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VIA ELECTRONIC MAIL

August 6, 2019

Pamela G. Monroe, Administrator
New Hampshire Site Evaluation Committee
21 South Fruit Street, Suite 10
Concord, NH 03301

Paul Kasper, Assistant Director
New Hampshire Public Utilities Commission
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 for a New 115k Transmission Line from Madbury Substation to Portsmouth Substation

Dear Ms. Monroe and Mr. Kasper:

Enclosed for filing in the above referenced docket please find the Pre-Construction Measurements of Electric and Magnetic Field Levels Report, dated August 6, 2019, prepared by Exponent on behalf of Eversource Energy.

Please call me with any questions.

Sincerely,

Adam M. Dumville

Enclosure

Electrical Engineering and
Computer Science Practice

Seacoast Reliability Project

Pre-Construction Measurements of Electric- and Magnetic-Field Levels

Exponent®

Seacoast Reliability Project

Pre-Construction Measurements of Electric- and Magnetic-Field Levels

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
Manchester, NH 03101

Prepared by

Exponent, Inc.
17000 Science Drive, Suite 200
Bowie, MD 20715

August 6, 2019

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Contents

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	Kilovolts 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 existing transmission and distribution lines along the route of the Seacoast Reliability Project (SRP). This report summarizes work performed to date 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 the client. 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 New Hampshire Public Utilities Commission's or New Hampshire Site Evaluation Committee's review of the SRP, 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 was approved with conditions in its Decision and Order granting a Certificate of Site and Facility on January 31, 2019. The Decision and Order included conditions for pre- and post-construction measurements of electric and magnetic fields (EMF) and comparison of the measured levels to published guidelines of the International Committee on Electromagnetic Safety (ICES) or the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

This report summarizes pre-construction EMF measurements to comply with the first part of the NHSEC order.

Exponent measured EMF levels from the existing lines under conditions as near as possible to conditions assumed in the original modeling. Measurement locations were selected by Eversource Energy in consultation with the New Hampshire Public Utilities Commission (PUC) in 11 Line Segments of the route proposed in the Application. These Line Segments describe all the proposed 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.

Introduction

The Seacoast Reliability Project (SRP or the Project) will be a new 115-kilovolt (kV) transmission line (designated F107) between the Madbury and Portsmouth Substations. The SRP will be constructed on existing rights-of-way (ROW) and will be approximately 12.9 miles in length. The F107 line is proposed to include 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 (Application) and was approved by a Decision and Order granting a Certificate of Site and Facility on January 31, 2019, with conditions for pre- and post-construction measurements of electric and magnetic fields (EMF) which reads:

> …Further Ordered that the Applicant, in consultation with the PUC 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 condition for pre-construction EMF measurements in the Order and Certificate of Site and Facility, Exponent and Eversource reviewed the proposed transmission line configurations and the residential density along the route of the proposed F107 transmission line and identified 11 Line Segments of the proposed Project route that cover the proposed configuration types along the entire route.[1]

The goal of the measurements performed at the 11 representative sites on the Project route was to compare measured EMF levels to those guidelines recommended by ICES and ICNIRP. Since measurements were not able to be performed at peak loading, 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. 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.

Measurement Methods

Prior to performing any measurements, Exponent and Eversource engineers jointly developed a measurement protocol, the purpose of which was 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, titled *Protocol for Measurements of Electric and Magnetic Fields*, was sent to both the NHSEC and the PUC for review and comment and a copy is

[1] No measurements were proposed for the small portion of the route between structures 102 and 109 where the proposed configuration changes rapidly (from underground to vertical to delta to H-frame and back to underground) over a relatively small area. Each of these configurations is measured elsewhere on the route except for the two spans where the F107 line is proposed in an H-frame configuration. No measurements were proposed for this configuration because it represents a very small portion (2 spans) of the route and because the nearest residence to this configuration is more than 400 feet away. *See Appendix F Protocol for Measurements of Electric and Magnetic Fields*, Docket 2015-04 at 2, n*2 (April 18, 2019).

attached in 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 (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 accessory for the EMDEX II 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 5- to 30-foot intervals with a minimum of five measurement locations

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[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 an alternating-current system.

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

performed in the immediate vicinity of each transmission or distribution line in accordance with IEEE Standard 644-1994-R2008.[5]

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).[6] All meters and measurement accessories were calibrated by EMDEX, LLC, using methods like those described in IEEE Std. 644-1994 (R2008). In addition, a Kestrel 4000 weather meter was used to record temperature, relative humidity, barometric pressure, and wind speed for reference.

Measurements at Little Bay Launch

At the Little Bay Crossing, the three cables of the F107 transmission line are proposed to be direct buried beneath the bay and were modeled in the Application at a burial depth of 8 feet and a horizontal separation distance of 15 feet. On land, the cables are proposed to be installed in an underground duct bank, and they will separate from one another to a horizontal distance of 15 feet for the Little Bay Crossing. The water depth (even at low tide) is too great to allow for measurements where the cables are separated by 15 feet from one another (as was modeled in the Application), and on land, the cables are too close together to allow for representative

[5] Institute of Electrical and Electronics Engineers (IEEE). IEEE Standard Procedures for Measurement of Power Frequency Electric and Magnetic Fields from Alternating Current Power Lines (IEEE Std. 644-1994, Reaffirmed 2008). New York: IEEE, 1994/2008. 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).

[6] 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.

measurements to be made over the configuration of the line proposed for the Little Bay Crossing. Magnetic-field modeling by Eversource, however, indicates that the highest magnetic-field level above the proposed F107 transmission line will be similar at a 10-foot separation as at a 15-foot separation. Measurements were possible to perform at a location where the cables of the F107 transmission line are proposed to be 10 feet apart.

On the day of measurements, a surveyor identified the centerline of the proposed F107 transmission line where the buried cables are expected to be separated by approximately 10 feet, at the location approximately 100 feet offshore. Although measurements were performed at low tide, the mud in Little Bay is too deep to allow for measurements to be performed using a survey wheel on the surface of the mud. To overcome this limitation, Exponent laid a series of 1 x 10 boards approximately perpendicular across the planned cable route in order to allow for the survey wheel to roll easily over the surface of the deep mud. Since the F107 transmission line is proposed to be buried at this location, there will be no electric fields above ground from the transmission line, therefore no electric-field measurements were performed.

Daily Pre-Measurement Calibration Procedure

The EMDEX II and EMDEX LITE were calibrated by the manufacturer on October 24, 2018 and July 5, 2018, respectively. In addition, to monitor the EMDEX II calibration throughout the week-long measurement trip, the calibration was checked with a portable calibration coil. The maximum change in any calibration from the expected level was approximately 4% indicating that the EMDEX II maintained calibration throughout the measurement trip.

Modeling Methods

At each measurement site, Exponent used the recorded conductor position and height of each transmission or distribution line obtained during the measurements, as well as voltage and loading information provided by Eversource, to develop an As-Measured Model to represent the operation of the lines at the site. 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 representative of the measurement site, but adjusted it to peak line loadings (As-Measured – Adjusted for Peak Model) 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.[7] 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 to make the calculations more tractable 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 a flat earth (also assumed infinite in extent) and was assumed to be parallel to all other conductors. All real-world conditions encountered in the measurements obviously 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 are not included in the model used to calculate EMF levels.

[7] 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 future F107 transmission line and accurately describe actual EMF levels for the entire route.[1]

Each of the 11 sites was selected to encompass as many of the following characteristics as possible to provide the best comparison with idealized models constructed for calculations:

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.

The criterion for initial site selection was to evaluate all F107 structure types (e.g., delta, delta with underbuilt distribution line, underground, etc.) and to combine segments with similar configurations. Next, specific segments were selected where the F107 transmission line would pass by a higher density of residences than at other segments of the route with similar configurations. These 11 Line Segments are described in Table 1 by the Line Section in the Application, structure type, and municipality, and include additional information about specific measurement location and date of measurements. The selection of a specific measurement site within each selected Line Section went through a multi-stage process beginning with review of aerial photographs to select potential locations. An in-person visit to each site followed to evaluate other factors not discernable from aerial photographs such as terrain roughness, variation, and the nature and density of brush. If the initially-selected site was found to be deficient in one aspect or another, additional sites were investigated.

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 (291 Durham Point Road) is located along this portion of the route.

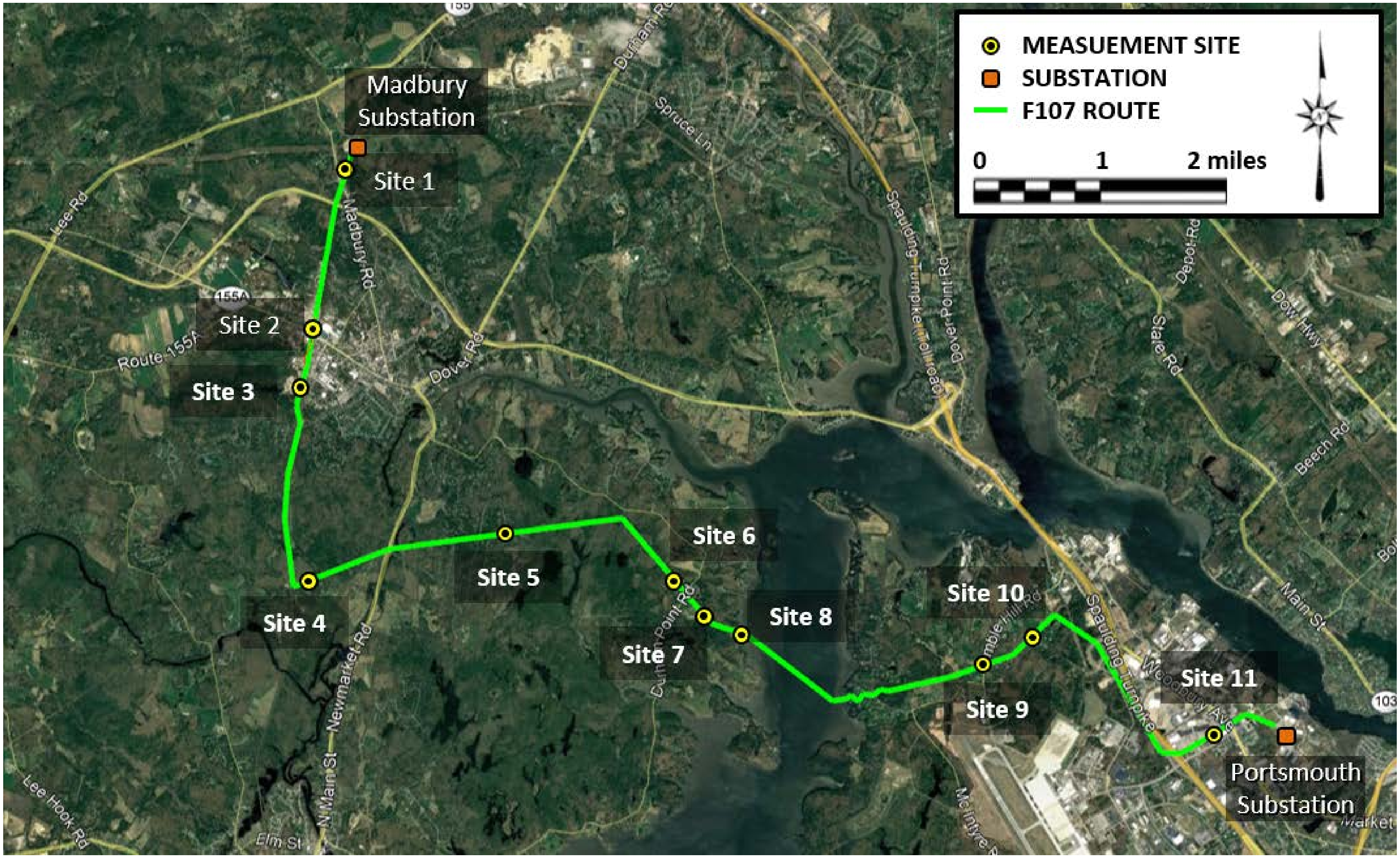

Figure 1. Route of the transmission line and locations of measurement sites.

Results

EMF measurements were performed on April 29, June 3, June 4, and June 6, 2019. 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. Despite taking measurements in the summer season when peak loading of transmission lines is expected (consistent with the NHSEC Order), measured loadings on the existing power lines did not reach levels forecasted in the Application, so magnetic-field measurements were summarized in raw form and after adjustment to peak-loading levels. The results fall in two general categories.

- For sites where the loading on the power line or lines at the time of measurements was approximately 20 Amperes or less, magnetic-field levels were so low as to be near background levels at most locations on the ROW, so there is a poor match between measured and modeled magnetic-field levels. This description applies to Sites 4 through 10.

- For sites where the loading on the power line or lines at the time of measurements was greater than approximately 100 Amperes, magnetic-field levels are further above background levels, so there is a better match between measured and modeled magnetic-field levels. This description applies to Sites 1 through 3 and Site 11.[8]

As shown in Appendix A, Table A-1, magnetic-field levels adjusted to peak loading levels were generally lower than calculated in the Application due to greater conductor height at the measurement locations as was conservatively assumed in the Application. Electric-field levels are not similarly affected by loading levels, so do not show a similar correlation. Instead, measured electric-field levels depend most upon the voltage of the power line conductors, their height above ground and the environment in which measurements are performed. For example,

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[8] At measurement Sites 1 and 2 where the railroad was in the immediate vicinity of the measurement transect, magnetic field levels were measured to be elevated near the railroad tracks, consistent with railroad signaling. The railroad operation frequency is unknown but was determined through additional measurements with the EMDEX II to be above 100 Hz. These measurements also indicated that the total magnetic-field levels reported near to the adjacent distribution lines, at nearly all distances from the line, included significant contributions from the railroad which helps to explain why the modeling results generally underestimated measurement levels at these Sites.

if there is brush or shrubs on the ROW at the measurement locations of the electric-field levels, they will be perturbed—sometimes higher, but more often lower than what would be observed (or calculated) in the absence of these conductive items. Similarly, for the relatively narrow ROWs upon which many of these power lines are situated, the tall trees at the edges of the ROW can reduce electric-field levels across most of the ROW.

The measurements and modeling values are compared to the ICES and ICNIRP levels 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.

Example Comparison: Site 3 (University of New Hampshire to Durham Substation)

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 3 was selected because the site conditions were among the most consistent with the conditions assumed in the calculation model described in the Application.

Figure 2 shows magnetic-field levels (left) and electric-field levels (right) separately. Actual measurement values are shown by a series of '+' markers while the As-Measured Model is 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 3 to 30 feet (with closer spacing near the transmission or distribution lines and at greater spacing on more distant portions of the ROW) and 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.

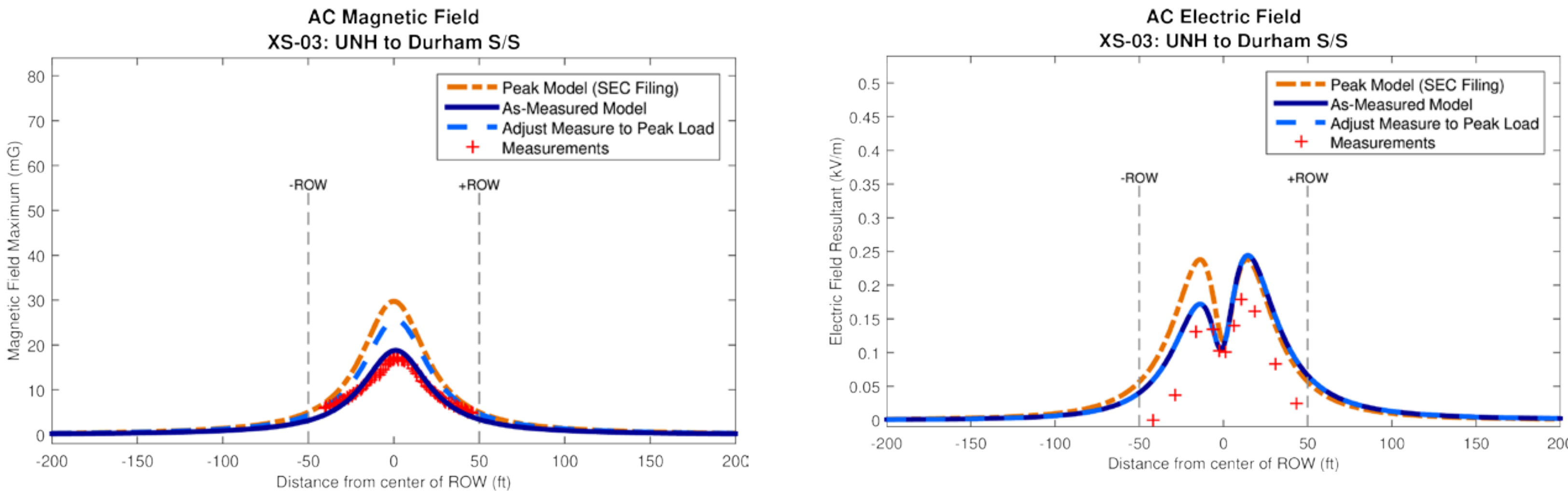

Figure 2. Comparison of measurements at Site 3 with calculations from the As-Measured Model, As Measured - Adjusted for Peak Model and the Peak Model from the Application for comparison.

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

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.[9]

All measured magnetic-field levels on the route were found to be far below (less than 1% of the limit) the ICNIRP or ICES limit. Even when adjusted to peak loading, these maximum levels were less than 3% of the ICNIRP or ICES limit. In addition, measured or modeled magnetic-field levels are below those presented in the Application (Appendix 41 and 41a) even when adjusted to peak-loading conditions. This serves to show that the modeling assumptions and calculations used in the Application were conservative so as to overestimate actual magnetic-field levels.

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, but were still approximately one-third of the ICNIRP or ICES limits.

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

Conclusion

The measurements and analysis in this report comply with the NHSEC 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. Following construction of the F107 transmission line, measurements of EMF levels will be taken again to compare to ICES and ICNIRP limits. 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 measured magnetic-field levels on the route were found to be less than 3% 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 below approximately one-third of the ICNIRP or ICES limits or less.

Appendix A

Summary Tables 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 tables below are therefore reported at the location where the electric- and magnetic-field measurement 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 also reported at these same locations, not at the precise ROW edge.

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]

[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 **June 6, 2019**	Peak Model (Application Filing)	5.7	48	3.3
	Modeled Field (for measured line height and load at time of measurements)	2.7	14	1.6
	Modeled Field (for measured line height, and load adjusted to peak level)	4.5	24	2.7
	Measured Field	5.1	22	3.7
Site 2 **June 6, 2019**	Peak Model (Application Filing)*	15	49	4.1
	Modeled Field (for measured line height and load at time of measurements)	5.0	9.3	1.9
	Modeled Field (for measured line height, and load adjusted to peak level)	7.9	15	3.0
	Measured Field	7.4	11	2.6
Site 3 **June 3, 2019**	Peak Model (Application Filing)	7.1	30	5.7
	Modeled Field (for measured line height and load at time of measurements)	4.4	19	3.9
	Modeled Field (for measured line height, and load adjusted to peak level)	6.0	26	5.3
	Measured Field	6.0	17	4.9
Site 4 **June 3, 2019**	Peak Model (Application Filing)	1.8	30	17
	Modeled Field (for measured line height and load at time of measurements)	0.2	0.5	0.1
	Modeled Field (for measured line height, and load adjusted to peak level)	1.8	18	11
	Measured Field	0.6	1.1	0.4
Site 5 **June 3, 2019**	Peak Model (Application Filing)	0.4	2.3	0.4
	Modeled Field (for measured line height and load at time of measurements)	0.1	0.5	0.2
	Modeled Field (for measured line height, and load adjusted to peak level)	0.3	1.0	0.3
	Measured Field	0.2	0.5	0.4
Site 6 **June 3, 2019**	Peak Model (Application Filing)	0.4	2.3	0.6
	Modeled Field (for measured line height and load at time of measurements)	0.1	0.4	0.2
	Modeled Field (for measured line height, and load adjusted to peak level)	0.2	0.7	0.3
	Measured Field	0.8	1.2	0.7

Site # Date	Condition	Value at Measurement Point: Nearest −ROW Edge	Max on ROW	Nearest +ROW Edge
Site 7 **June 4, 2019**	Peak Model (Application Filing)*	0.0	0.0	0.0
	Modeled Field (for measured line height and load at time of measurements)	0.2	0.5	0.2
	Modeled Field (for measured line height, and load adjusted to peak level)	0.3	0.8	0.3
	Measured Field	0.1	0.4	0.4
Site 8 **June 4, 2019**	Peak Model (Application Filing)	0.0	0.0	0.0
	Modeled Field (for measured line height and load at time of measurements)	0.0	0.0	0.0
	Modeled Field (for measured line height, and load adjusted to peak level)	0.0	0.0	0.0
	Measured Field	0.0	0.2	0.0
Site 9 **June 4, 2019**	Peak Model (Application Filing)*	0.0	0.0	0.0
	Modeled Field (for measured line height and load at time of measurements)	0.8	1.7	0.8
	Modeled Field (for measured line height, and load adjusted to peak level)	4.9	12	4.8
	Measured Field	0.7	1.6	1.0
Site 10 **June 4, 2019**	Peak Model (Application Filing)	6.8	41	7.0
	Modeled Field (for measured line height and load at time of measurements)	0.6	1.4	0.7
	Modeled Field (for measured line height, and load adjusted to peak level)	5.0	16	5.1
	Measured Field	0.5	1.2	0.5
Site 11 **April 29, 2019**	Peak Model (Application Filing)	9.8	141	39
	Modeled Field (for measured line height and load at time of measurements)	1.2	16	8.8
	Modeled Field (for measured line height, and load adjusted to peak level)	9.5	48	26
	Measured Field	1.9	16	8.8

* 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.

Table A-1. 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 **June 6, 2019**	Peak Model (Application Filing)	<0.1	0.3	<0.1
	Modeled Field (for measured line height at time of measurements)	<0.1	0.2	<0.1
	Modeled Field (for measured line height; no adjustment for peak loading needed)	<0.1	0.2	<0.1
	Measured Field	<0.1	0.1	<0.1
Site 2 **June 6, 2019**	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 **June 3, 2019**	Peak Model (Application Filing)	0.1	0.2	0.1
	Modeled Field (for measured line height at time of measurements)	0.1	0.2	0.1
	Modeled Field (for measured line height; no adjustment for peak loading needed)	0.1	0.2	0.1
	Measured Field	<0.1	0.2	<0.1
Site 4 **June 3, 2019**	Peak Model (Application Filing)	0.1	0.3	0.2
	Modeled Field (for measured line height at time of measurements)	0.1	0.2	0.2
	Modeled Field (for measured line height; no adjustment for peak loading needed)	0.1	0.2	0.2
	Measured Field	0.1	0.1	0.1
Site 5 **June 3, 2019**	Peak Model (Application Filing)	0.1	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 6 **June 3, 2019**	Peak Model (Application Filing)	0.1	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 # Date	Condition	Value at Measurement Point: Nearest −ROW Edge	Max on ROW	Nearest +ROW Edge
Site 7 **June 4, 2019**	Peak Model (Application Filing)*	0.1	0.1	<0.1
	Modeled Field (for measured line height at time of measurements)	0.1	0.3	0.1
	Modeled Field (for measured line height; no adjustment for peak loading needed)	0.1	0.3	0.1
	Measured Field	0.2	0.3	<0.1
Site 8 **June 4, 2019**	Peak Model (Application Filing)	0.0	0.0	0.0
	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 9 **June 4, 2019**	Peak Model (Application Filing)*	<0.1	<0.1	<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 10 **June 4, 2019**	Peak Model (Application Filing)	0.1	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 11 **April 29, 2019**	Peak Model (Application Filing)	0.3	4.1	0.9
	Modeled Field (for measured line height at time of measurements)	0.2	1.5	0.8
	Modeled Field (for measured line height; no adjustment for peak loading needed)	0.2	1.5	0.8
	Measured Field	0.2	1.3	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.

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, the Little Bay Crossing, where only magnetic-field levels were measured because there is no existing overhead line and the proposed F107 line will be underground). For each measurement site, an aerial photograph showing the 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 and 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 '+' markers.

Site 1

Measurements at Site 1 (north of Madbury Rd.) were performed on June 6, 2019. A graphical summary of results is presented below.

