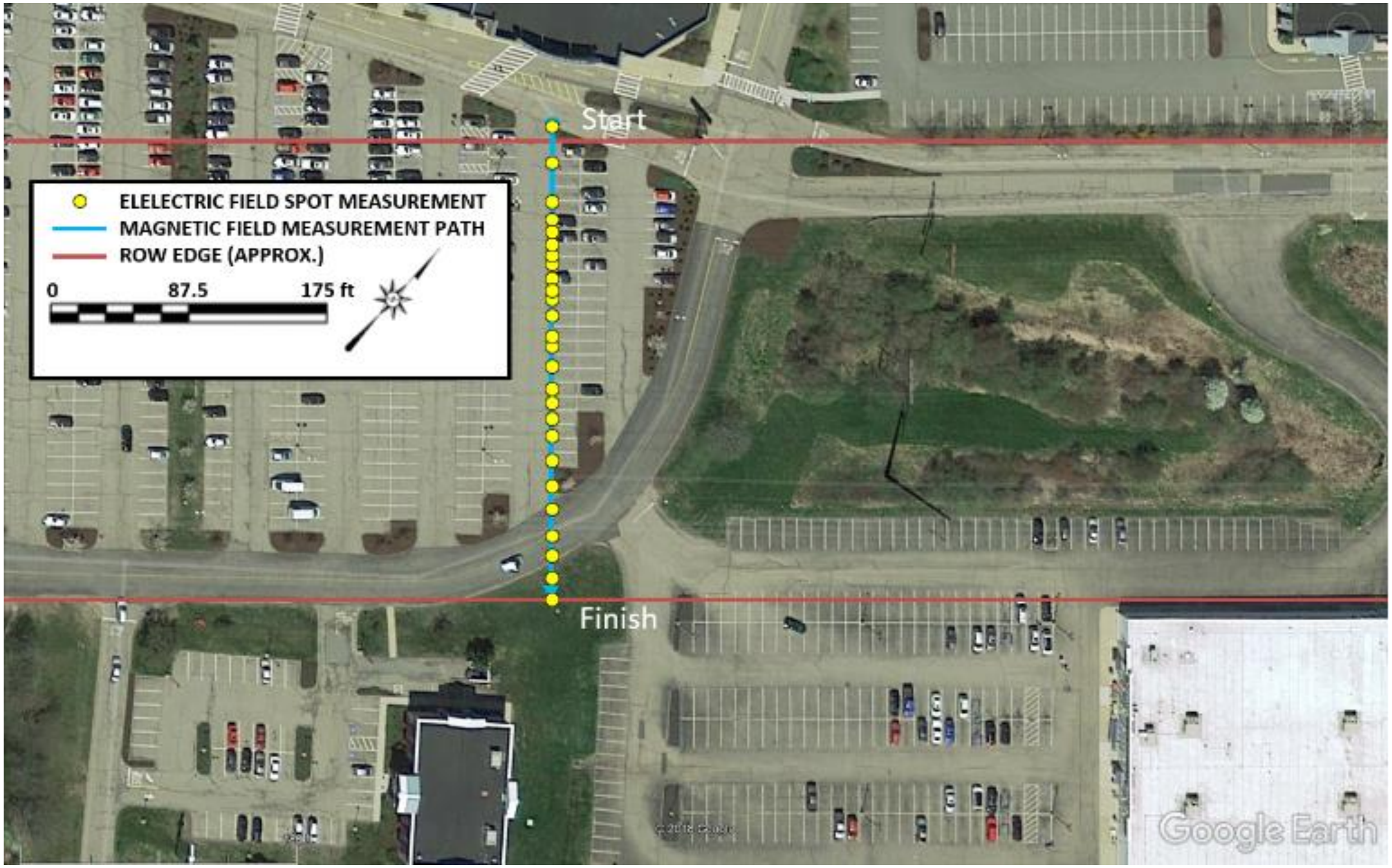

Figure C-11. Aerial photograph of measurement Site 11 (Mall parking lot) showing the approximate location of the magnetic-field measurement path and electric-field spot measurements performed on July 20, 2020.

Appendix D

Power Line Loading and Conductor Heights at Time of Measurements

Table D-1. Table of conductor height and loading at each measurement location for pre-construction cases.

Site No.	Location	Line No.	Line-Line Voltage (kV)	Measurement Loading	Application (Peak Loading)	Minimum Conductor Height (ft)	
				Amperes	Amperes	Measurement	Application
Site 1	Madbury Substation to Route 4 Crossing	380	34.5	335	417	25.8	25.0
		F107	115	166	318	32.3	30.0
Site 2	Underground through UNH Parking Lot	380	34.5	334	417	40.9	25.0
		F107	115	169	318	-4.1	-4.3
		UNH_12	12	8.0	N/A	41.8	N/A
Site 3	UNH to Durham Substation	380	34.5	334	260	38.5	25.0
		F107	115	173	318	58.9	40.5
		UNH_12	12	8.0	N/A	34.8	N/A
		UNH_6	0	0	N/A	18.3	N/A
Site 4	Packers Falls Substation to Newmarket Rd.	3162	34.5	9.1	20	60.8	40.5
		3152	34.5	7.4	256	38.8	25.0
		F107	115	131	318	29.5	25.0
Site 5	Timber Brook Ln. to Sandy Brook Dr.	3162	34.5	8.8	20	40.5	25.0
		F107	115	143	318	60.9	40.5
Site 6	Sandy Brook Dr. to Durham Point Rd.	3162	34.5	15	20	28.0	25.0
		F107	115	176	318	42.0	30.0
Site 7	Durham Point Rd. to Little Bay Launch	F107	115	136	318	40.0	30.0
		3162	34.5	0	N/A	27.6	N/A
Site 8	Little Bay Crossing	F107	115	137	318	-1.5	-8.0

Site No.	Location	Line No.	Line-Line Voltage (kV)	Measurement Loading	Application (Peak Loading)	Minimum Conductor Height (ft)	
				Amperes	Amperes	Measurement	Application
Site 9	Underground through Frink Farm	F107	115	170	318	-4.8	-4.3
Site 10	Fox Point Rd. to Spaulding Turnpike Crossing	3850	34.5	11	357	42.3	25.0
		F107	115	156	318	44.6	30.0
Site 11	Crossing at Fox Run to Portsmouth Substation	E194	115	113	277	39.4	30.0
		F107	115	120	318	43.5	30.0
		U181	115	58	98	35.3	30.0
		3135	345	578	1138	58.9	35.0

* Loading not available during measurements. Assumed to be zero in modeling as field levels are not noticeably different beneath these lines.

Appendix E

Calibration Certificates

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: 3074

Date of Calibration: 12/27/2019

Re-calibration suggested at one year from above date.

EMDEX LLC

Calibration Inspector: H. Christopher Hooper

EMDEX LLC
1356 Beaver Creek Drive
Patterson, California 95363
(408) 866-7266

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: 1134

Date of Calibration: 01/16/2020

Re-calibration suggested at one year from above date.

EMDEX LLC

Calibration Inspector: H. Christopher Hooper

EMDEX LLC
1356 Beaver Creek Drive
Patterson, California 95363
(408) 866-7266

Appendix F

Measurement Protocol Sent to the PUC and NHSEC on June 15, 2020

Exponent®

MEMORANDUM

TO:	Pamela Monroe, Administrator, New Hampshire Site Evaluation Committee
FROM:	Benjamin Cotts, Ph.D.
CC:	Paul Kasper, Assistant Director, Safety and Security, New Hampshire Public Utilities Commission Dena Champy, P.M.P, Eversource Energy Christopher Soderman, P.E., Eversource Energy
DATE:	June 15, 2020
PROJECT:	1501863.001 Seacoast Reliability Project (New Hampshire Site Evaluation Committee Docket 2015-04)
SUBJECT:	Protocol for Post-energization Measurements of Electric and Magnetic Fields

To comply with the Order and Certificate of Site and Facility with Conditions issued by the New Hampshire Site Evaluation Committee (NHSEC) for the Seacoast Reliability Project (SRP or Project) on January 31, 2019, Eversource Energy (Eversource) requested that Exponent provide a draft protocol for performing measurements of electric and magnetic fields (EMF) both before and after the Project is placed into service. Exponent submitted this protocol on April 18, 2019 in consultation with the Safety Division of the of the New Hampshire Public Utilities Commission (PUC).

Exponent conducted pre-construction measurements in April (1 site) and June (10 sites) 2019, and a report on the findings was submitted to the NHSEC and PUC on August 6, 2019.

The SRP 115-kV (F107) line was energized and in-service on May 29, 2020; all of the distribution line re-builds associated with the Project were completed and energized by June 10, 2020. Post-energization measurements are planned to be performed in July and August 2020 to comply with the condition requiring that measurements be performed at or near summer peak loading of the lines, with the acknowledgement that the Applicants cannot know in advance when peak loading will occur, or if compliance with state or local requirements or public safety concerns about SARS-CoV-2 might delay measurements or measurement analysis.

Proposed Measurement Protocol

The proposed measurement protocol is divided into sections including measurement locations, measurement procedure, and reporting.

Measurement Locations

Locations for measurements in 11 cross sections were previously selected for pre-energization measurements. Table 1 summarizes the locations of these pre-construction measurements as well as the corresponding Application Line Section description and, F107 structure type. An aerial photograph showing these locations also is included in Figure 1. Post-energization measurements will be performed at the same pre-energization measurement locations. Where it is not feasible to take post-energization measurements at the same location as previously performed, Eversource and Exponent will find another suitable location for the post-energization measurements and note the change in the final report. Spot measurements of magnetic field levels also will be performed beneath the F107 line and at various points on the property of the Fitch residence at 291 Durham Point Road.