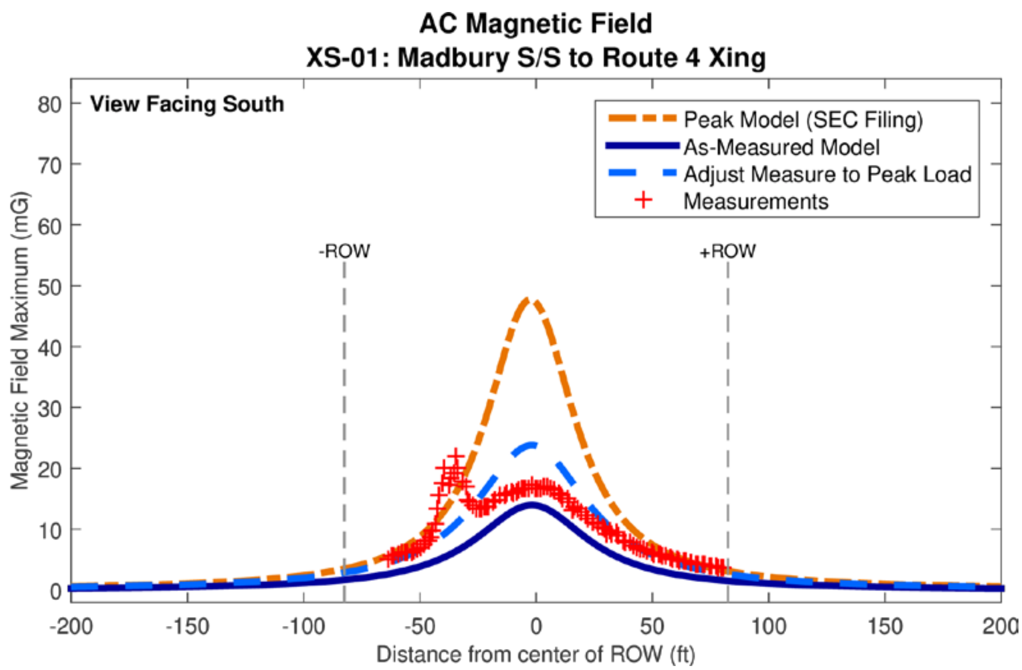

Figure B-1. Measured and modeled magnetic-field levels at Site 1.

The elevated magnetic-field level near -45 feet is from the signaling current on the adjacent train tracks. The additional magnetic field from the tracks influenced measurements out to at least 60 feet from the railroad

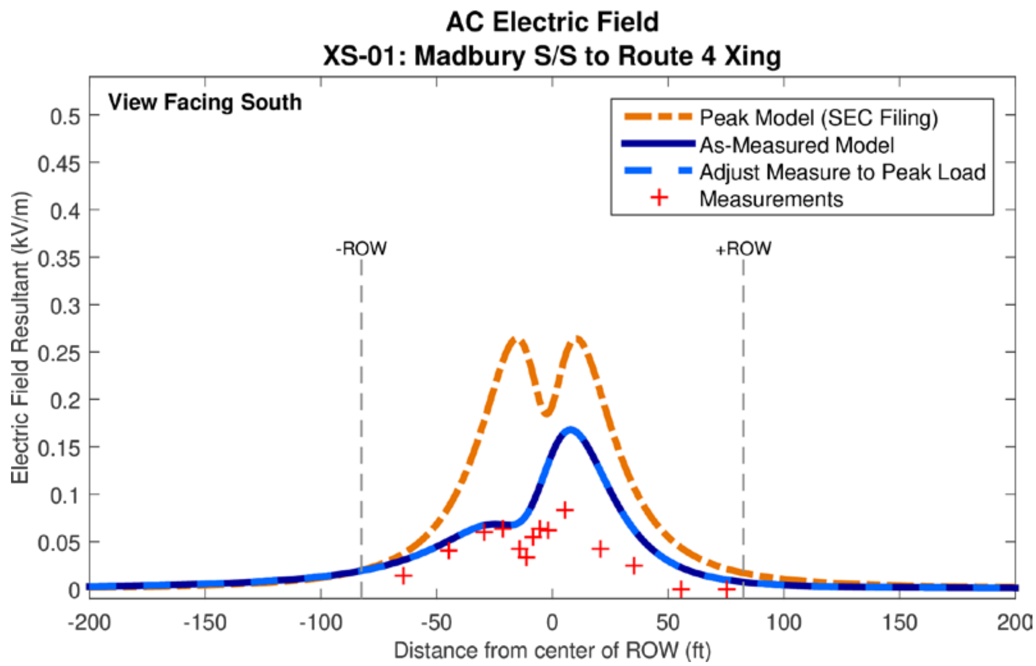

Figure B-2. Measured and modeled electric-field levels at Site 1.

Site 2

Measurements at Site 2 (in UNH parking lot A) were performed on June 6, 2019. A graphical summary of results is presented below.

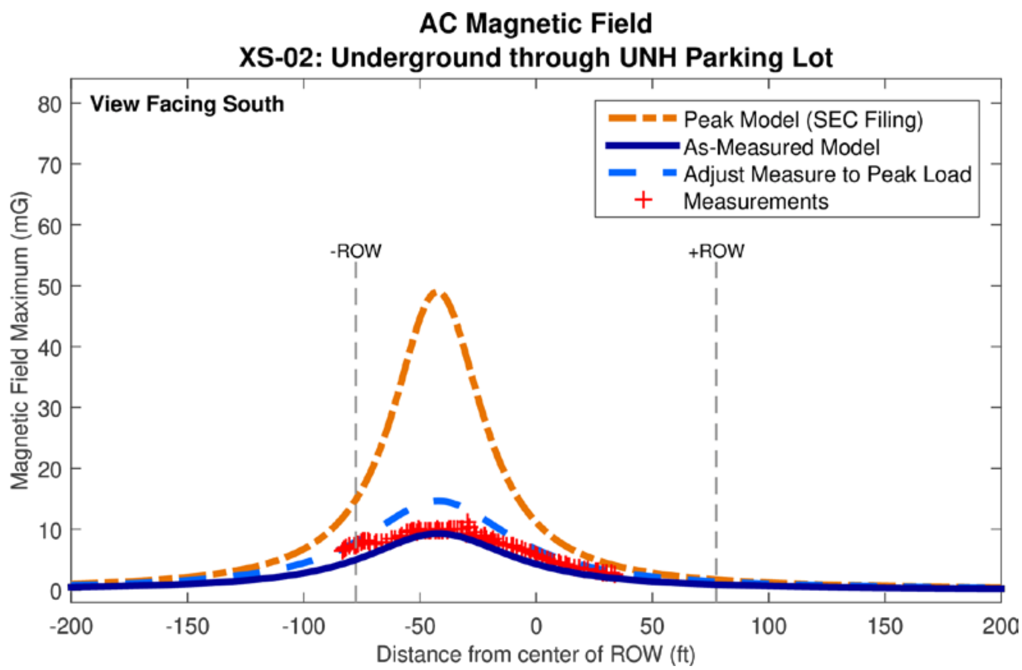

Figure B-3. Measured and modeled magnetic-field levels at Site 2.

The elevated magnetic-field level near the -ROW edge is from the signaling current on the adjacent train tracks.

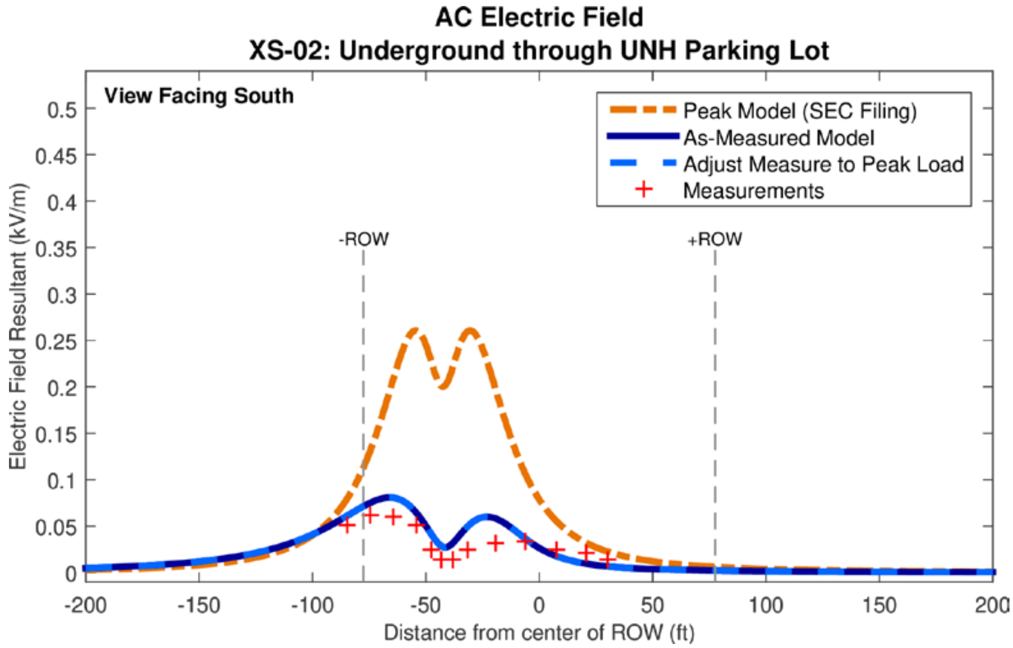

Figure B-4. Measured and modeled electric-field levels at Site 2.

Site 3

Measurements at Site 3 (off Water Works Rd.) were performed on June 3, 2019. A graphical summary of results is presented below.

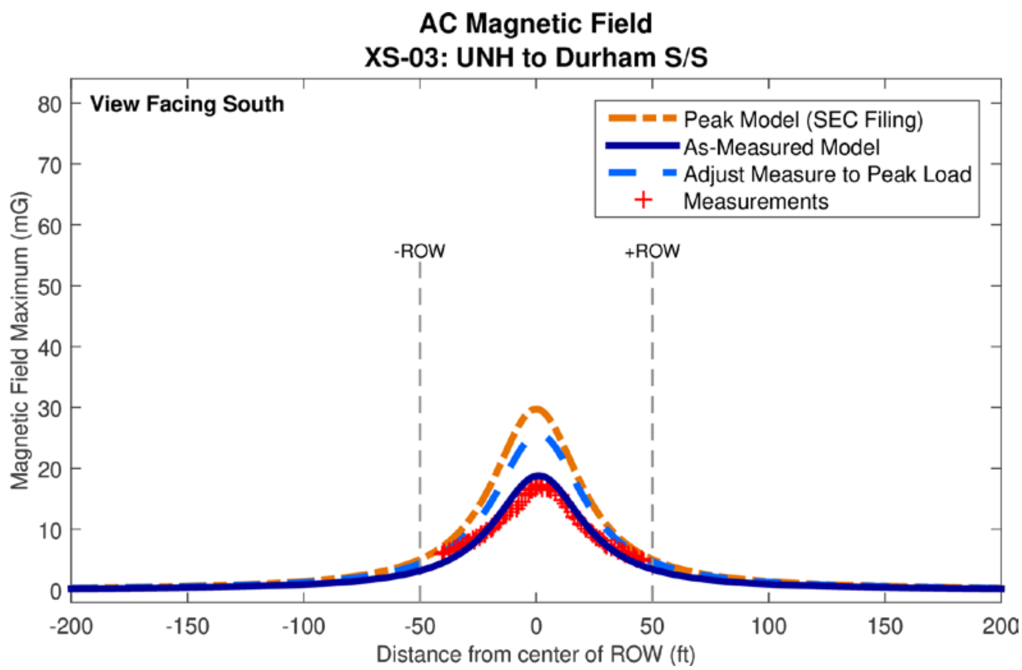

Figure B-5. Measured and modeled magnetic-field levels at Site 3.

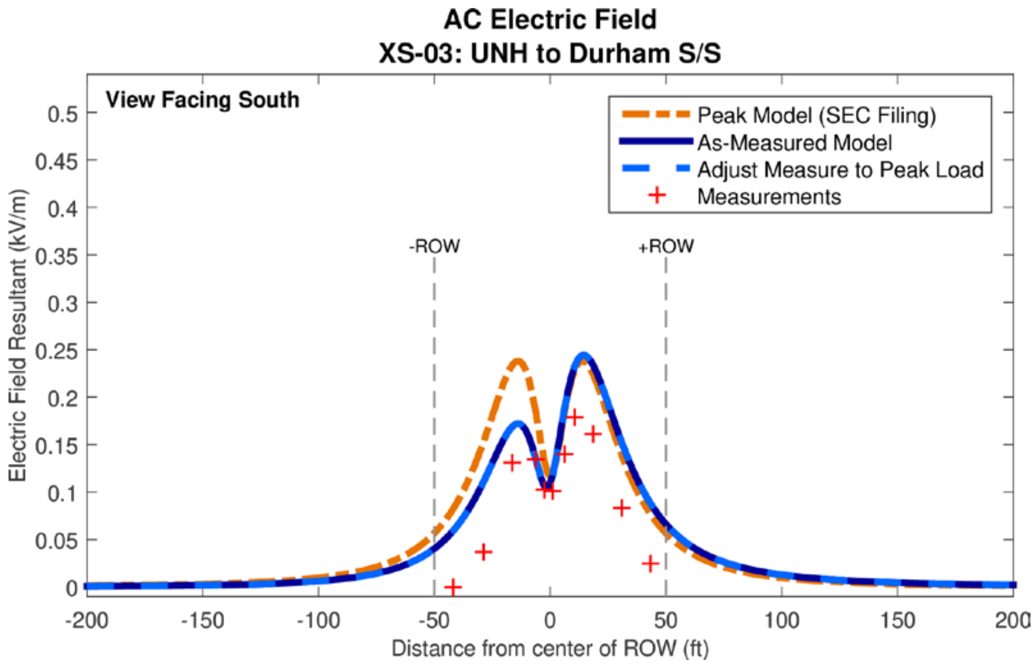

Figure B-6. Measured and modeled electric-field levels at Site 3.

Site 4

Measurements at Site 4 (north of Bennett Rd.) were performed on June 3, 2019. A graphical summary of results is presented below.

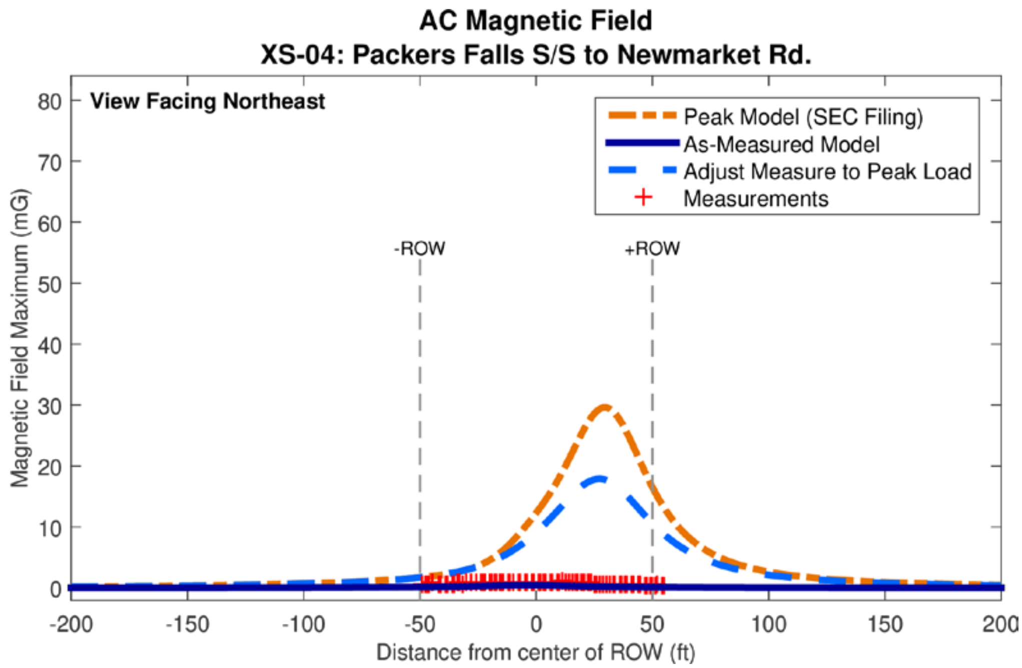

Figure B-7. Measured and modeled magnetic-field levels at Site 4.

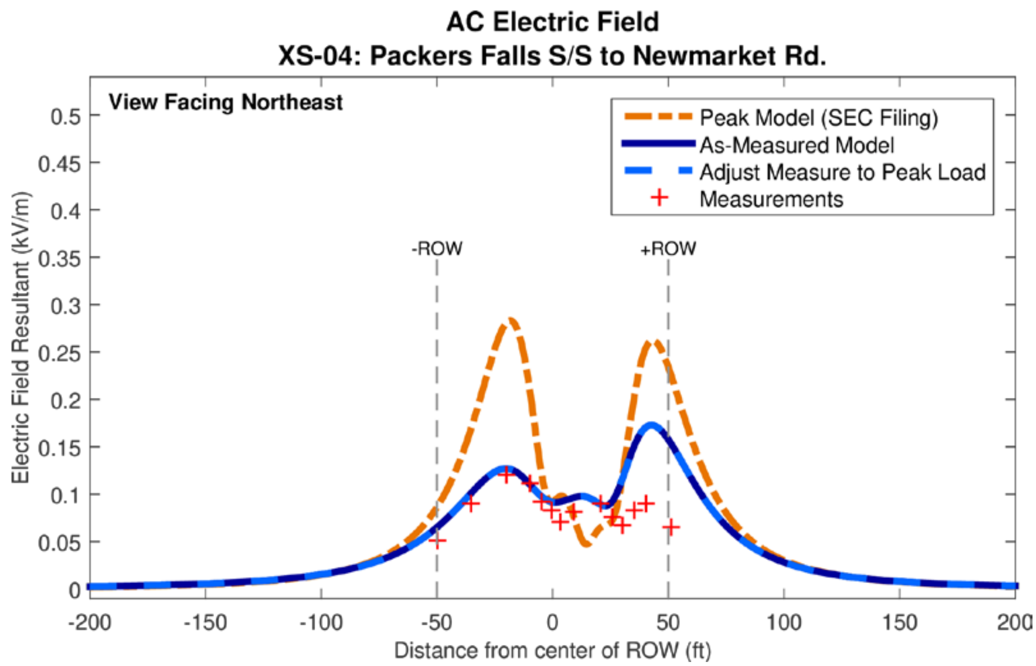

Figure B-8. Measured and modeled electric-field levels at Site 4.

Site 5

Measurements at Site 5 (east of Sandy Brook Rd.) were performed on June 3, 2019. A graphical summary of results is presented below.

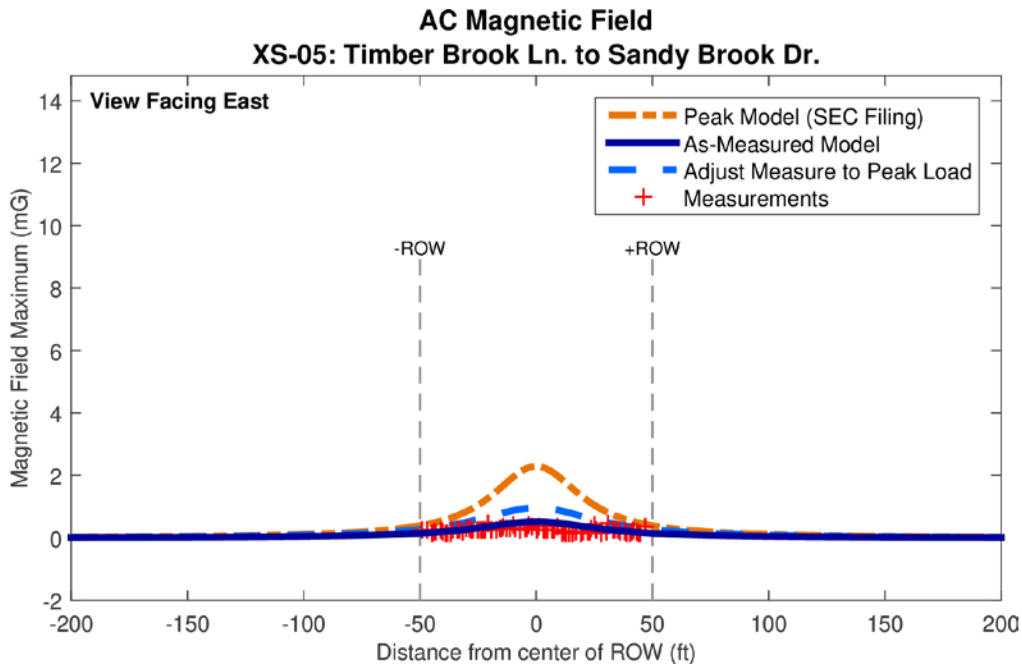

Figure B-9. Measured and modeled magnetic-field levels at Site 5.

Note the vertical scale is different than previous figures

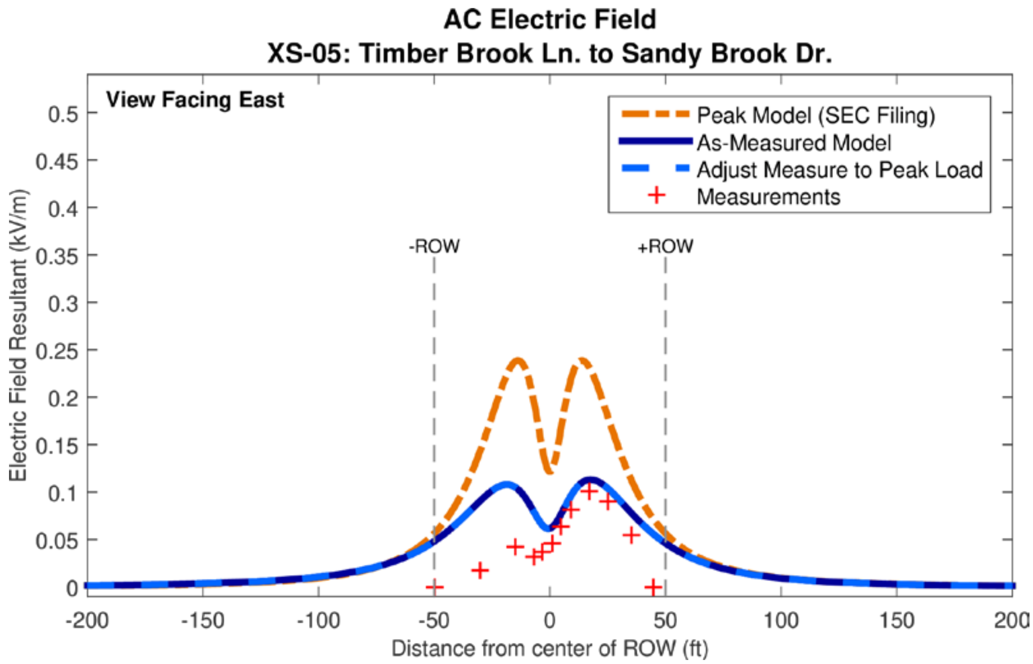

Figure B-10. Measured and modeled electric-field levels at Site 5.

Site 6

Measurements at Site 6 (north of Durham Point Rd.) were performed on June 3, 2019. A graphical summary of results is presented below.

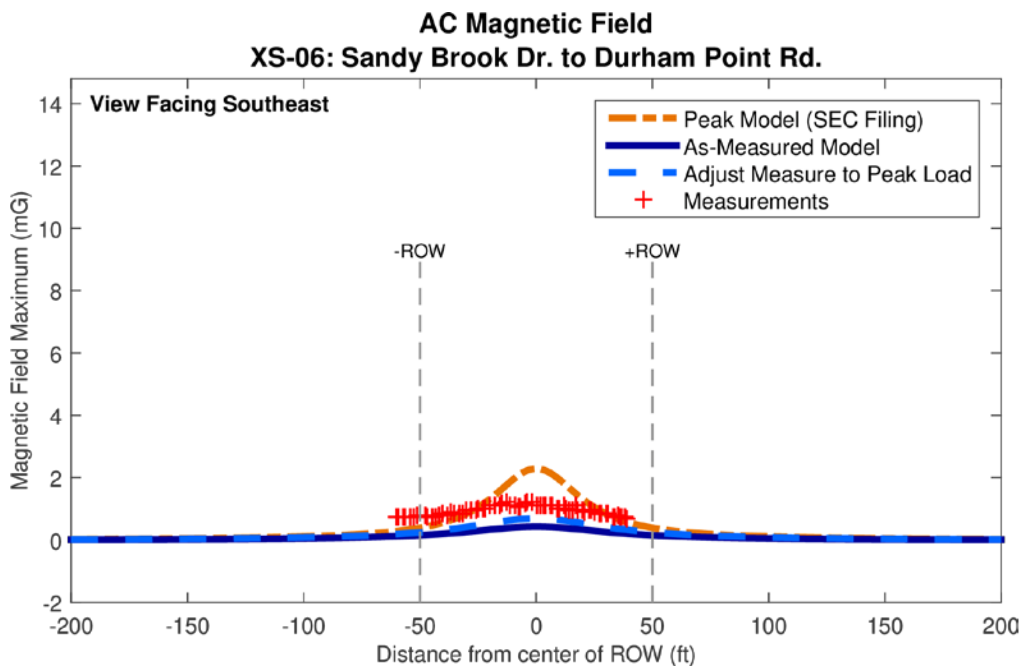

Figure B-11. Measured and modeled magnetic-field levels at Site 6.

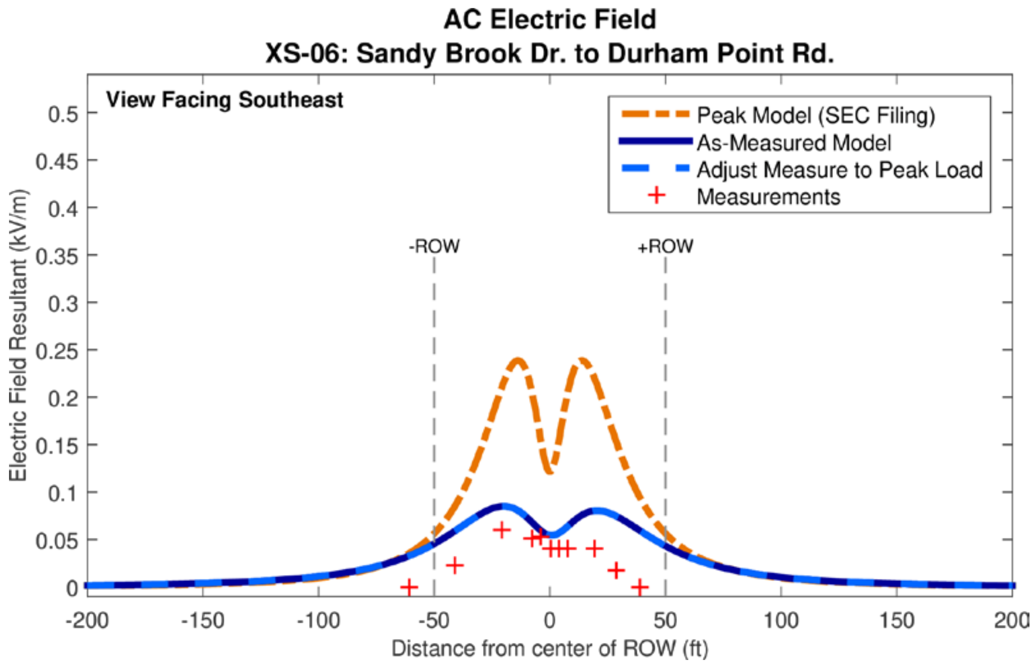

Figure B-12. Measured and modeled electric-field levels at Site 6.

Site 7

Measurements at Site 7 (south of Durham Point Rd.) were performed on June 4, 2019. A graphical summary of results is presented below.

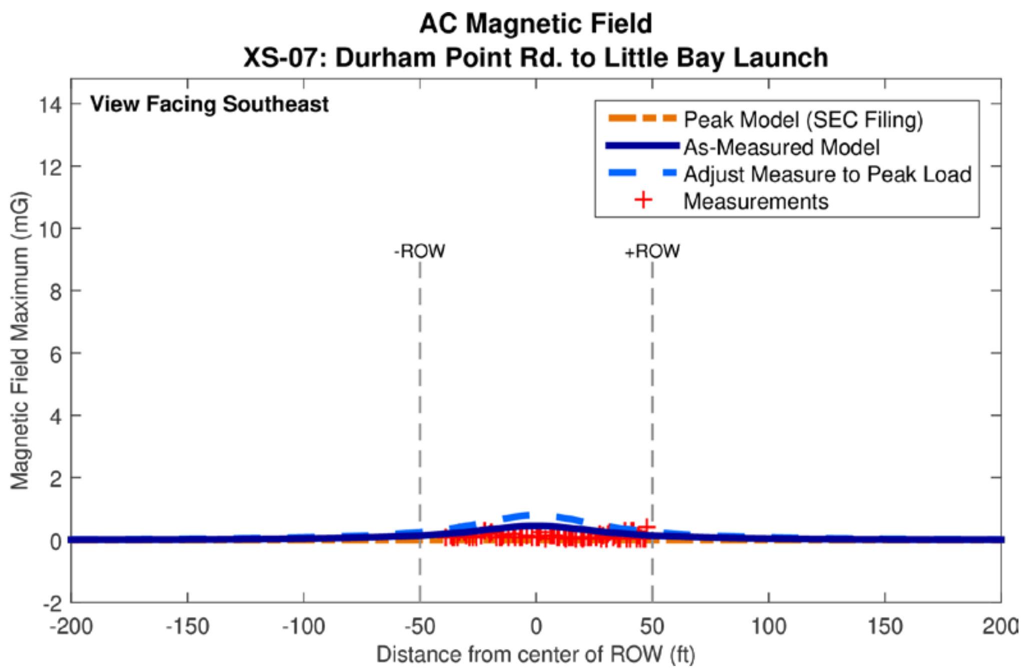

Figure B-13. Measured and modeled magnetic-field levels at Site 7.

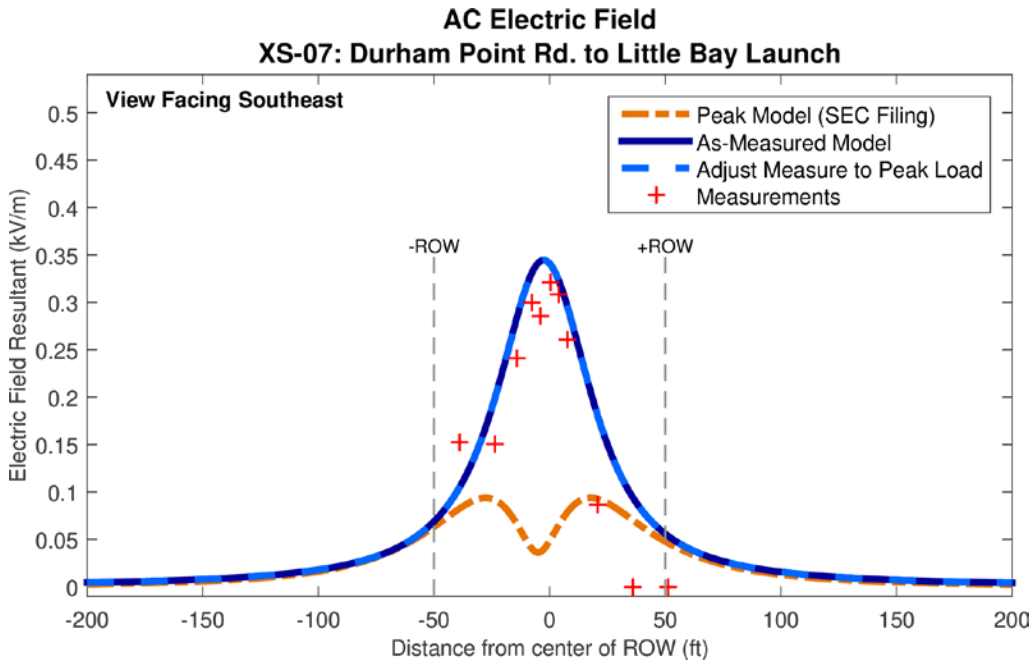

Figure B-14. Measured and modeled electric-field levels at Site 7.

Electric-field levels are higher than calculated in the Application because the 3-phase distribution line in this portion of the route is de-energized and only a single phase (19.9 kV L-N) conductor below the 3-phase distribution line (not included in the Application modeling) is energized.

Site 8

Measurements at Site 8 (west side of Little Bay) were performed on June 4, 2019. A graphical summary of results is presented below.

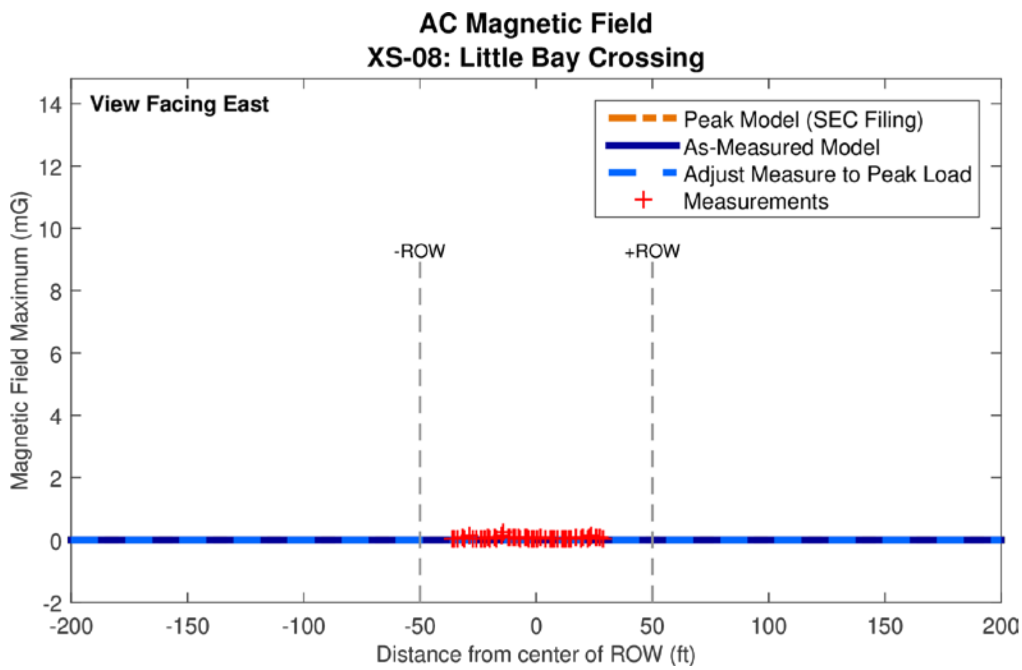

Figure B-15.   Measured and modeled magnetic-field levels at Site 8.

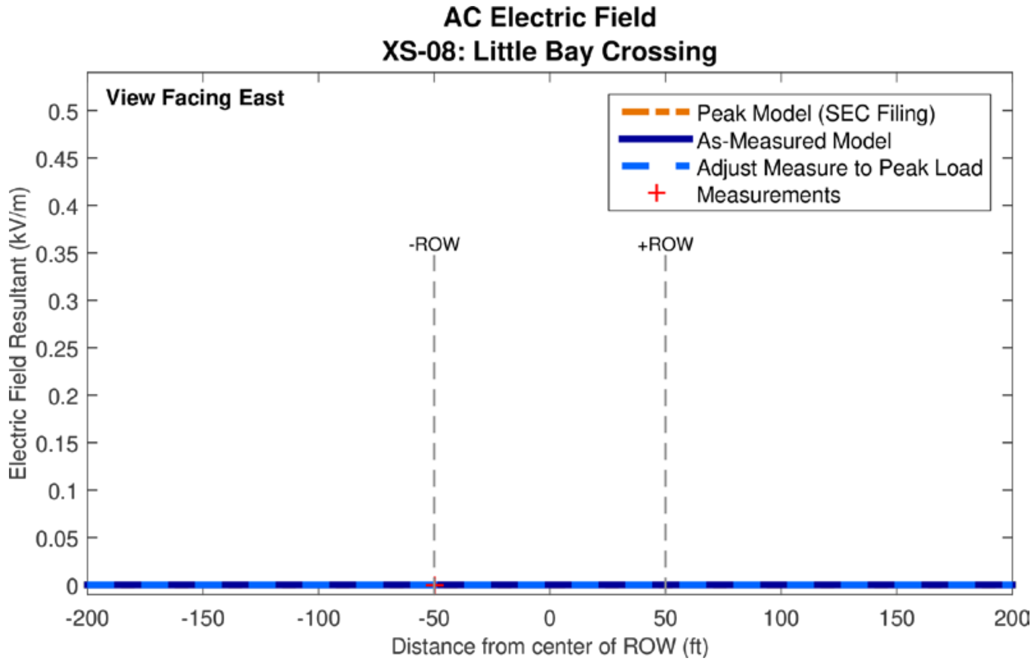

Figure B-16. No electric-field measurements were performed at Site 8. There is no existing source of electric field above ground or the bottom of the Crossing. No electric field was calculated post-construction because the voltage on the conductors of the F107 cable will not produce an electric field outside the cable.

Site 9

Measurements at Site 9 (west of Nimble Hill Rd.) were performed on June 4, 2019. A graphical summary of results is presented below.

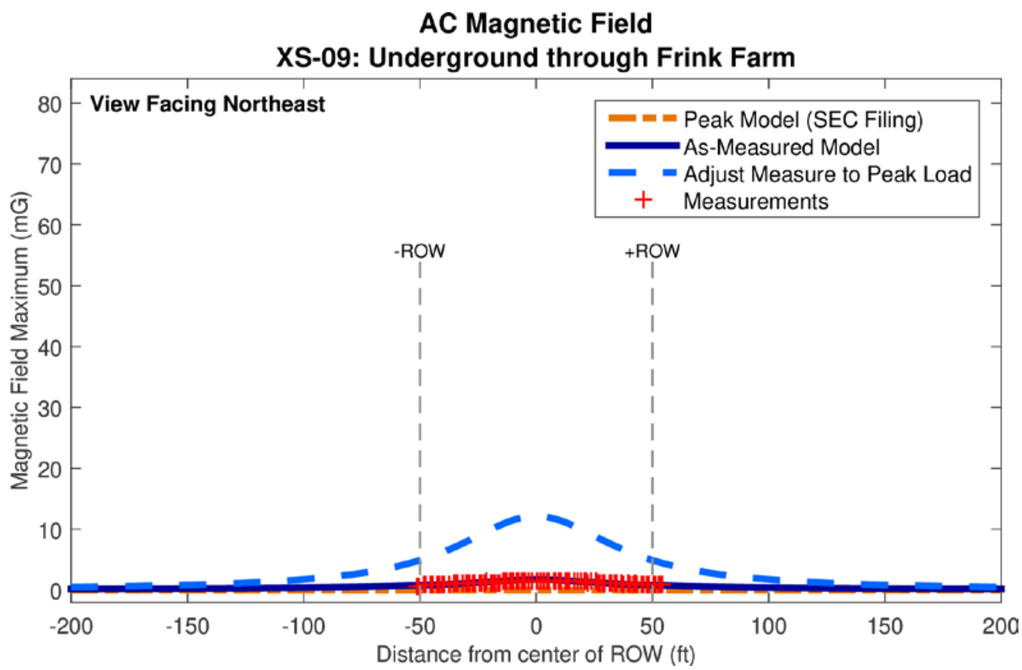

Figure B-17. Measured and modeled magnetic-field levels at Site 9.

Note the different vertical scale than for Sites 4 through 8.

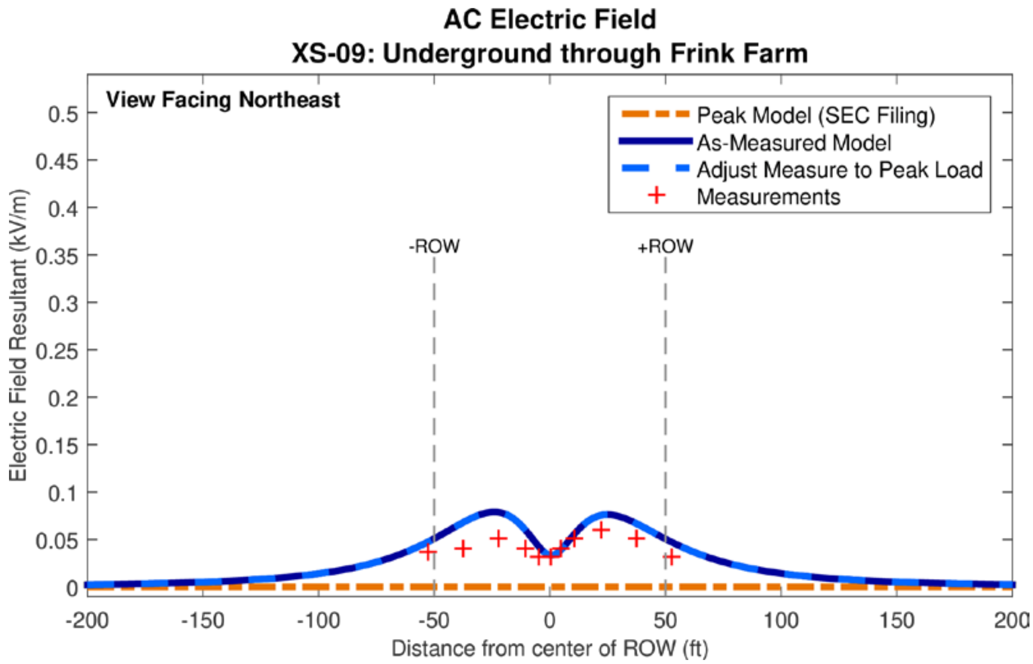

Figure B-18. Measured and modeled electric-field levels at Site 9.

No electric fields were calculated in the application because the F107 transmission line is proposed to be constructed underground in this section of the route and will therefore not be a source of electric fields above ground.

Site 10

Measurements at Site 10 (north of Fox Point Rd.) were performed on June 4, 2019. A graphical summary of results is presented below.

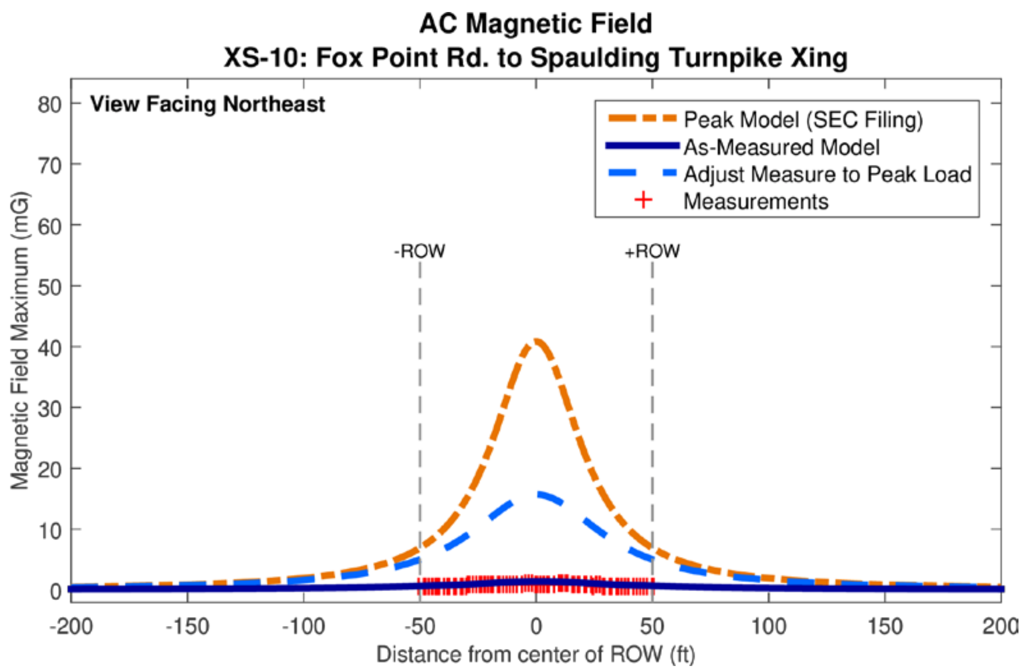

Figure B-19. Measured and modeled magnetic-field levels at Site 10.

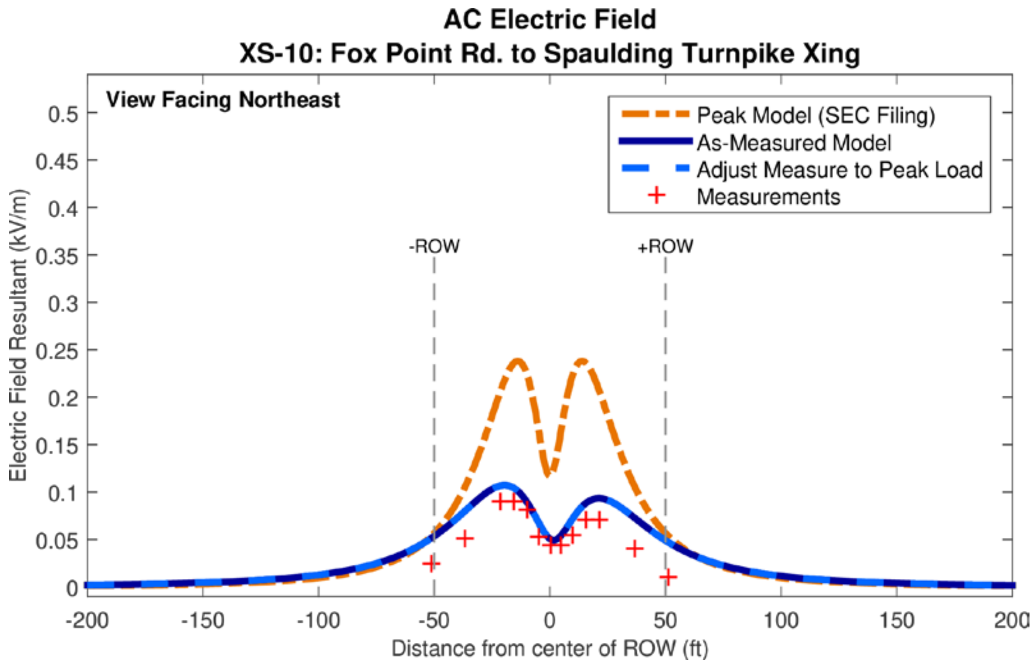

Figure B-20. Measured and modeled electric-field levels at Site 10.

Site 11

Measurements at Site 11 (in the Mall parking lot) were performed on April 29, 2019. A graphical summary of results is presented below.

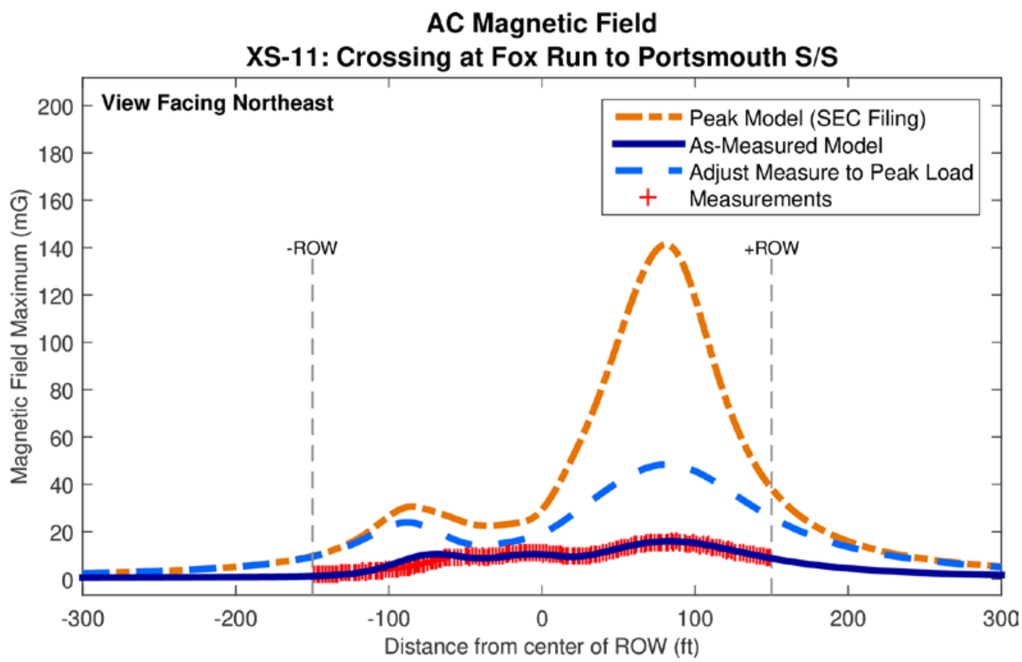

Figure B-21. Measured and modeled magnetic-field levels at Site 11.