Table 1. EMF measurement location summary

Site	Line Section (Application Section)	F107 Structure Type	Municipality	Monitoring Location
1	Madbury Substation to Route 4 Crossing	Delta	Madbury	North of Madbury Rd.
2	Underground through University of New Hampshire Parking Lot A	Underground	Durham	University of New Hampshire Parking Lot A
3	University of New Hampshire to Durham Substation	Delta with underbuild	Durham	Off Water Works Rd.
4	Packers Falls Substation to Newmarket Rd.	Delta with underbuild and adjacent line	Durham	North of Bennett Rd.
5	Timber Brook Ln. to Sandy Brook Dr.	Delta with underbuild	Durham	East of Sandy Brook Rd.
6†	Sandy Brook Dr. to Durham Point Rd.	Delta and adjacent line	Durham	North of Durham Point Rd.
7*	Durham Point Rd. to Little Bay Launch	Delta	Durham	South of Durham Point Rd.
8	Little Bay Crossing	Direct bury	Durham	West side of Little Bay
9†	Underground through Frink Farm	Underground	Newington	West of Nimble Hill Rd.
10	Fox Point Rd. to Spaulding Turnpike Crossing	Delta and adjacent line	Newington	North of Fox Point Rd.
11	Crossing at Fox Run to Portsmouth Substation	Vertical and adjacent lines	Newington	Mall Parking Lot

† Amended line section
* The Fitch property (291 Durham Point Road) is located along this portion of the route.