Note the different vertical scale than for previous figures.

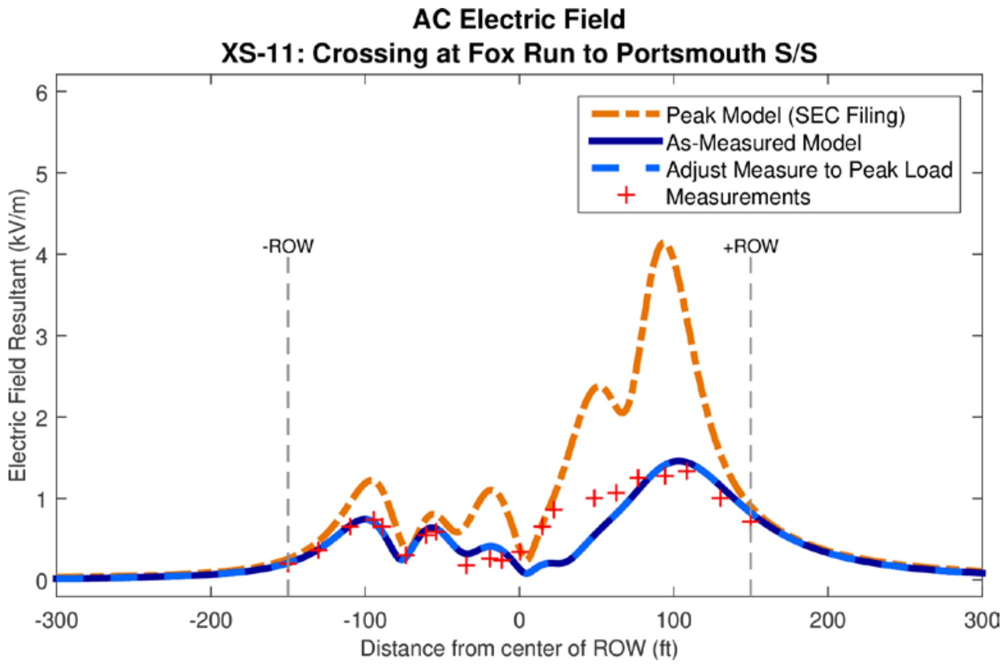

Figure B-22. Measured and modeled electric-field levels at Site 11.

Appendix C

Aerial Maps of Measurement Sites

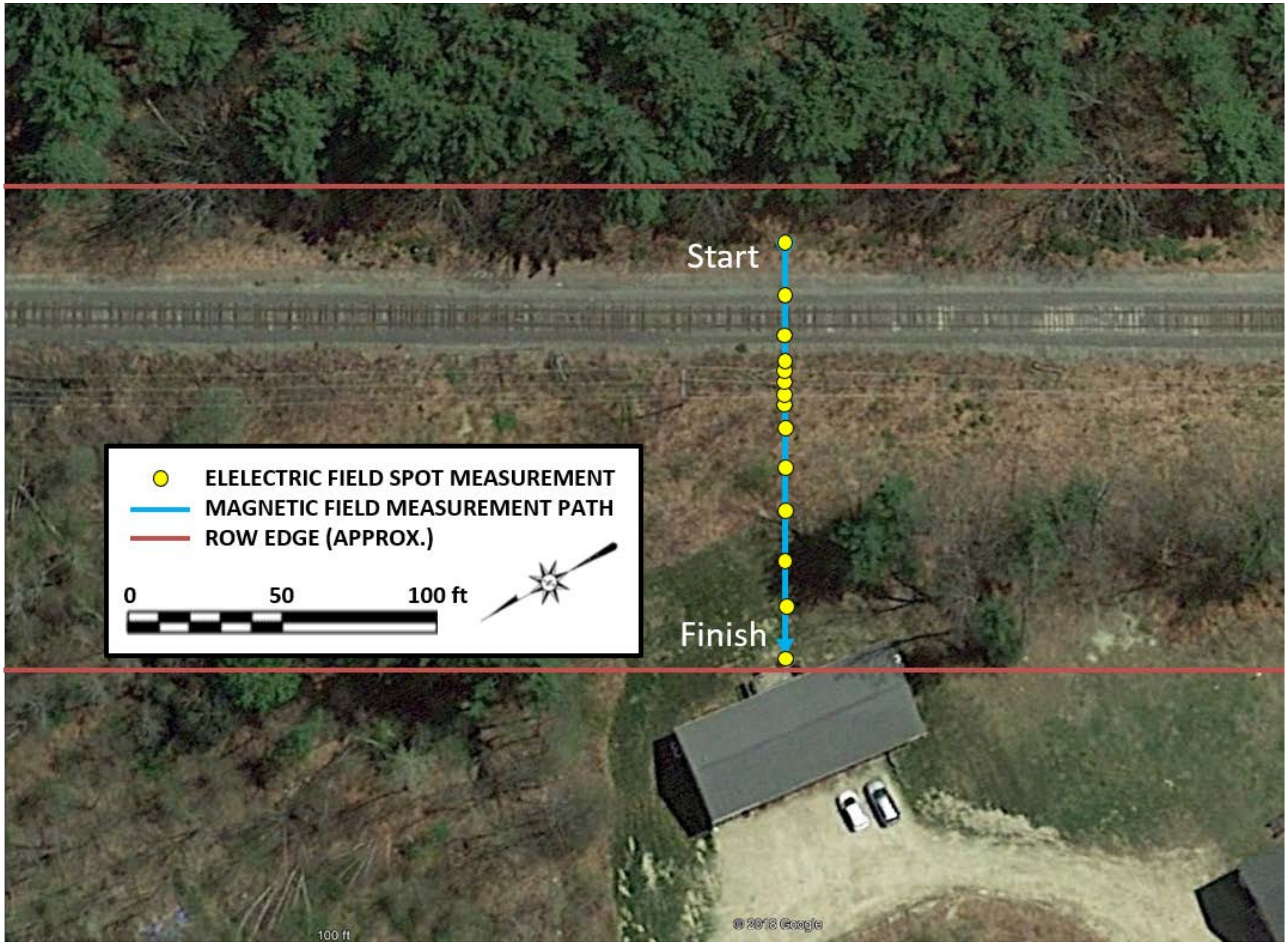

Figure C-1. Aerial photograph of measurement Site 1 (north of Madbury Rd.) showing the approximate location of the magnetic-field measurement path and electric-field spot measurements performed on June 6, 2019.

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 June 6, 2019.

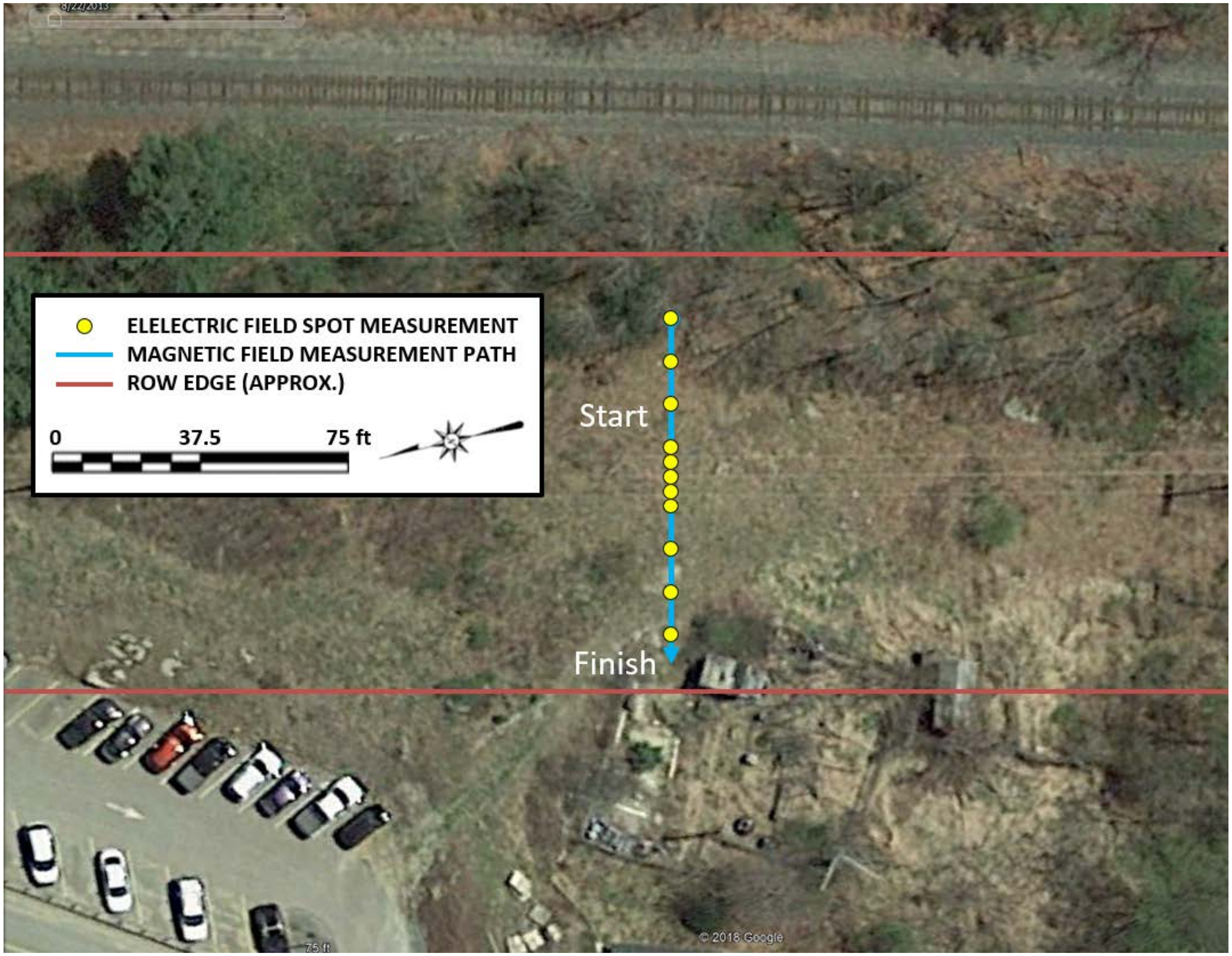

Figure C-3. Aerial photograph of measurement Site 3 (off Waterworks Rd.) showing the approximate location of the magnetic-field measurement path and electric-field spot measurements performed on June 3, 2019.

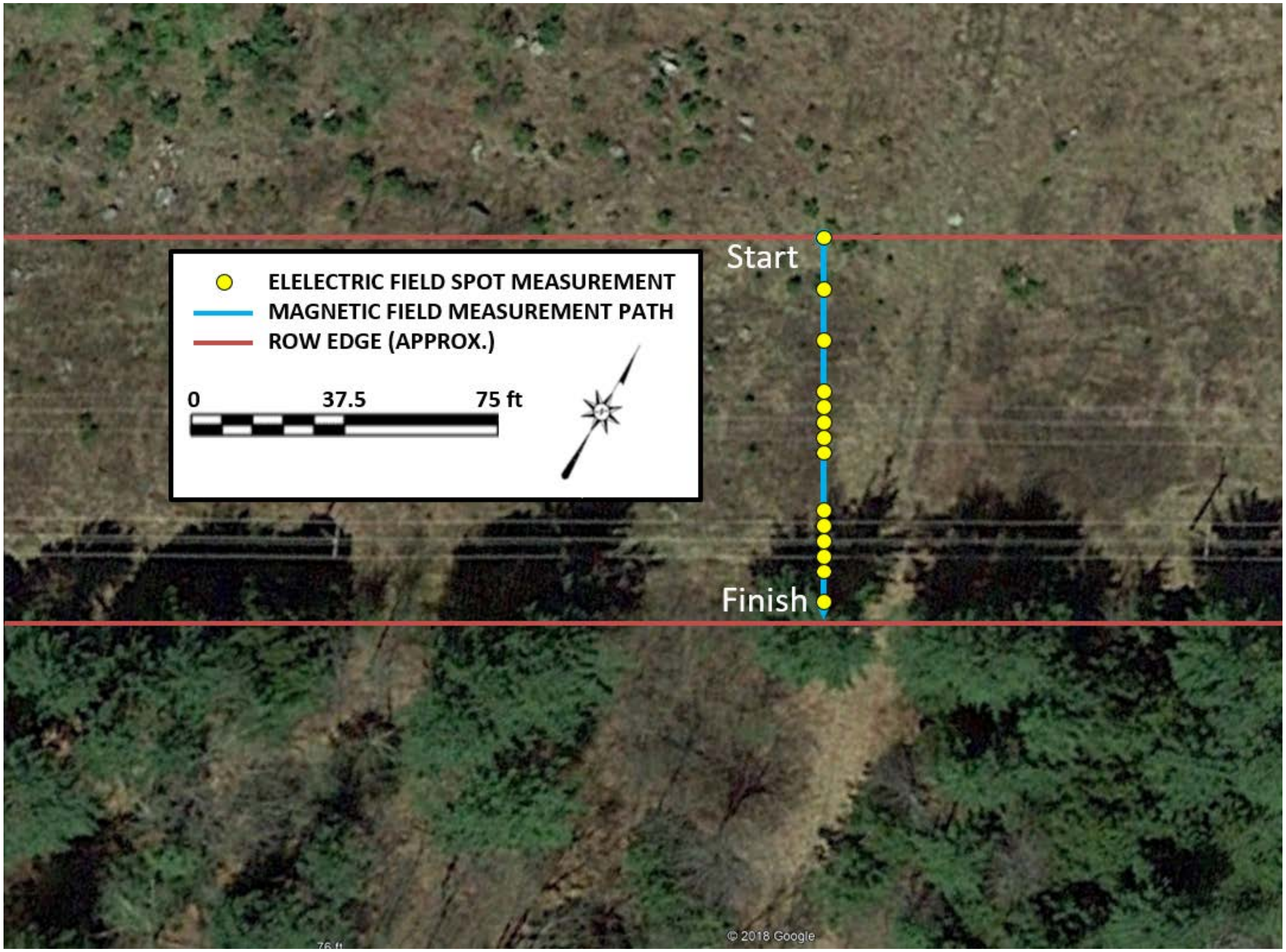

Figure C-4. Aerial photograph of measurement Site 4 (north of Bennett Rd.) showing the approximate location of the magnetic-field measurement path and electric-field spot measurements performed on June 3, 2019.

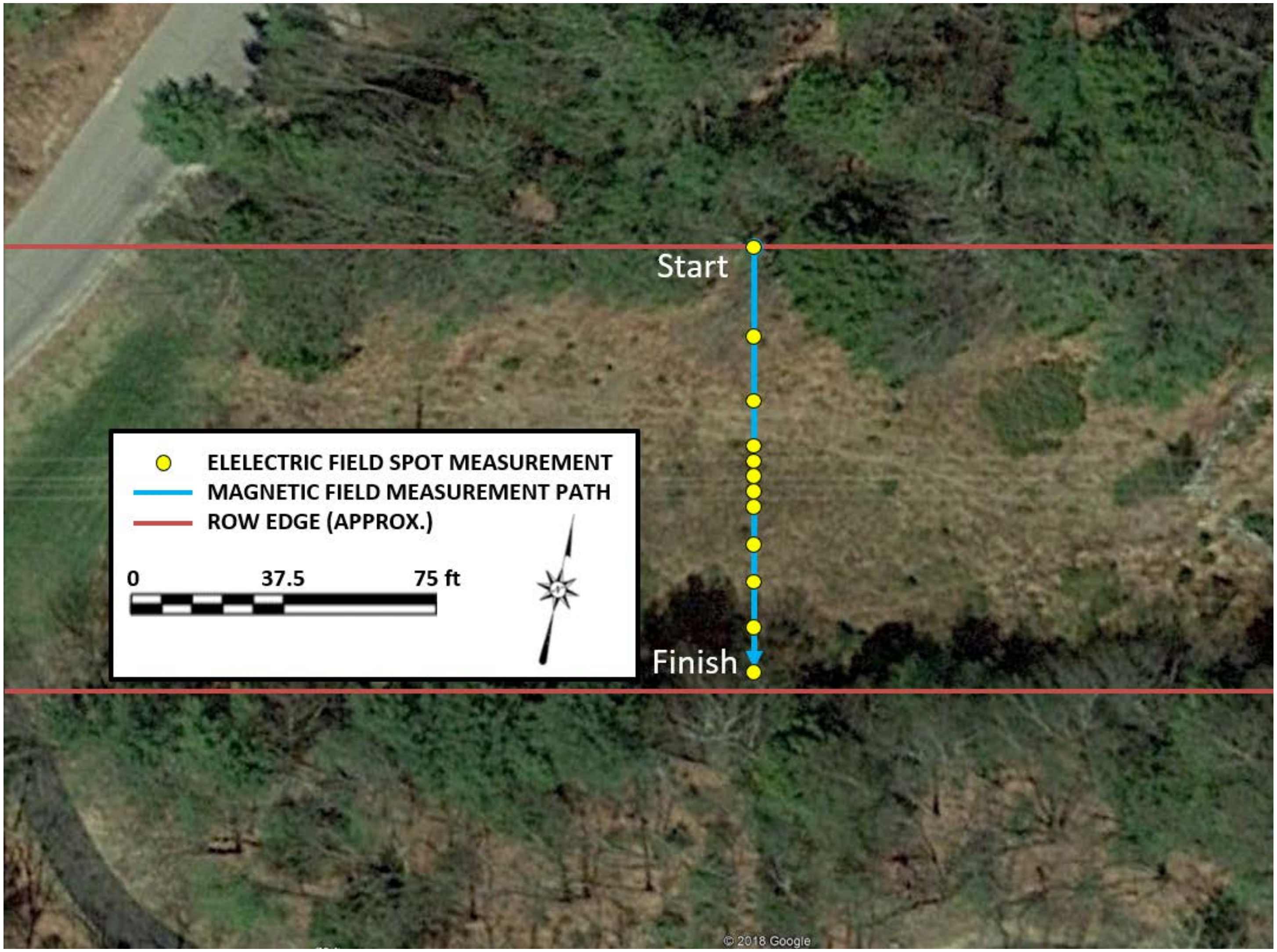

Figure C-5. Aerial photograph of measurement Site 5 (east of Sandy Brook Rd.) showing the approximate location of the magnetic-field measurement path and electric-field spot measurements performed on June 3, 2019.

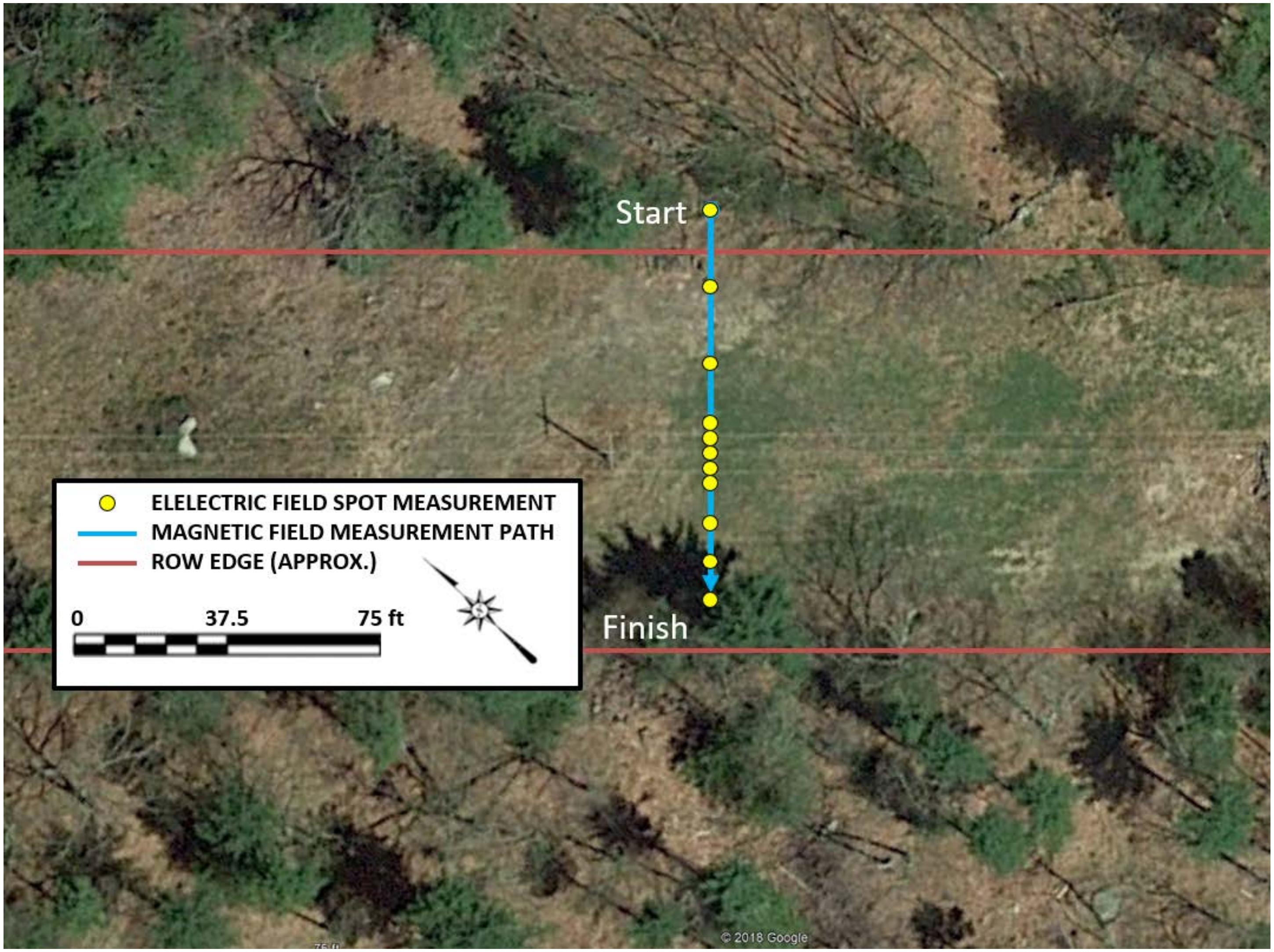

Figure C-6. Aerial photograph of measurement Site 6 (north of Durham Point Rd.) showing the approximate location of the magnetic-field measurement path and electric-field spot measurements performed on June 3, 2019.

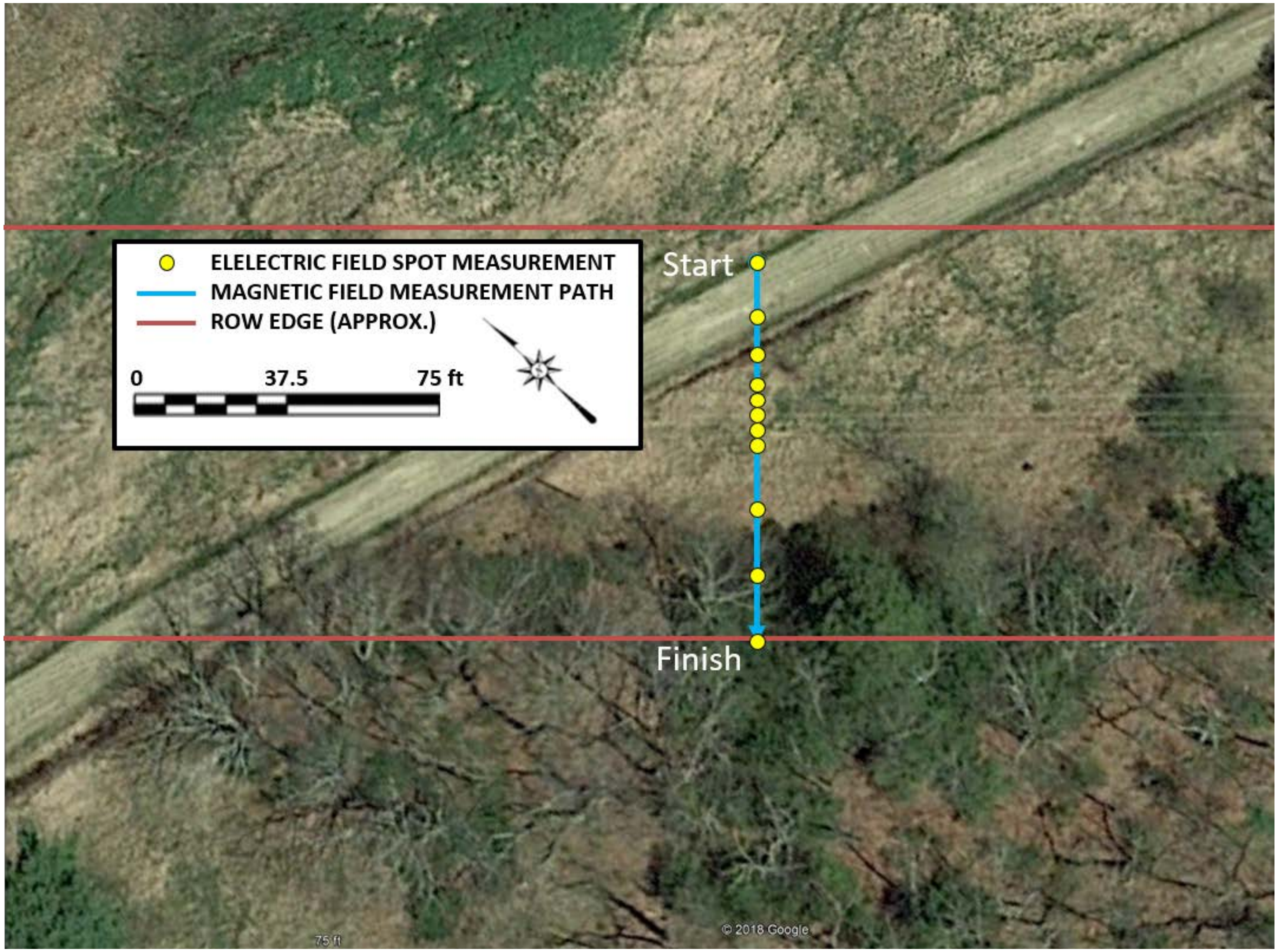

Figure C-7. Aerial photograph of measurement Site 7 (south of Durham Point Rd.) showing the approximate location of the magnetic-field measurement path and electric-field spot measurements performed on June 4, 2019.

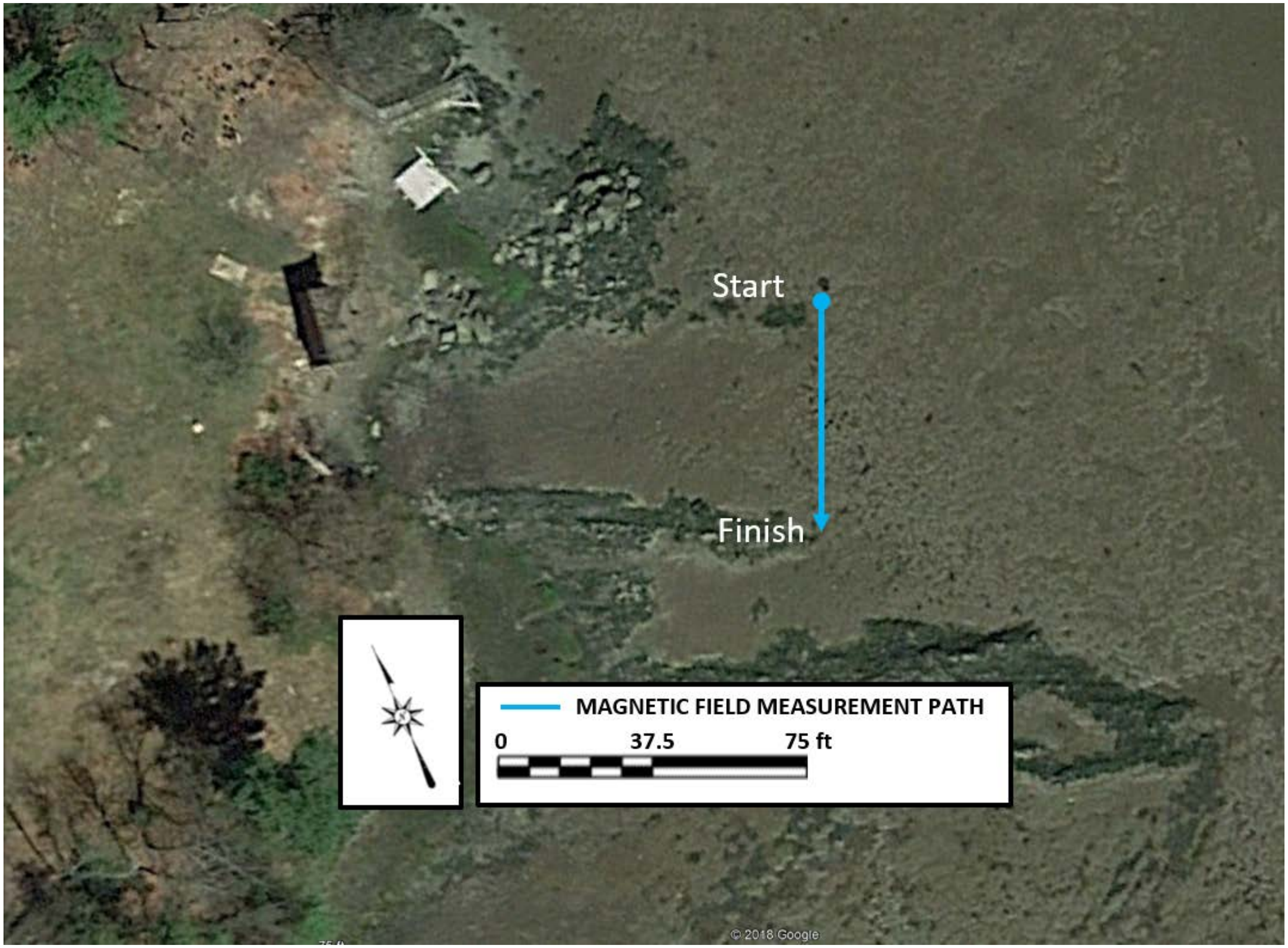

Figure C-8. Aerial photograph of measurement Site 8 (west side of Little Bay) showing the approximate location of the magnetic-field measurement path performed on June 4, 2019.

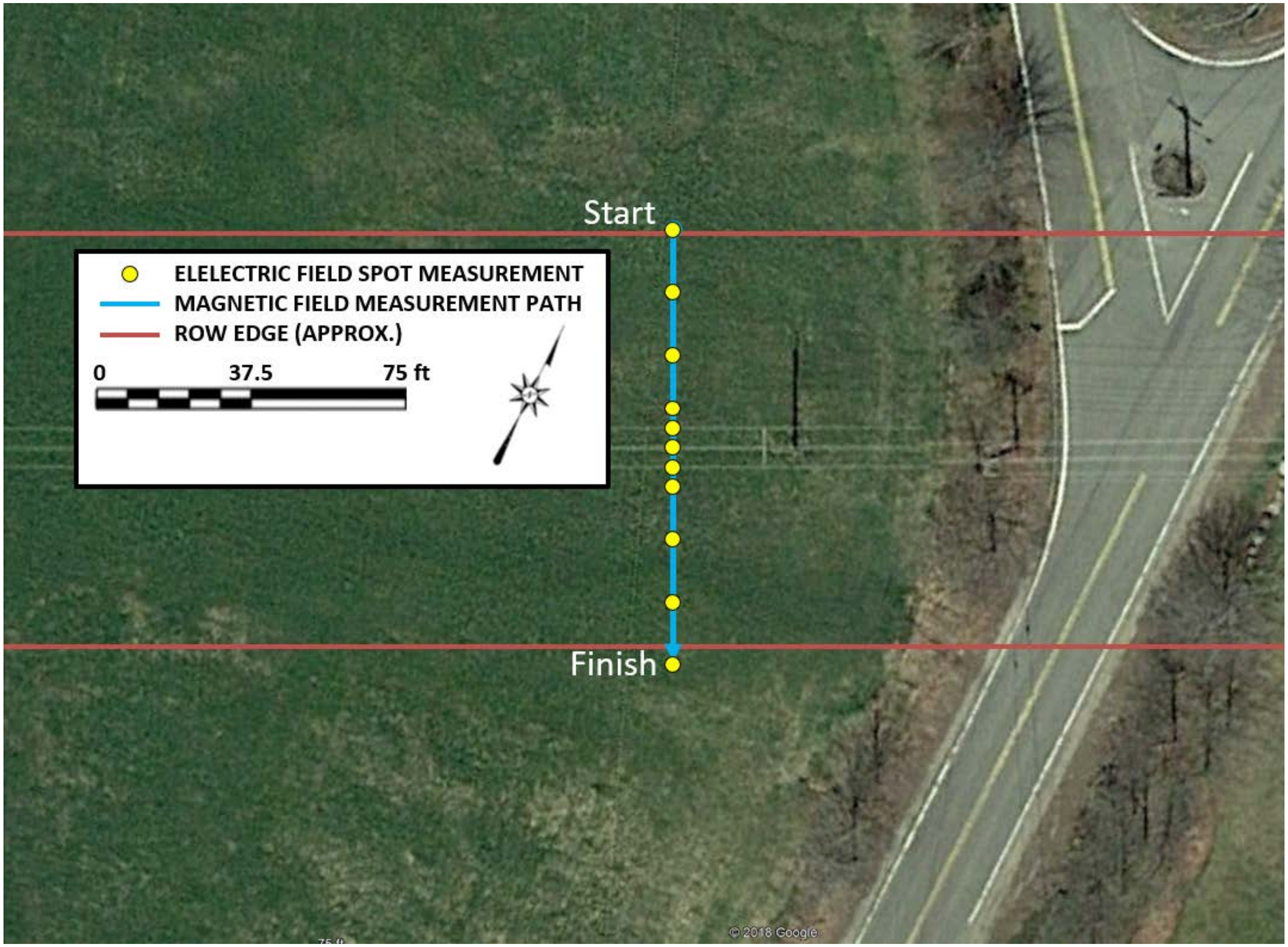

Figure C-9. Aerial photograph of measurement Site 9 (west of Nimble Hill Rd.) showing the approximate location of the magnetic-field measurement path and electric-field spot measurements performed on June 4, 2019.

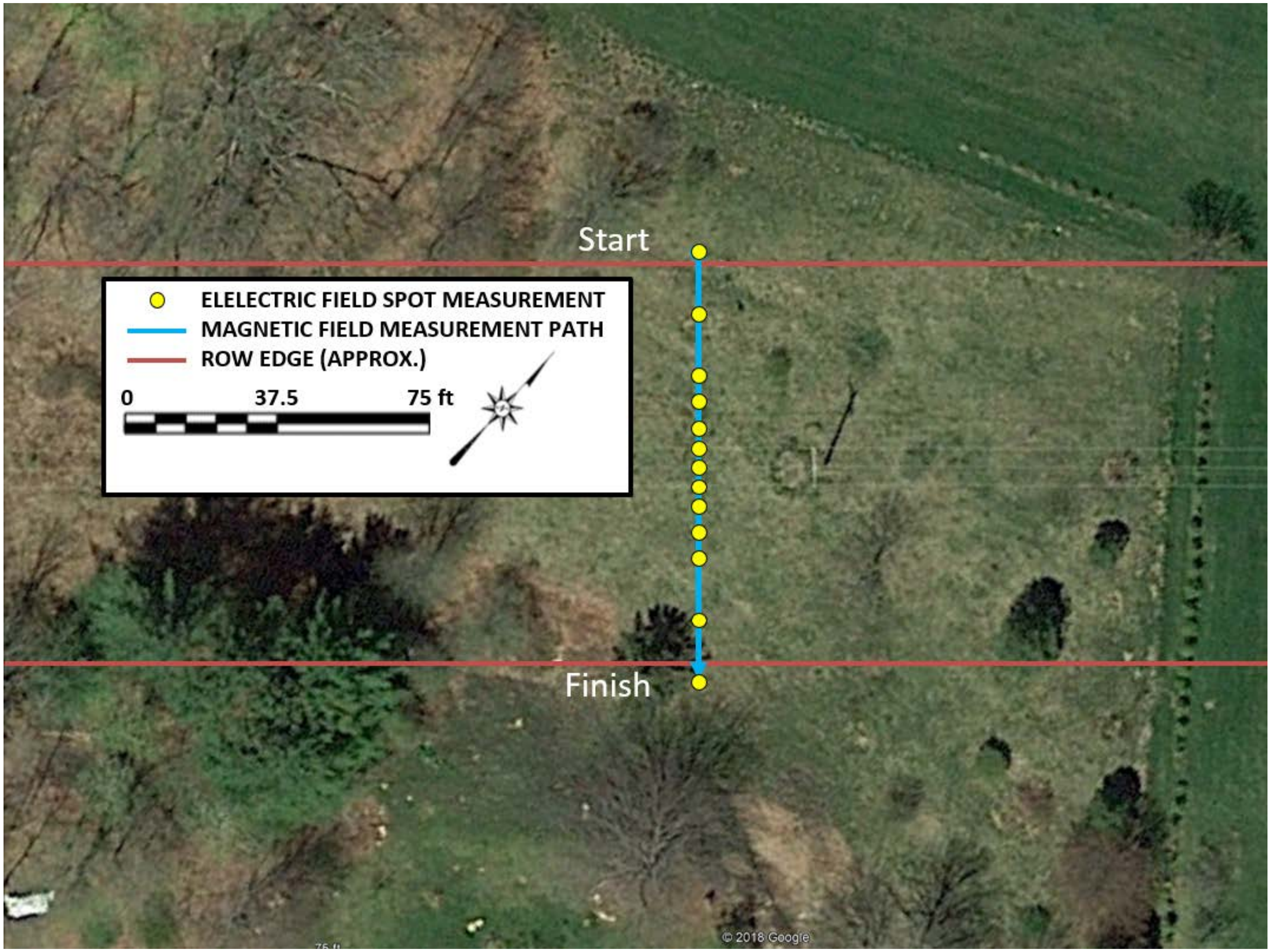

Figure C-10. Aerial photograph of measurement Site 10 (north of Fox Point Rd.) showing the approximate location of the magnetic-field measurement path and electric-field spot measurements performed on June 4, 2019.

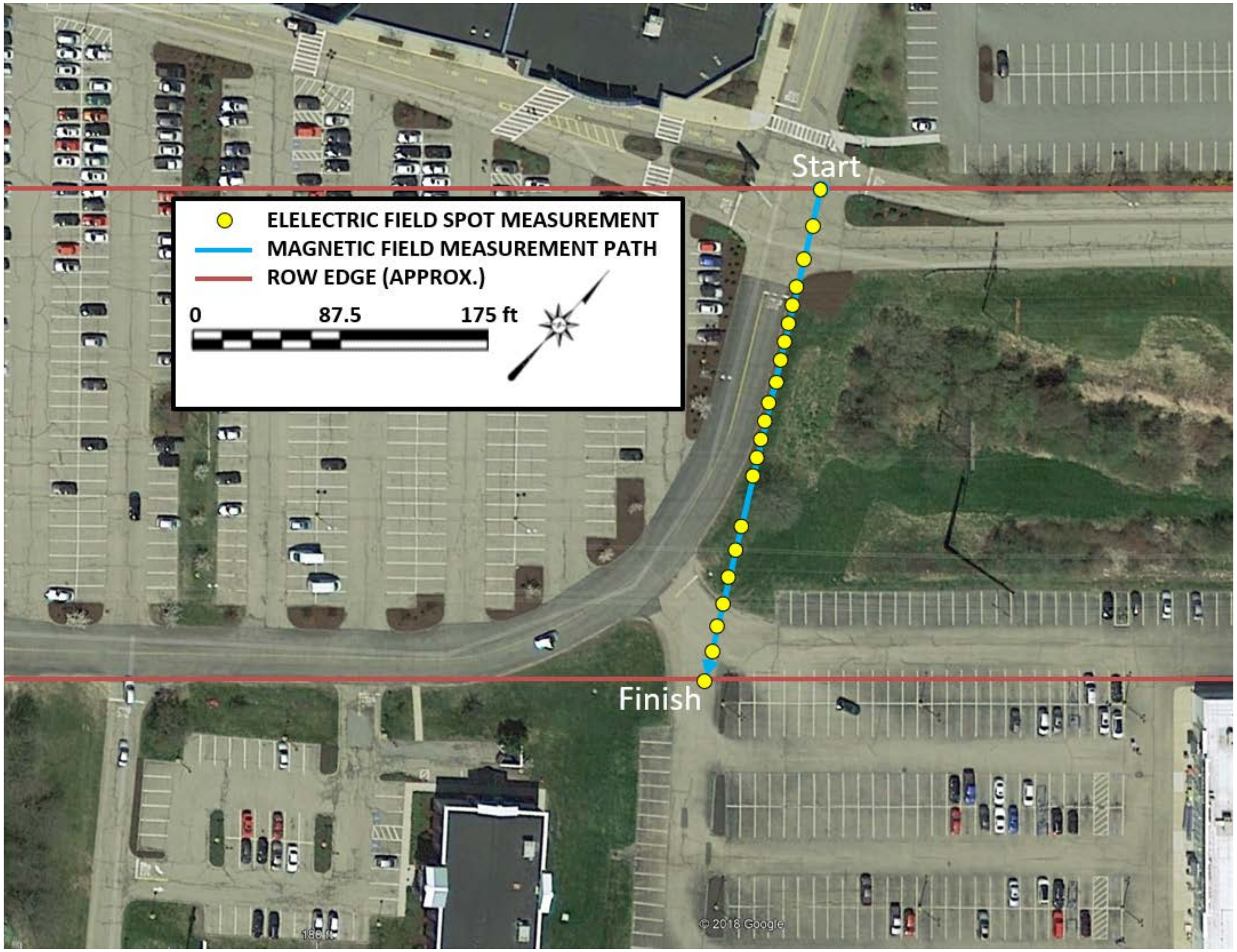

Figure C-11. Aerial photograph of measurement Site 11 (Mall parking lot) showing the approximate location of the magnetic-field measurement path and electric-field spot measurements performed on April 29, 2019.

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)	Application (Peak Loading) Amperes	Measurement Loading Amperes	Minimum Conductor Height (ft) Application	Minimum Conductor Height (ft) Measurement
Site 1	Madbury Substation to Route 4 Crossing	380	34.5	417	244.5	25	30.2
Site 2	Underground through UNH Parking Lot	380	34.5	417	263.5	25	41.2
		UNH 12	12	n/a	22	n/a	41.6
Site 3	UNH to Durham Substation	380	34.5	260	190	25	25.6
Site 4	Packers Falls Substation to Newmarket Rd.	3162	34.5	20	10.4	25	34.7
		3152	34.5	256	0	25	29.8
Site 5	Timber Brook Ln. to Sandy Brook Dr.	3162	34.5	20	10.7	25	33.7
Site 6	Sandy Brook Dr. to Durham Point Rd.	3162	34.5	20	12.3	25	39.6
Site 7	Durham Point Rd. to Little Bay Launch	3162	0	n/a	11.4	n/a	36.8
		1-φ	19.9 (L-N)	n/a	0*	n/a	26.8
Site 8	Little Bay Crossing	n/a	n/a	n/a	n/a	n/a	n/a
Site 9	Underground through Frink Farm	3850	34.5	n/a	12*	n/a	43.8
		Neutral	0	n/a	6.5*	n/a	28.4
Site 10	Fox Point Rd. to Spaulding Turnpike Crossing	3850	34.5	357	12*	25	37.1
		Neutral	0	n/a	5.5*	n/a	30.1
Site 11	Crossing at Fox Run to Portsmouth Substation	E194	115	213	51.6	30	33.8
		E181	115	52	47.1	30	39.1
		3135	345	1141	360.1	35	66

* Loading not available during measurements. This is an assumed value based on reasonable match with measured values.

Appendix E

Calibration Certificates

Certificate of Calibration

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

Instrument Model: EMDEX II

Frequency: 60 Hertz

Serial Number: 1134

Date of Calibration: 10/24/2018

Re-Calibration suggested at one year from above date.

EMDEX LLC

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

H. Christopher Hooper
Calibration Inspector

suparule

Calibration Certificate

Holland Road,
National Technology Park,
Limerick, Ireland.

Tel: +353 (0) 61 201030
Fax: +353 (0) 61 330812

Email: info@suparule.com
Web: www.suparule.com

MODEL	***600E***
Description	***Cable Height Meter***
Serial No.	***A41142***
Date of Calibration	***20th May 2019***
CHM Calibration Due Date	***20th May 2020***

Equipment used:

Model	Serial No.	Control No.	Calibration Due Date
SupaRule T30 Thermometer	8310412	CAL ID 041	8th May 2020
Leica Dista A2	4070150304		8th May 2020

Instrument calibrated to a national or international standards to better than ± 0.15°C (T30).

Method: After temperature stabilisation, readings taken are as follows:
Actual Temperature: 22.1°C
Temperature reading before adjustment: 22.2°C

Adjustment made.
Waveform calibrated.

Calibration accuracy:

After calibration the instrument will have an accuracy of ± 0.5% +/- 2digits provided that the displayed temperature is within ± 0.5°C of the ambient temperature. (Temperature range = 0°C to 35°C), as per its specification.

Eoin O'Loughlin

Approved Signatory
Eoin O'Loughlin

All the equipments used in this calibration are traceable to National or International standards.

ISO 9001:2008 EQA QUALITY ASSURED COMPANY

Directors: J. McDonnell, M.Meehan, B. O'Donoghue.
Suparule Systems Ltd., Registered in Ireland. Company No. 152205. Registered Office is at the above address

Kestrel®
Weather & Environmental Meters
by NK

Certificate of Conformity

This instrument was produced under rigorous factory production control and documented standard procedures. It was individually visually inspected, leak tested and function tested for display, backlight, button and software performance. The accuracy of each of its primary measurements was individually calibrated and/or tested against standards traceable to the National Institute of Standards and Technology ("NIST") or calibrated intermediary standards. This instrument is certified to have performed at the time of manufacture in compliance with the following specifications as they apply to this meter's specific model, measurements and features.

Methods Used in Calibration and Testing

Wind Speed:

The Kestrel Weather & Environmental Meter impeller installed in this unit was individually tested in a subsonic wind tunnel operating at approximately 300 fpm (1.5 m/s) and 1200 fpm (6.1 m/s) monitored by a Gill Instruments Model 1350 ultrasonic time-of-flight anemometer. The Standard's maximum combined uncertainty is +/–1.04% within the airspeed range 706.6 to 3923.9 fpm (3.59 to 19.93 m/s), and +/–1.66% within the airspeed range 166.6 to 706.6 fpm (0.85 to 3.59 m/s).

Temperature:

Temperature response is verified in comparison with a Eutechnics 4600 Precision Thermometer or a standard Kestrel 4000 Weather & Environmental Meter calibrated weekly against the Eutechnics 4600. The Eutechnics 4600 is calibrated annually and is traceable to NIST with a system accuracy of +/– 0.05 °C.

Direction / Heading

The sensitivity of the magnetic directional sensor is verified at the component level by applying a magnetic field to the sensor and measuring the signal output at 4 points, as well as after assembly by orienting the unit to the cardinal directions and measuring the magnetic field output. In both cases, the compass output must be accurate to within +/– 5 degrees.

Relative Humidity:

Relative humidity receives a two-point calibration in humidity and temperature controlled chambers at 75.3% RH and 32.8% RH at 25° C. The calibration tanks are monitored with an Edgetech Model 2002 DewPrime II Standard Chilled Mirror Hygrometer. Following calibration, performance is further verified at an RH of approximately 43.2% against the Edgetech Hygrometer. The Edgetech Hygrometer is calibrated annually and is traceable to NIST with a maximum relative expanded uncertainty of +/– 0.2% RH.