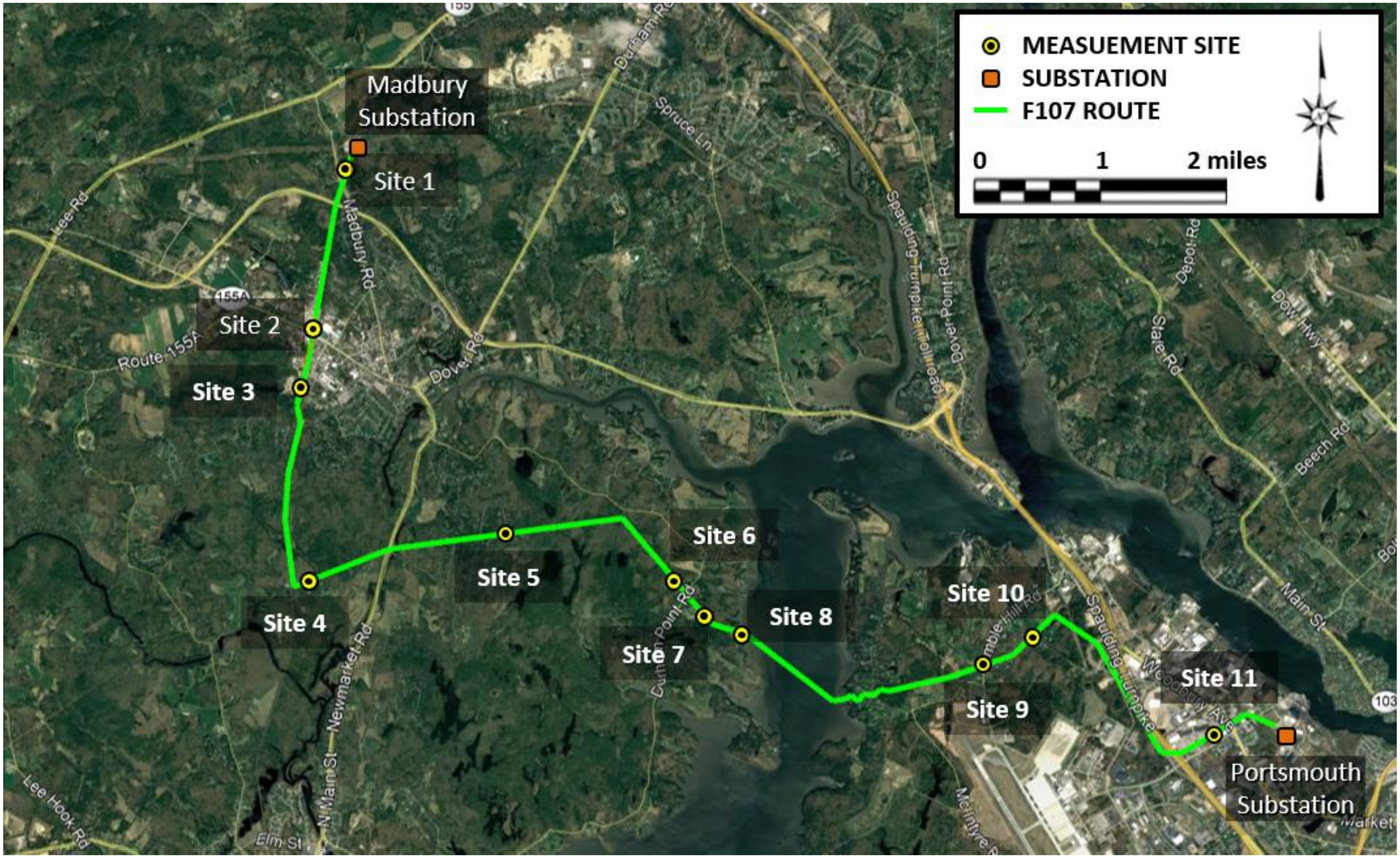

Figure 1. Route of the transmission line and locations of pre-construction measurement sites.

Measurement Procedure (same as pre-construction measurement procedure)

At each measurement location, Eversource will clear underbrush and other conductive objects, if necessary, to facilitate access and minimize interference with the electric field measurements. Exponent engineers will photo-document the condition of the right-of-way (ROW) at each location where measurements around the lines will be made. Engineers will then lay a long measuring tape on the ground beneath the lines that will be used to identify the horizontal location of conductors. The vertical height of each conductor will be measured and recorded using an acoustic or optical line height sensor, or both. The time and date of the field measurements will be noted so that the loading on each of the lines can later be determined.

Engineers will then proceed to perform EMF measurements using measurement equipment and methodology outlined in Institute of Electrical and Electronics Engineers (IEEE) Standard 644-2019 and IEEE Std. C95.3.1-2010. Measurements will be performed at a height of 1 meter above ground and will be performed along a transect perpendicular to the transmission line. If a transect other than perpendicular is necessary, the angle of the transect to the transmission line will be noted and measurement distances will be adjusted accordingly.

The measurements of electric fields and magnetic fields will be reported as the total field computed as the resultant of field vectors measured along vertical, transverse, and longitudinal axes.[1] The magnetic field will be measured in units of milligauss (mG) by orthogonally-mounted sensing coils whose output is recorded by a digital meter (EMDEX II) manufactured by Enertech Consultants.

The electric field will be measured in units of kilovolts per meter (kV/m) with a single-axis sensor accessory also manufactured by Enertech Consultants for the EMDEX II meter. The single-axis sensor will be aligned sequentially along vertical, transverse, and longitudinal axes to capture the full vector electric field. These instruments meet the IEEE instrumentation standard for obtaining accurate field measurements at power line frequencies (IEEE Std.1308-1994). All meters and measurement accessories will be calibrated by the manufacturer using methods like those described in IEEE Std. 644-2019.

The EMDEX II is calibrated annually by the manufacturer and receives a certificate of calibration. The most recent calibration certificates for the two EMDEX II units to be used for these measurements are included in Appendix A. In addition, the EMDEX II will be checked each morning prior to measurements with a portable calibration coil to ensure that it maintains calibration throughout the measurement trip. If post-energization measurements are taken at line loadings lower than peak levels, magnetic field levels will be adjusted for peak loading conditions on existing lines and the new SRP line for comparisons to values in Appendix 41 and 41a (as applicable) in the Petition.

[1] Measurements along the vertical, transverse, and longitudinal axes will be recorded as root-mean-square magnitude, which refers to the common mathematical method of defining the effective voltage, current, or field of an alternating current system.

Exponent and Eversource will provide 7 days' written notice to the NHSEC and PUC prior to planned measurements. If inclement weather or other factors require rescheduling, Exponent and Eversource will provide the NHSEC and PUC as much notice as possible and provide regular updates on the status of planned measurements.

Report

Exponent will prepare a measurement report summarizing measurements taken after the Project is placed into service. This report will detail the measurement methods and include aerial maps of each measurement location with annotations reflecting the specific locations of electric- and magnetic-field measurements as well as a graphical summary of both electric- and magnetic-field measurement results. The measurement report will be submitted within 60 days of completion of the measurements. Consistent with the NHSEC Certificate of Site and Facility, measurement values performed outside of near-peak or peak loading conditions will be summarized in raw form as well as adjusted to the peak loading condition specified in the application.

Appendix A

EMDEX II Calibration Certificates

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: 3074

Date of Calibration: 12/27/2019

Re-calibration suggested at one year from above date.

Calibration Inspector: H. Christopher Hooper

EMDEX LLC
1356 Beaver Creek Drive
Patterson, California 95363
(408) 866-7266

Certificate of Calibration

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Instrument Model: EMDEX II - Standard

Frequency: 60 Hz

Serial Number: 1134

Date of Calibration: 01/16/2020

Re-calibration suggested at one year from above date.

EMDEX LLC

Calibration Inspector: H. Christopher Hooper

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