Barometric Pressure:

Pressure response is verified against a Vaisala PTB210A Digital Barometer or a standard Kestrel 4000 Weather & Environmental Meter calibrated weekly against the Vaisala Barometer. The Vaisala Barometer is calibrated annually and is traceable to NIST with an accuracy of +/-0.15 hPa at +20°C defined as the root sum of the squares (RSS) of end point non-linearity, hysteresis error, repeatability error and calibration uncertainty at room temperature.

Approved By:

Michael Naughton, Engineering Manager

The enclosed Kestrel Weather & Environmental Meter was manufactured by Nielsen-Kellerman Co. at its facilities located at 21 Creek Circle, Boothwyn, PA 19061 USA.

Appendix F

Measurement Protocol Sent to the PUC and NHSEC on April 18, 2019

Exponent®

MEMORANDUM

TO:	Pamela Monroe, Administrator, NH SEC
FROM:	Benjamin Cotts, Ph.D., P.E.
CC:	Paul Kasper, Assistant Director, Safety and Security, NH PUC Dena Champy, PMP, Eversource Energy, Christopher Soderman, P.E., Eversource Energy,
DATE:	April 18, 2019
PROJECT:	1501863.001 Seacoast Reliability Project (NH SEC Docket 2015-04)
SUBJECT:	Protocol for 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 on January 31, 2019, Eversource requested Exponent to provide a draft protocol for performing measurements of electric and magnetic fields (EMF) both before and after the Project is placed into service in consultation with the Safety Division of the New Hampshire Public Utilities Commission (PUC).

Order and Certificate of Site and Facility Condition

The Order and Certificate of Site and Facility with Conditions issued by the New Hampshire Site Evaluation Committee (NHSEC) for the SRP dated January 31, 2019 states that it is:

> "Further Ordered that the Applicant, in consultation with the PUC 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; . . . ."

Proposed Measurement Protocol

The proposed measurement protocol is divided into several sections including Measurement Preparation, Measurement Procedure, and Reporting.

Measurement Preparation and Location Identification

Exponent and Eversource have reviewed in detail the configuration and the residential density along the route of the proposed F107 transmission line and have identified 11 segments of the proposed project route where measurements are proposed to be taken before and after construction of the Project. These 11 route segments cover all the proposed configuration types and are expected to conservatively evaluate electric and magnetic field (EMF) levels for the entire route.[1,2] The criterion for initial site selection was to evaluate all F107 structure types (e.g., delta, delta with underbuild, underground etc.) and to combine segments where similar configurations are proposed. Next, specific locations were selected where the F107 line would pass by a higher density of residences than other segments of the route with similar configurations. These 11 route segments for which measurements are proposed are described in Table 1 by the Line Section in the Application, structure type, and beginning and ending structure numbers.

Table 1. EMF measurement section proposal

Measure #	**Line Section** (Application Section)	**F107 Structure Type**	**Begin Segment Structure #**	**End Segment Structure #**
1	Madbury S/S to Route 4 Xing	Delta	Madbury S/S	9
2	Underground through UNH Parking Lot	Underground	23	24
3	UNH to Durham S/S	Delta w/ underbuild	25	32
4	Packers Falls S/S to Newmarket Rd.	Delta w/ underbuild & adjacent line	49	59
5	Timber Brook Ln. to Sandy Brook Dr.	Delta w/ underbuild	64	70
6	Sandy Brook Dr. to Durham Point Rd.	Delta & adjacent line	71	93
7*	Durham Point Rd. to Little Bay Launch	Delta	96	100
8	Little Bay Xing	Direct bury	Shoreline on west side of Bay	
9†	Underground through Frink Farm	Underground	109	113
10	Fox Point Rd. to Spaulding Turnpike Xing	Delta & adjacent line	115	137
11	Crossing at Fox Run to Portsmouth S/S	Vertical & adjacent lines	138	Portsmouth S/S

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

Within each of these 11 cross sections of the route Exponent and Eversource will select one measurement location (preferably with at least one alternate location), which is anticipated to be appropriate for measurements both before and after the Project is placed into service. These

[1] Spot measurements of magnetic field levels were previously performed on August 8, 2018 beneath the existing transmission line and at various points on the property and inside the Fitch residence at 291 Durham Point Rd.

[2] No measurements are proposed for the small portion of the route between structures 102 and 109 where the proposed configuration changes rapidly (from underground to vertical, to delta to H-frame and back to underground) over a relatively small area. Each of these configurations is measured elsewhere on the route except for the two spans where the F107 line is proposed in an H-frame configuration. No measurements are proposed for this configuration because it represents a very small (2 spans) portion of the route and because the nearest residence to this configuration is more than 400 feet away.

locations ideally will have the following characteristics that increase the likelihood of obtaining good quality measurements:

1) Free from other sources of EMF which may affect measured levels (e.g., overhead/underground distribution lines) or other facilities which can alter measured EMF levels (e.g., water or sewer pipes, gas or oil pipelines).
2) Flat, level surface beneath the transmission lines (or above underground transmission lines) that is away from transmission line structures (ideally near midspan of lines).
3) Free of underbrush, trees or other conductive objects which is necessary in order to match the conditions for which the modeled the electric field was calculated.

Additionally, foul weather, particularly precipitation, will interfere with the function of instruments and the valid measurement of electric field levels. Exponent will therefore coordinate with utility personnel and the Safety Division to identify a time-frame with anticipated favorable weather conditions. This timeframe (or timeframes) will be discussed with Eversource to confirm that there are no expected line outages, construction or system repairs, or other unusual line conditions scheduled for that period. Additionally, utility personnel will work with appropriate departments to ensure that necessary data (e.g., loading information of all transmission lines at the measurement locations) can be logged and available during the proposed measurement period. Post-construction measurements will be made during summer peak loading season.

Measurement Procedure

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

Engineers will then proceed to perform EMF measurements using measurement equipment and methodology outlined in Institute of Electrical and Electronics Engineers IEEE Standard 644-1994 (R2008) and IEEE Std. C95.3.1-2010. Measurements will be performed at a height of 1 meter above ground and will be performed for a transect perpendicular to the transmission line. If a transect other than perpendicular is necessary, the angle of the transect to the transmission lines will be noted and measurement distances will be adjusted accordingly.

Both electric fields and magnetic fields will be measured as the total field computed as the resultant of field vectors measured along vertical, transverse, and longitudinal axes.[3] 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 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. 644-1994.

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 measurements before the Project is placed into service are taken at line loadings lower than peak levels, 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.

Exponent and Eversource will provide 7 days' 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 two measurement reports: the first summarizing measurements taken before Project commences construction; and the second summarizing measurements taken after the Project is placed into service. These reports 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 two measurement reports will each be submitted within 60 days of completion of the respective 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 and as adjusted to the peak loading condition specified in the application.

[3] 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.

Appendix A

EMDEX II Calibration Certificates

Certificate of Calibration

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

Instrument Model: EMDEX II

Frequency: 60 Hertz

Serial Number: 1134

Date of Calibration: 10/24/2018

Re-Calibration suggested at one year from above date.

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

H. Christopher Hooper
Calibration Inspector

Certificate of Calibration

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

Instrument Model: EMDEX II

Frequency: 60 Hertz

Serial Number: 3074

Date of Calibration: 7/5/2018

Re-Calibration suggested at one year from above date.

EMDEX LLC

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

H. Christopher Hooper
Calibration Inspector

Appendix A

Summary Tables 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 tables below are therefore reported at the location where the electric- and magnetic-field measurement 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 also reported at these same locations, not at the precise ROW edge.

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]

[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 **June 6, 2019**	Peak Model (Application Filing)	5.7	48	3.3
	Modeled Field (for measured line height and load at time of measurements)	2.7	14	1.6
	Modeled Field (for measured line height, and load adjusted to peak level)	4.5	24	2.7
	Measured Field	5.1	22	3.7
Site 2 **June 6, 2019**	Peak Model (Application Filing)*	15	49	4.1
	Modeled Field (for measured line height and load at time of measurements)	5.0	9.3	1.9
	Modeled Field (for measured line height, and load adjusted to peak level)	7.9	15	3.0
	Measured Field	7.4	11	2.6
Site 3 **June 3, 2019**	Peak Model (Application Filing)	7.1	30	5.7
	Modeled Field (for measured line height and load at time of measurements)	4.4	19	3.9
	Modeled Field (for measured line height, and load adjusted to peak level)	6.0	26	5.3
	Measured Field	6.0	17	4.9
Site 4 **June 3, 2019**	Peak Model (Application Filing)	1.8	30	17
	Modeled Field (for measured line height and load at time of measurements)	0.2	0.5	0.1
	Modeled Field (for measured line height, and load adjusted to peak level)	1.8	18	11
	Measured Field	0.6	1.1	0.4
Site 5 **June 3, 2019**	Peak Model (Application Filing)	0.4	2.3	0.4
	Modeled Field (for measured line height and load at time of measurements)	0.1	0.5	0.2
	Modeled Field (for measured line height, and load adjusted to peak level)	0.3	1.0	0.3
	Measured Field	0.2	0.5	0.4
Site 6 **June 3, 2019**	Peak Model (Application Filing)	0.4	2.3	0.6
	Modeled Field (for measured line height and load at time of measurements)	0.1	0.4	0.2
	Modeled Field (for measured line height, and load adjusted to peak level)	0.2	0.7	0.3
	Measured Field	0.8	1.2	0.7

Site # Date	Condition	Value at Measurement Point: Nearest −ROW Edge	Max on ROW	Nearest +ROW Edge
Site 7 June 4, 2019	Peak Model (Application Filing)*	0.0	0.0	0.0
	Modeled Field (for measured line height and load at time of measurements)	0.2	0.5	0.2
	Modeled Field (for measured line height, and load adjusted to peak level)	0.3	0.8	0.3
	Measured Field	0.1	0.4	0.4
Site 8 June 4, 2019	Peak Model (Application Filing)	0.0	0.0	0.0
	Modeled Field (for measured line height and load at time of measurements)	0.0	0.0	0.0
	Modeled Field (for measured line height, and load adjusted to peak level)	0.0	0.0	0.0
	Measured Field	0.0	0.2	0.0
Site 9 June 4, 2019	Peak Model (Application Filing)*	0.0	0.0	0.0
	Modeled Field (for measured line height and load at time of measurements)	0.8	1.7	0.8
	Modeled Field (for measured line height, and load adjusted to peak level)	4.9	12	4.8
	Measured Field	0.7	1.6	1.0
Site 10 June 4, 2019	Peak Model (Application Filing)	6.8	41	7.0
	Modeled Field (for measured line height and load at time of measurements)	0.6	1.4	0.7
	Modeled Field (for measured line height, and load adjusted to peak level)	5.0	16	5.1
	Measured Field	0.5	1.2	0.5
Site 11 April 29, 2019	Peak Model (Application Filing)	9.8	141	39
	Modeled Field (for measured line height and load at time of measurements)	1.2	16	8.8
	Modeled Field (for measured line height, and load adjusted to peak level)	9.5	48	26
	Measured Field	1.9	16	8.8

* 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.

Table A-1. 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 June 6, 2019	Peak Model (Application Filing)	<0.1	0.3	<0.1
	Modeled Field (for measured line height at time of measurements)	<0.1	0.2	<0.1
	Modeled Field (for measured line height; no adjustment for peak loading needed)	<0.1	0.2	<0.1
	Measured Field	<0.1	0.1	<0.1
Site 2 June 6, 2019	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 June 3, 2019	Peak Model (Application Filing)	0.1	0.2	0.1
	Modeled Field (for measured line height at time of measurements)	0.1	0.2	0.1
	Modeled Field (for measured line height; no adjustment for peak loading needed)	0.1	0.2	0.1
	Measured Field	<0.1	0.2	<0.1
Site 4 June 3, 2019	Peak Model (Application Filing)	0.1	0.3	0.2
	Modeled Field (for measured line height at time of measurements)	0.1	0.2	0.2
	Modeled Field (for measured line height; no adjustment for peak loading needed)	0.1	0.2	0.2
	Measured Field	0.1	0.1	0.1
Site 5 June 3, 2019	Peak Model (Application Filing)	0.1	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 6 June 3, 2019	Peak Model (Application Filing)	0.1	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 # / Date	Condition	Value at Measurement Point: Nearest −ROW Edge	Max on ROW	Nearest +ROW Edge
Site 7 **June 4, 2019**	Peak Model (Application Filing)*	0.1	0.1	<0.1
	Modeled Field (for measured line height at time of measurements)	0.1	0.3	0.1
	Modeled Field (for measured line height; no adjustment for peak loading needed)	0.1	0.3	0.1
	Measured Field	0.2	0.3	<0.1
Site 8 **June 4, 2019**	Peak Model (Application Filing)	0.0	0.0	0.0
	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 9 **June 4, 2019**	Peak Model (Application Filing)*	<0.1	<0.1	<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 10 **June 4, 2019**	Peak Model (Application Filing)	0.1	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 11 **April 29, 2019**	Peak Model (Application Filing)	0.3	4.1	0.9
	Modeled Field (for measured line height at time of measurements)	0.2	1.5	0.8
	Modeled Field (for measured line height; no adjustment for peak loading needed)	0.2	1.5	0.8
	Measured Field	0.2	1.3	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.

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, the Little Bay Crossing, where only magnetic-field levels were measured because there is no existing overhead line and the proposed F107 line will be underground). For each measurement site, an aerial photograph showing the 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 and 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 '+' markers.

Site 1

Measurements at Site 1 (north of Madbury Rd.) were performed on June 6, 2019. A graphical summary of results is presented below.

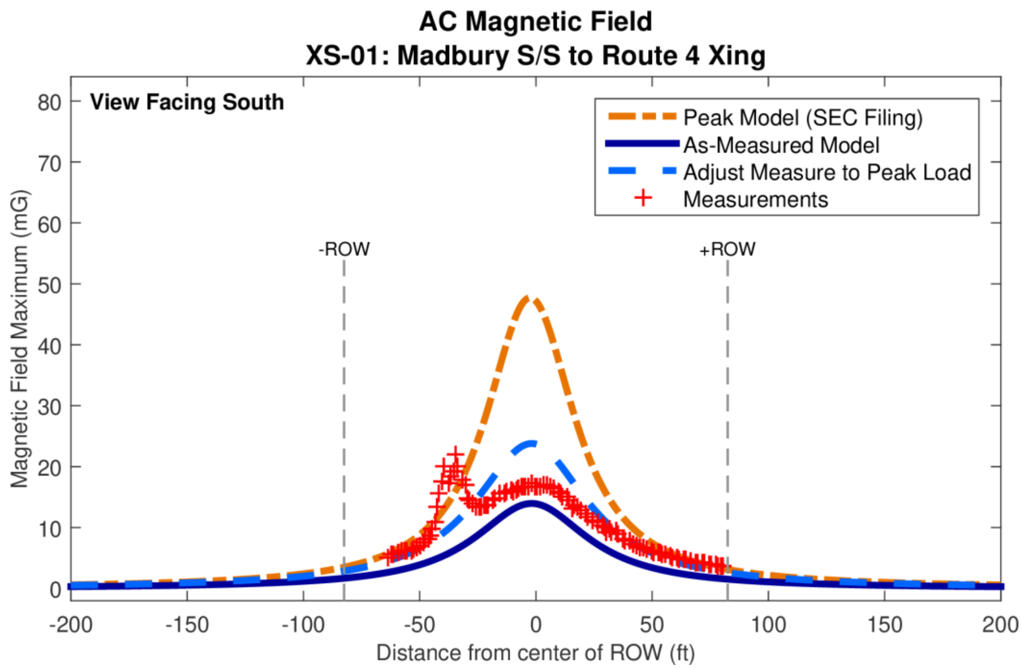

Figure B-1. Measured and modeled magnetic-field levels at Site 1.

The elevated magnetic-field level near -45 feet is from the signaling current on the adjacent train tracks. The additional magnetic field from the tracks influenced measurements out to at least 60 feet from the railroad

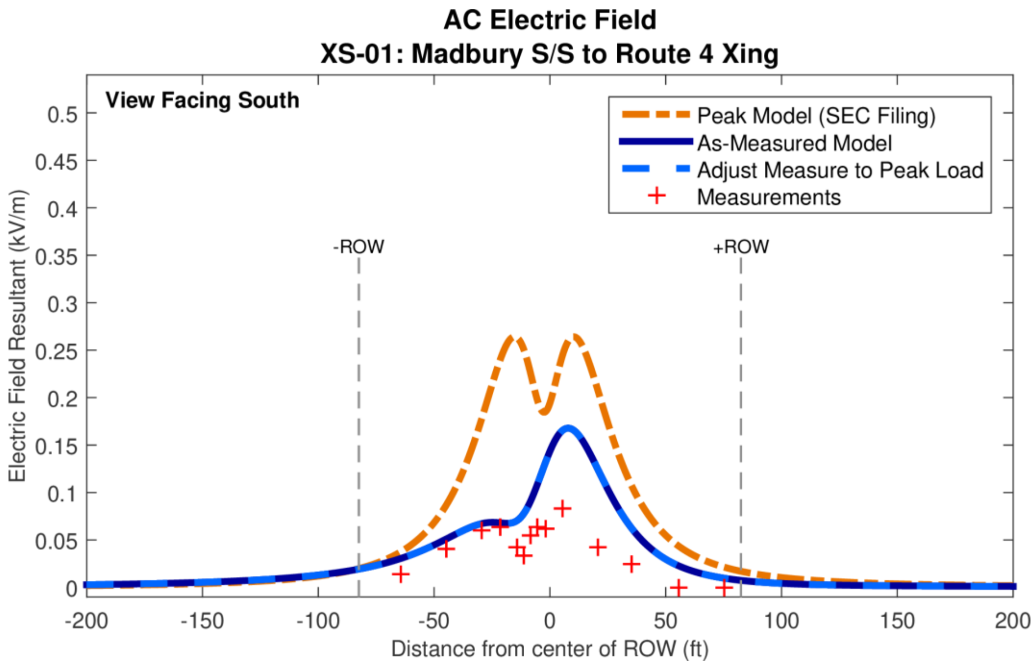

Figure B-2. Measured and modeled electric-field levels at Site 1.

Site 2

Measurements at Site 2 (in UNH parking lot A) were performed on June 6, 2019. A graphical summary of results is presented below.

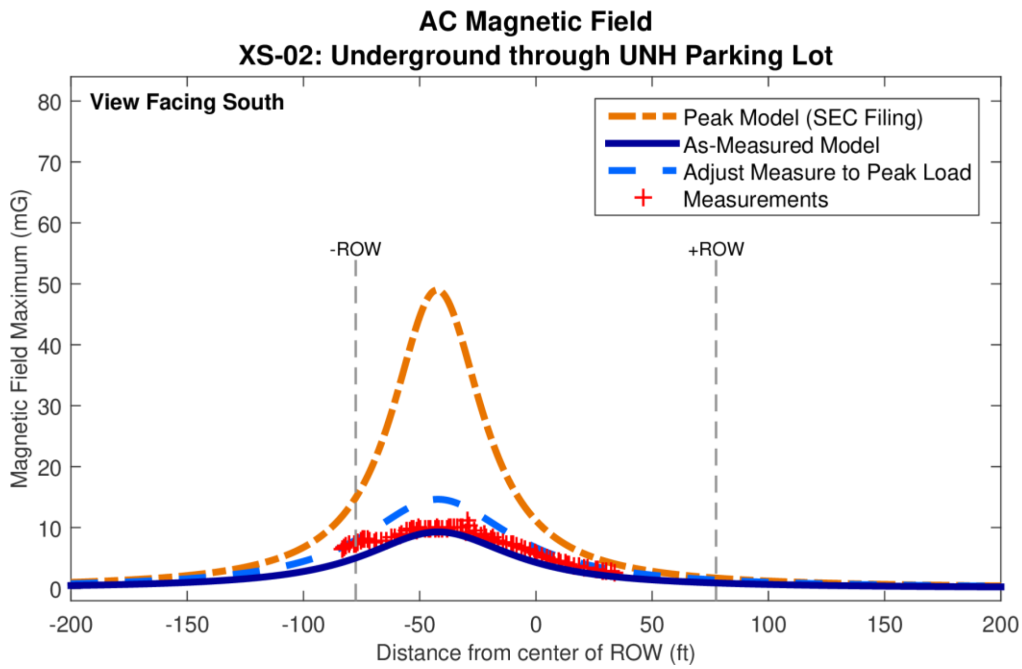

Figure B-3. Measured and modeled magnetic-field levels at Site 2.

The elevated magnetic-field level near the -ROW edge is from the signaling current on the adjacent train tracks.

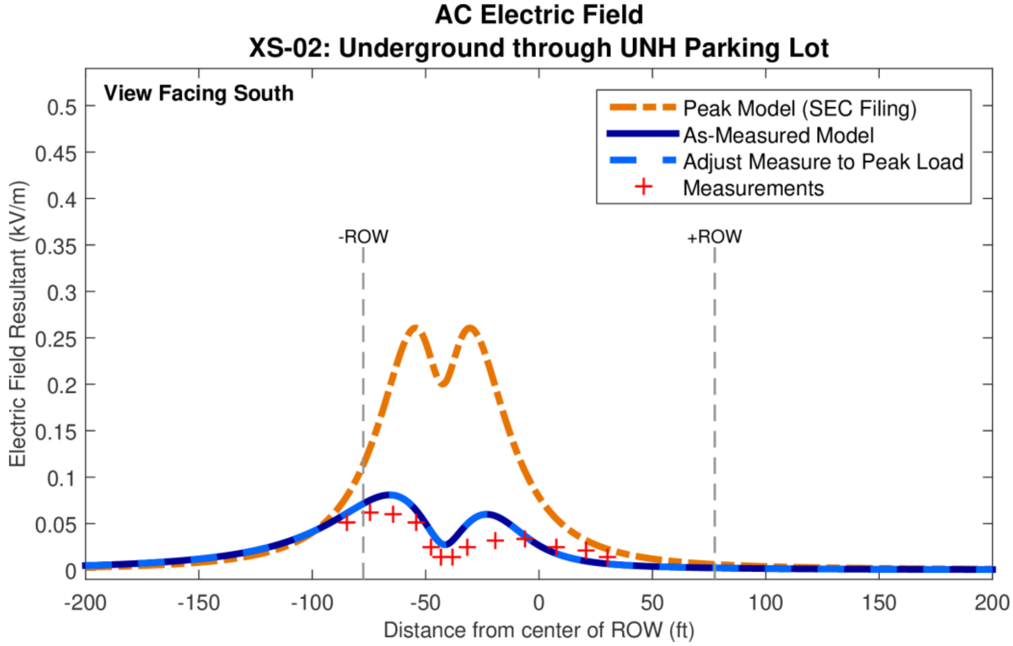

Figure B-4. Measured and modeled electric-field levels at Site 2.

Site 3

Measurements at Site 3 (off Water Works Rd.) were performed on June 3, 2019. A graphical summary of results is presented below.

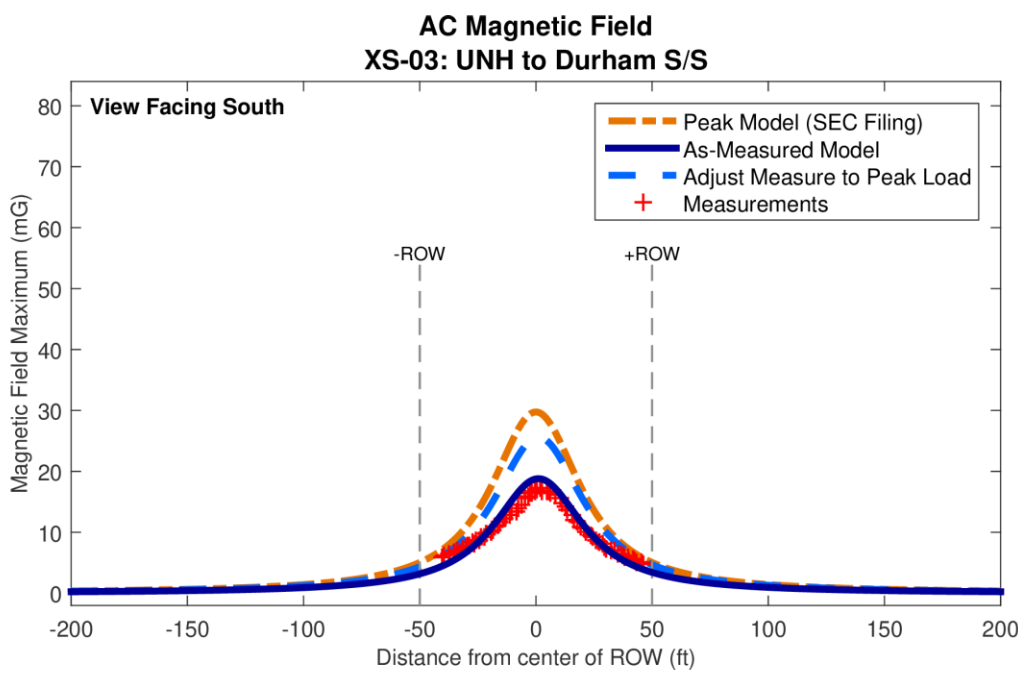

Figure B-5. Measured and modeled magnetic-field levels at Site 3.

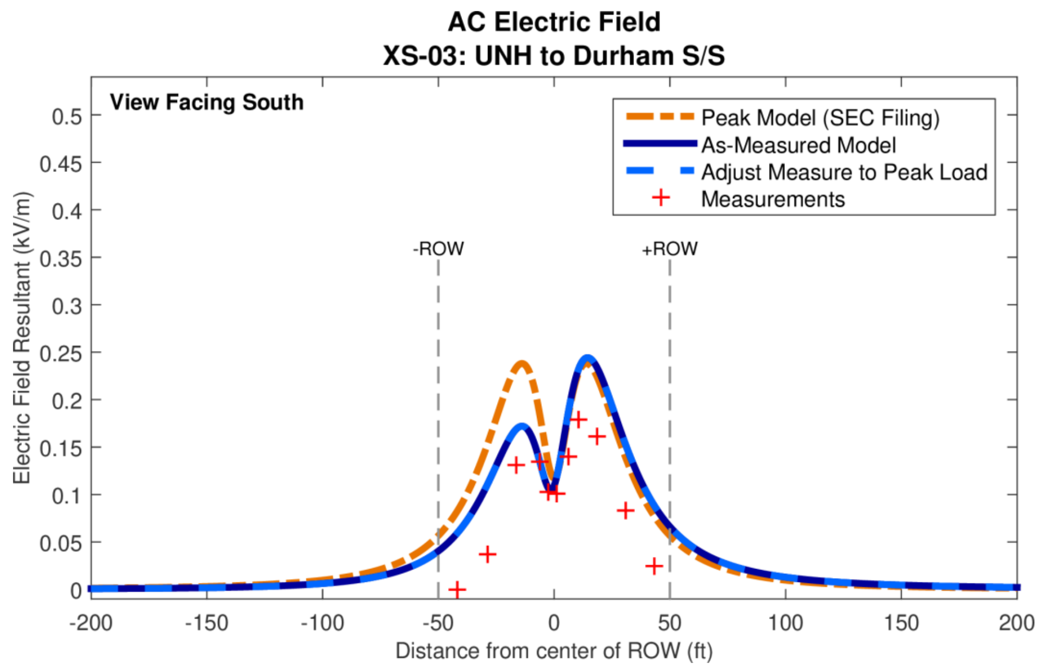

Figure B-6. Measured and modeled electric-field levels at Site 3.

Site 4

Measurements at Site 4 (north of Bennett Rd.) were performed on June 3, 2019. A graphical summary of results is presented below.

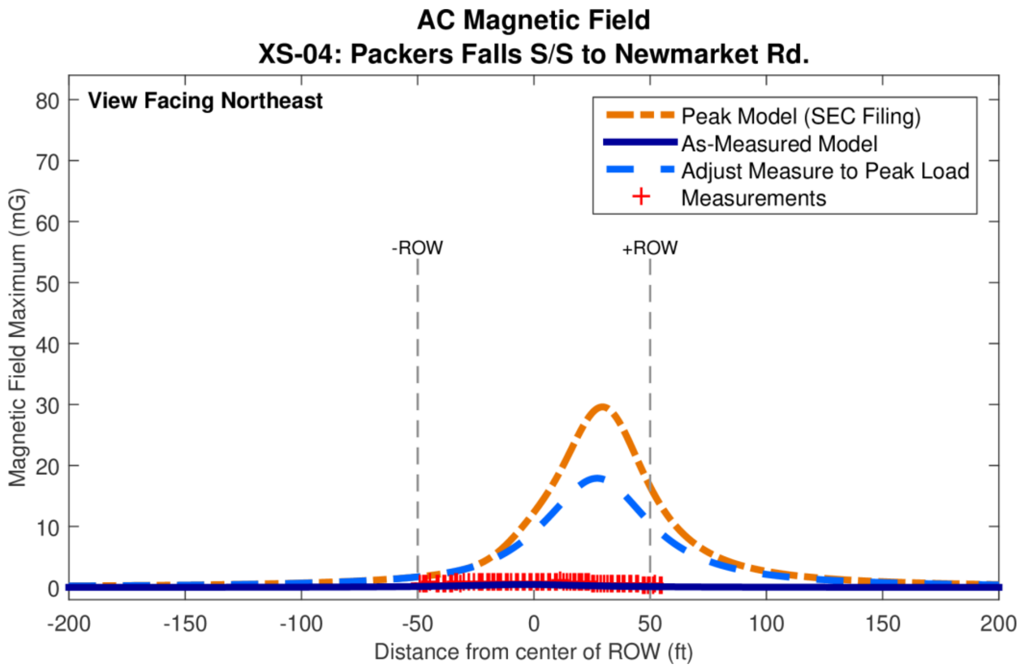

Figure B-7. Measured and modeled magnetic-field levels at Site 4.

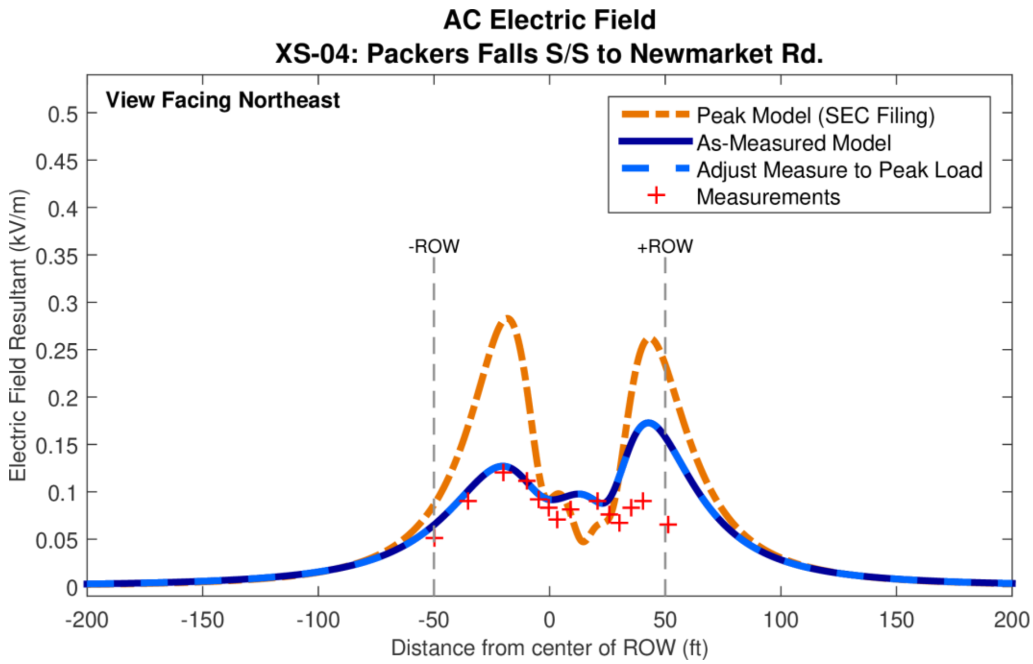

Figure B-8. Measured and modeled electric-field levels at Site 4.

Site 5

Measurements at Site 5 (east of Sandy Brook Rd.) were performed on June 3, 2019. A graphical summary of results is presented below.

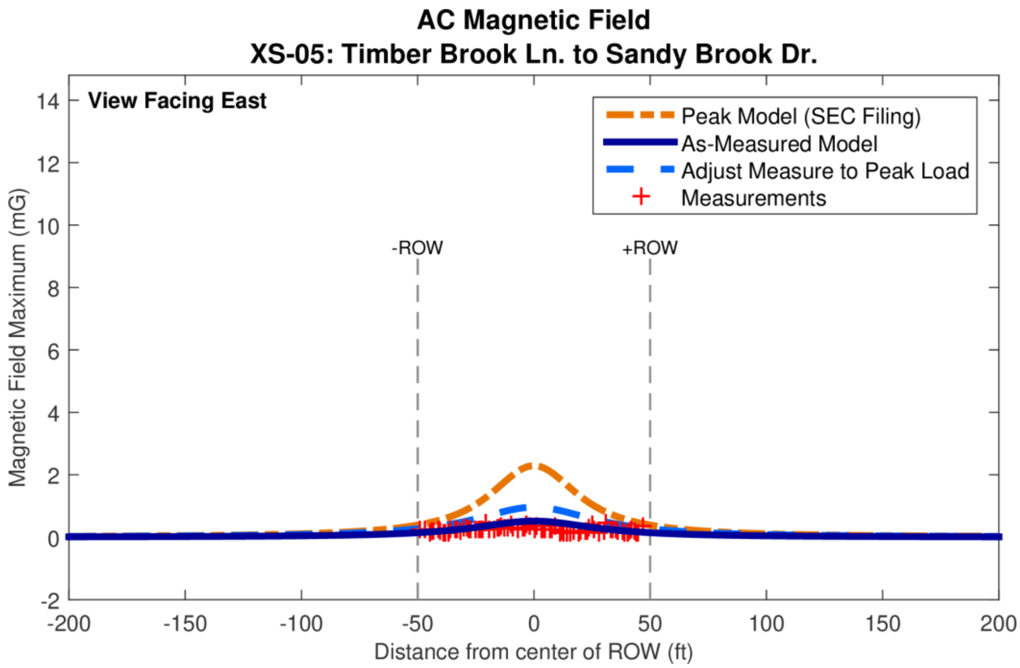

Figure B-9. Measured and modeled magnetic-field levels at Site 5.

Note the vertical scale is different than previous figures

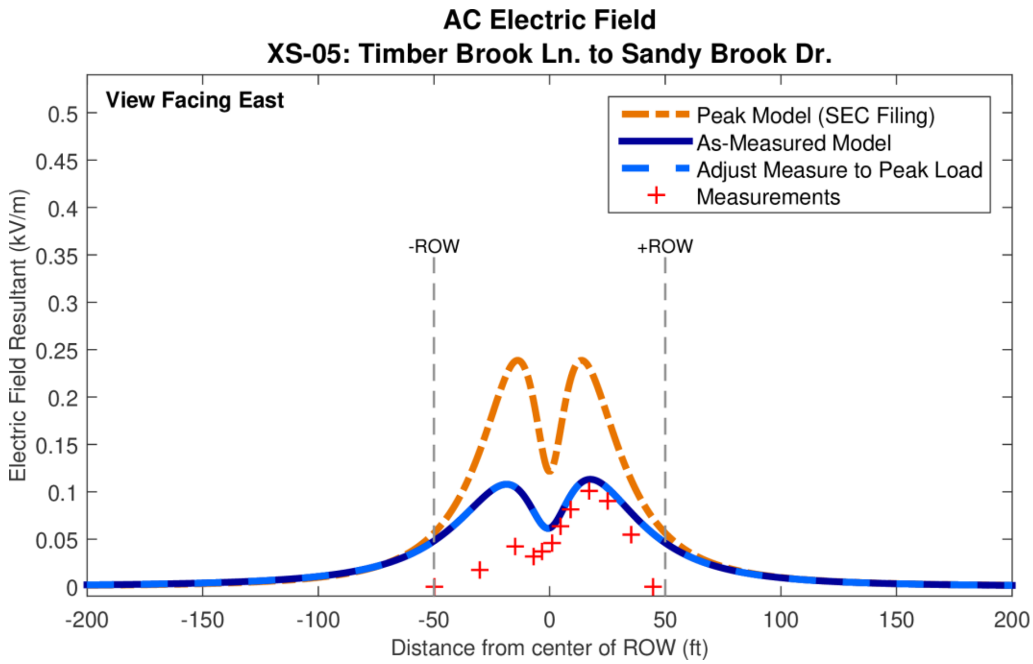

Figure B-10. Measured and modeled electric-field levels at Site 5.

Site 6

Measurements at Site 6 (north of Durham Point Rd.) were performed on June 3, 2019. A graphical summary of results is presented below.

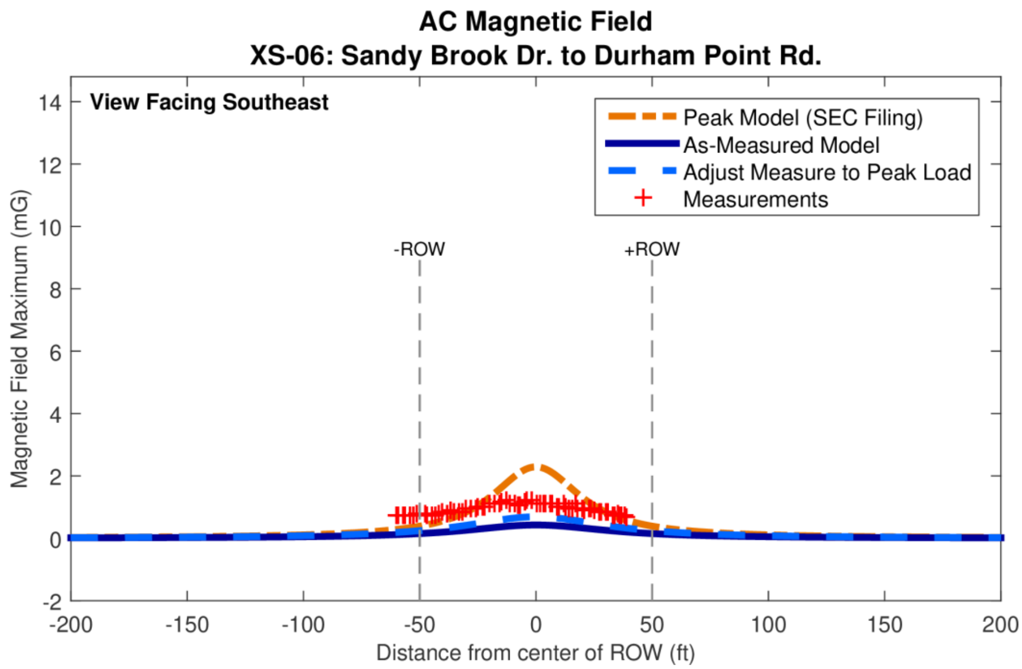

Figure B-11. Measured and modeled magnetic-field levels at Site 6.

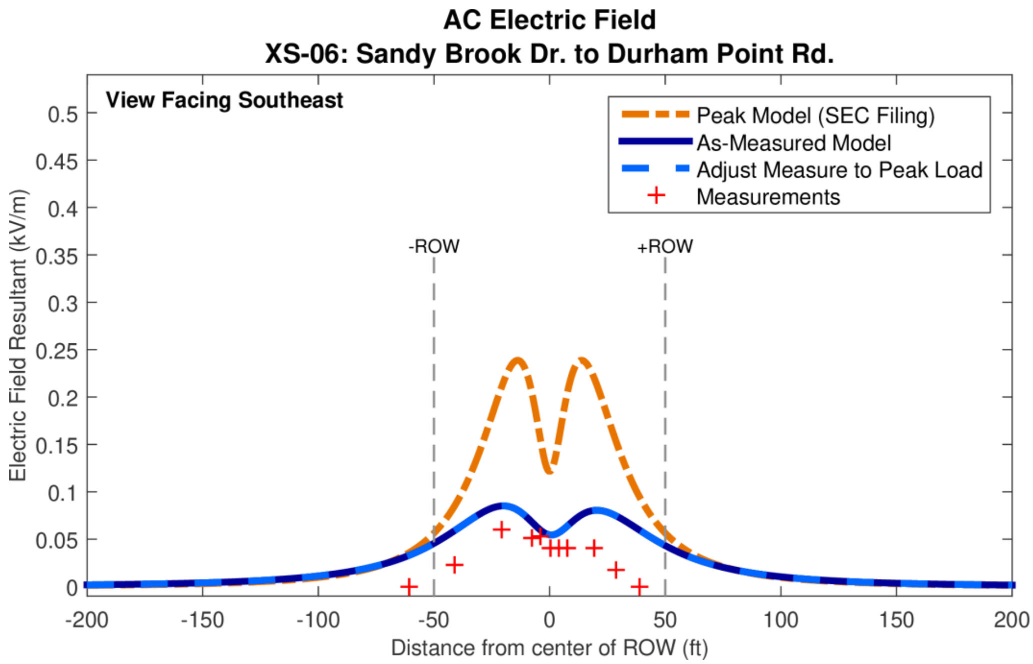

Figure B-12. Measured and modeled electric-field levels at Site 6.

Site 7

Measurements at Site 7 (south of Durham Point Rd.) were performed on June 4, 2019. A graphical summary of results is presented below.

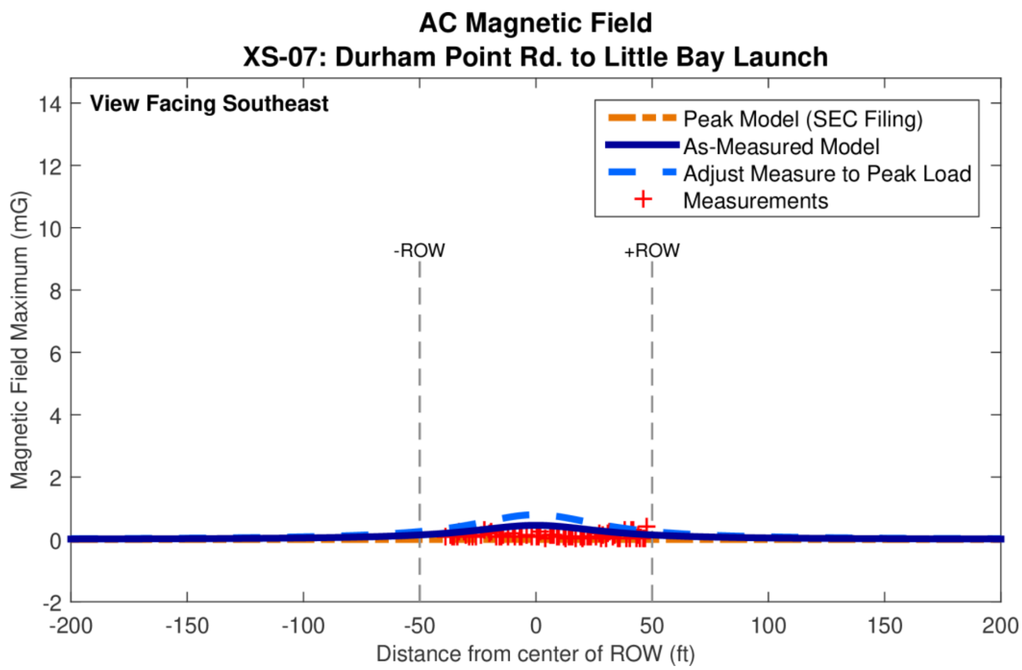

Figure B-13. Measured and modeled magnetic-field levels at Site 7.

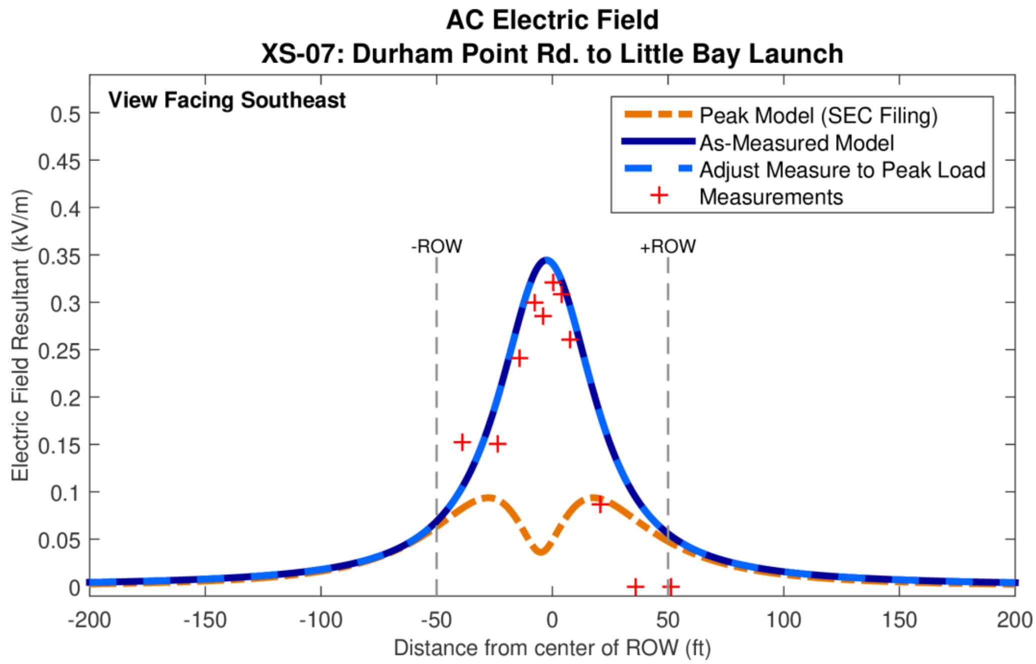

Figure B-14. Measured and modeled electric-field levels at Site 7.

Electric-field levels are higher than calculated in the Application because the 3-phase distribution line in this portion of the route is de-energized and only a single phase (19.9 kV L-N) conductor below the 3-phase distribution line (not included in the Application modeling) is energized.

Site 8

Measurements at Site 8 (west side of Little Bay) were performed on June 4, 2019. A graphical summary of results is presented below.

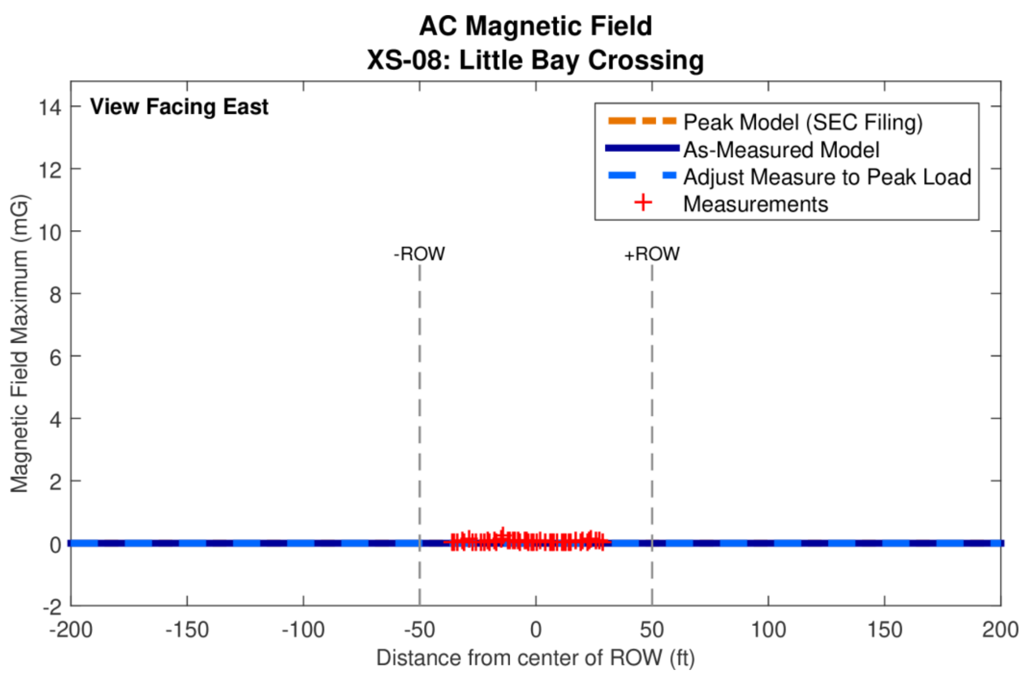

Figure B-15. Measured and modeled magnetic-field levels at Site 8.

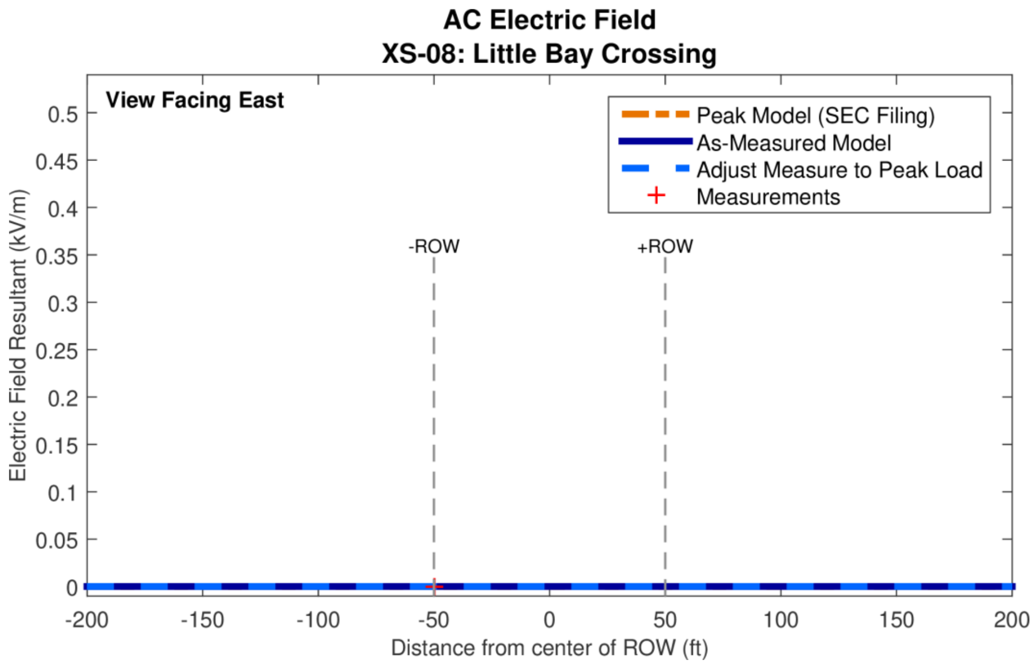

Figure B-16. No electric-field measurements were performed at Site 8.

Site 9

Measurements at Site 9 (west of Nimble Hill Rd.) were performed on June 4, 2019. A graphical summary of results is presented below.

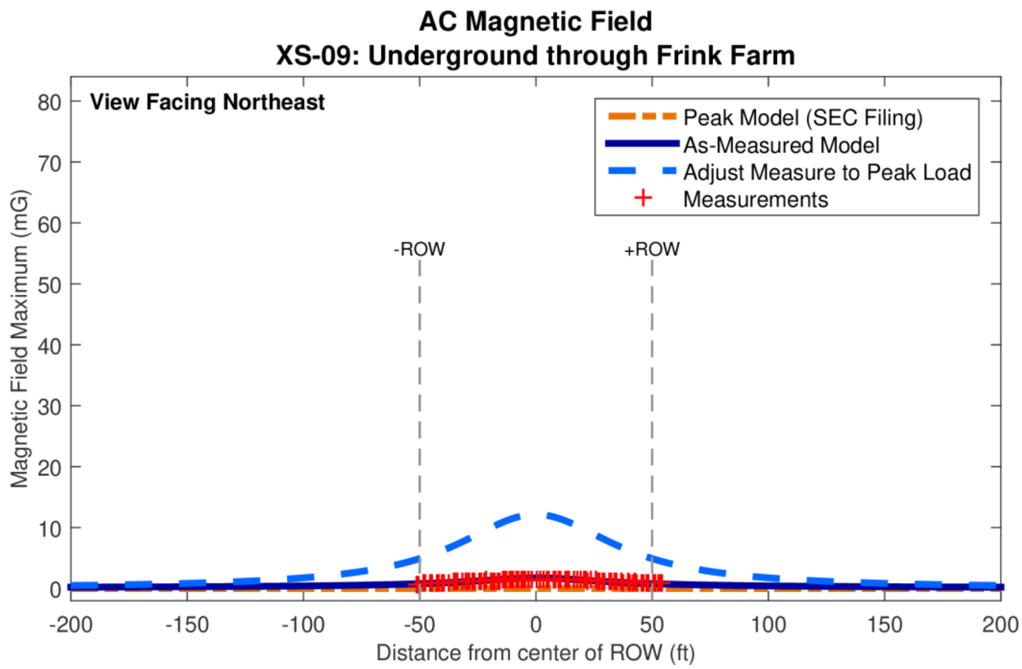

Figure B-17. Measured and modeled magnetic-field levels at Site 9.

Note the different vertical scale than for Sites 4 through 8.

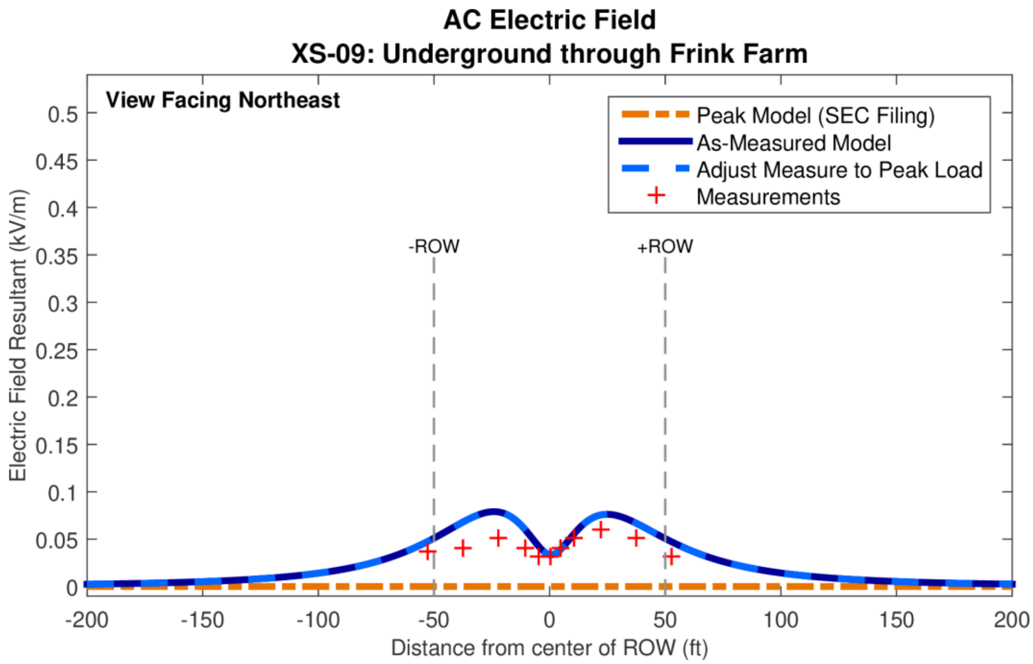

Figure B-18. Measured and modeled electric-field levels at Site 9.

No electric fields were calculated in the application because the F107 transmission line is proposed to be constructed underground in this section of the route and will therefore not be a source of electric fields above ground.

Site 10

Measurements at Site 10 (north of Fox Point Rd.) were performed on June 4, 2019. A graphical summary of results is presented below.

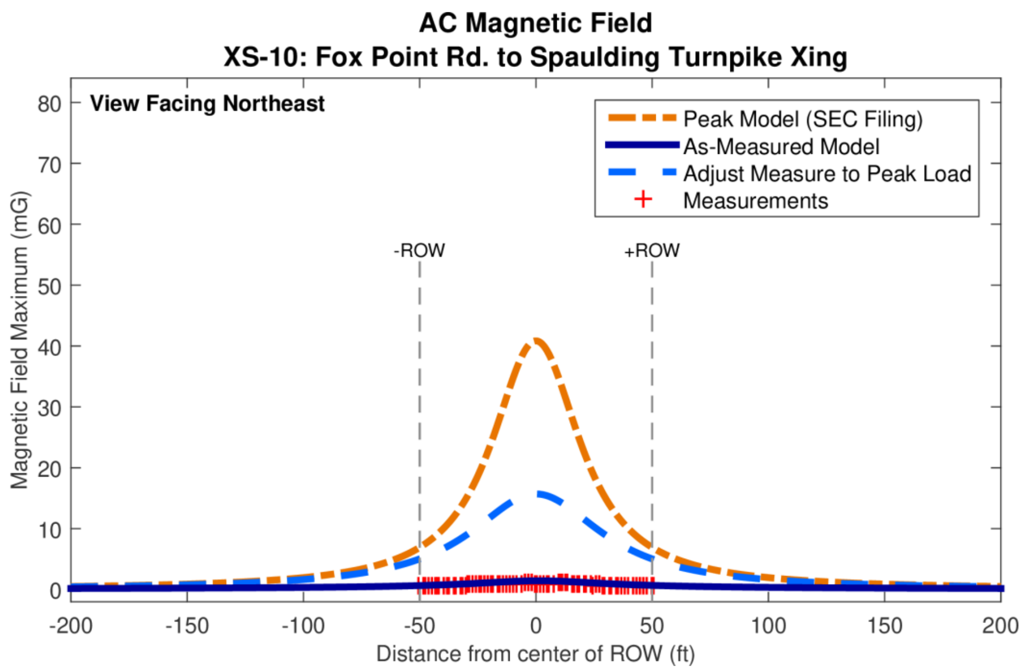

Figure B-19. Measured and modeled magnetic-field levels at Site 10.

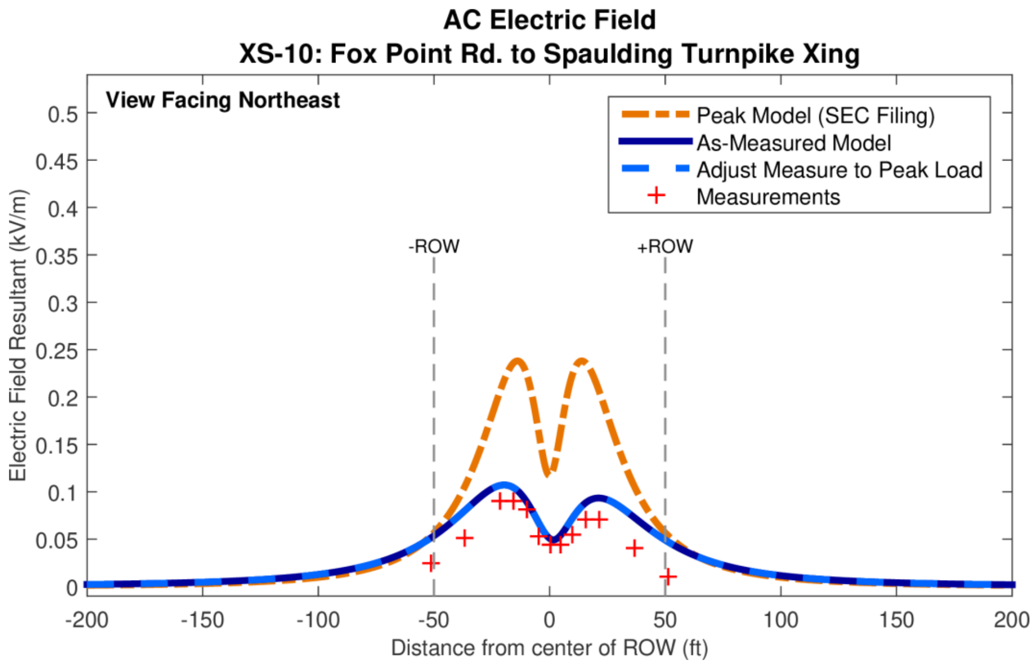

Figure B-20. Measured and modeled electric-field levels at Site 10.

Site 11

Measurements at Site 11 (in the Mall parking lot) were performed on April 29, 2019. A graphical summary of results is presented below.

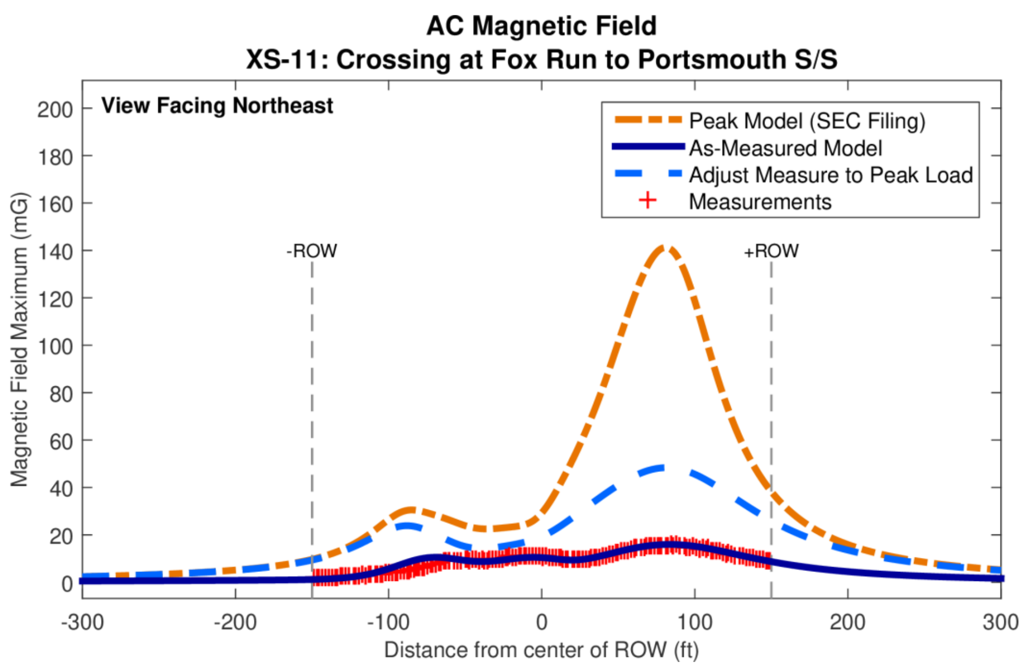

Figure B-21. Measured and modeled magnetic-field levels at Site 11.

Note the different vertical scale than for previous figures.

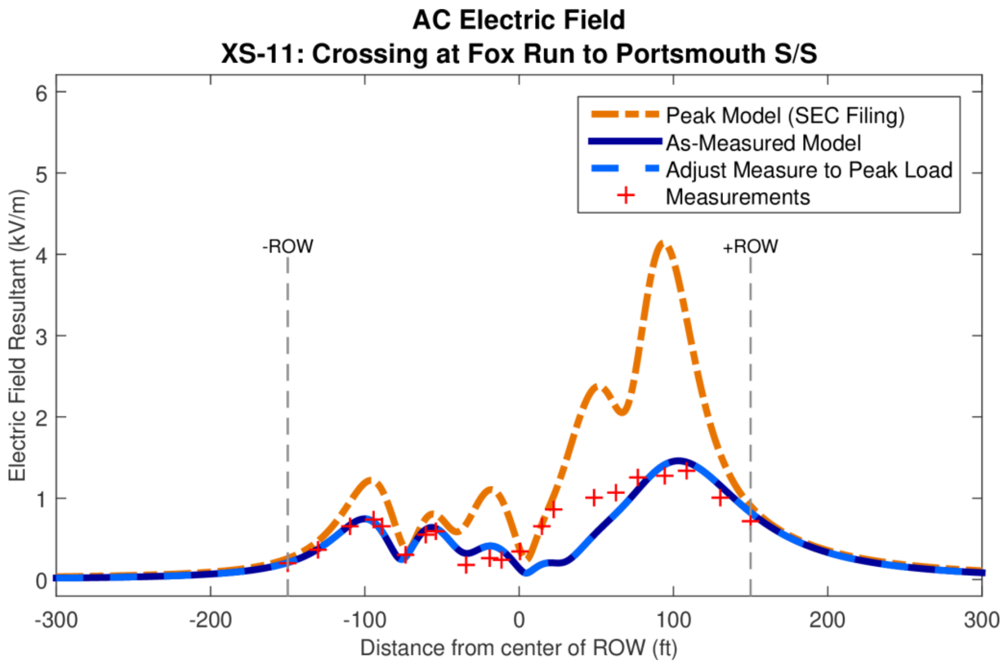

Figure B-22. Measured and modeled electric-field levels at Site 11.

Appendix C

Aerial Maps of Measurement Sites

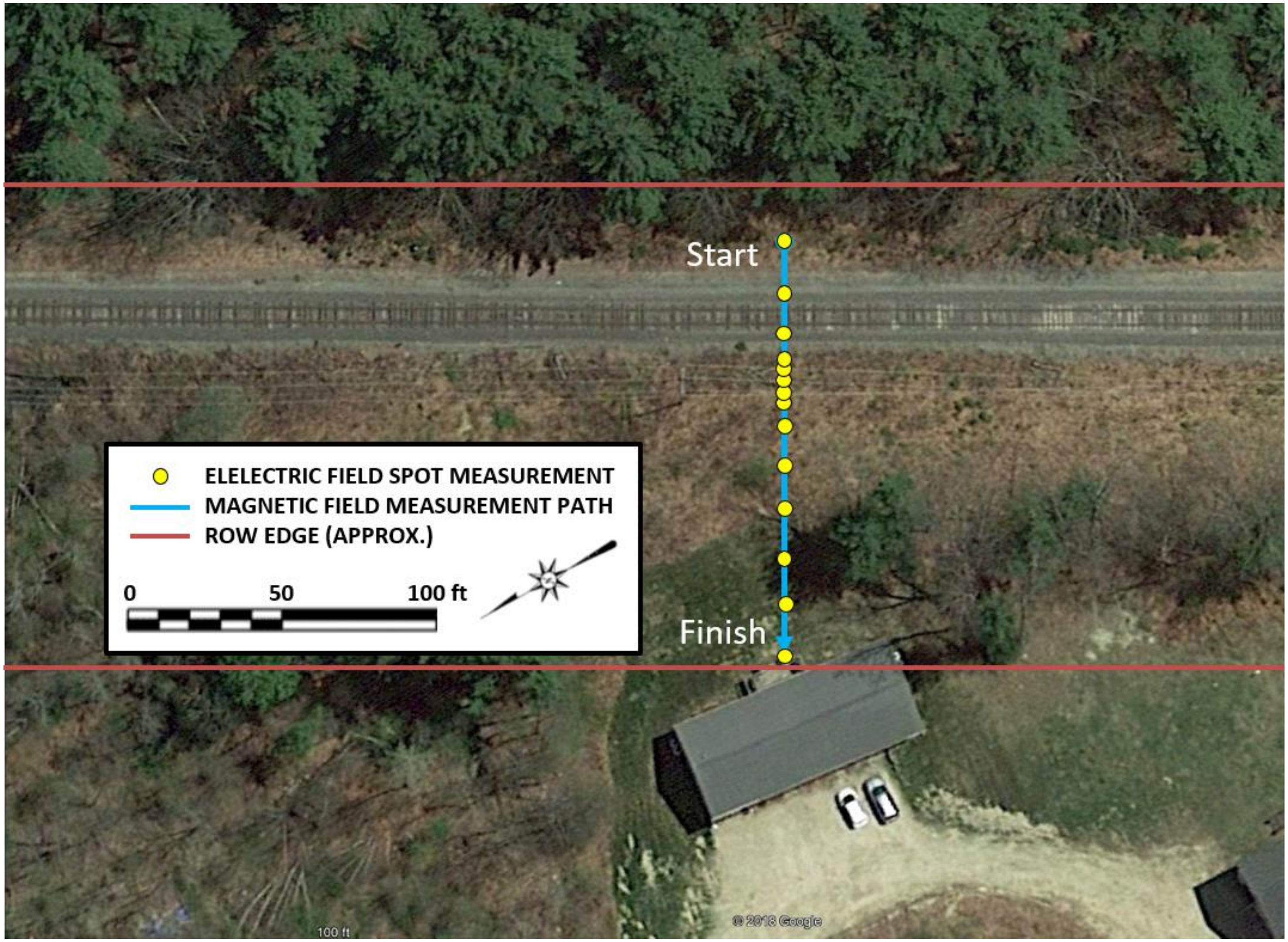

Figure C-1. Aerial photograph of measurement Site 1 (north of Madbury Rd.) showing the approximate location of the magnetic-field measurement path and electric-field spot measurements performed on June 6, 2019.

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 June 6, 2019.

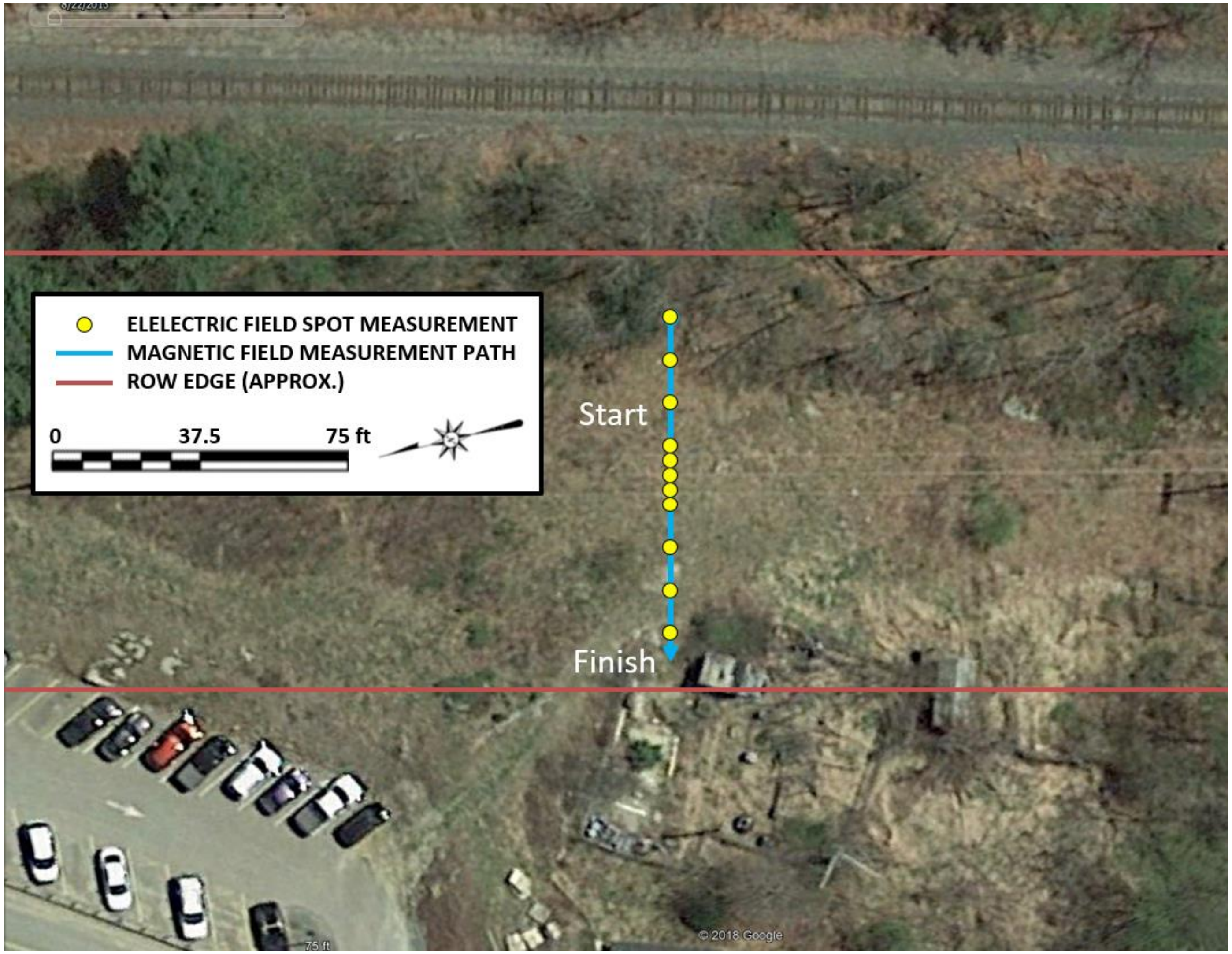

Figure C-3. Aerial photograph of measurement Site 3 (off Waterworks Rd.) showing the approximate location of the magnetic-field measurement path and electric-field spot measurements performed on June 3, 2019.

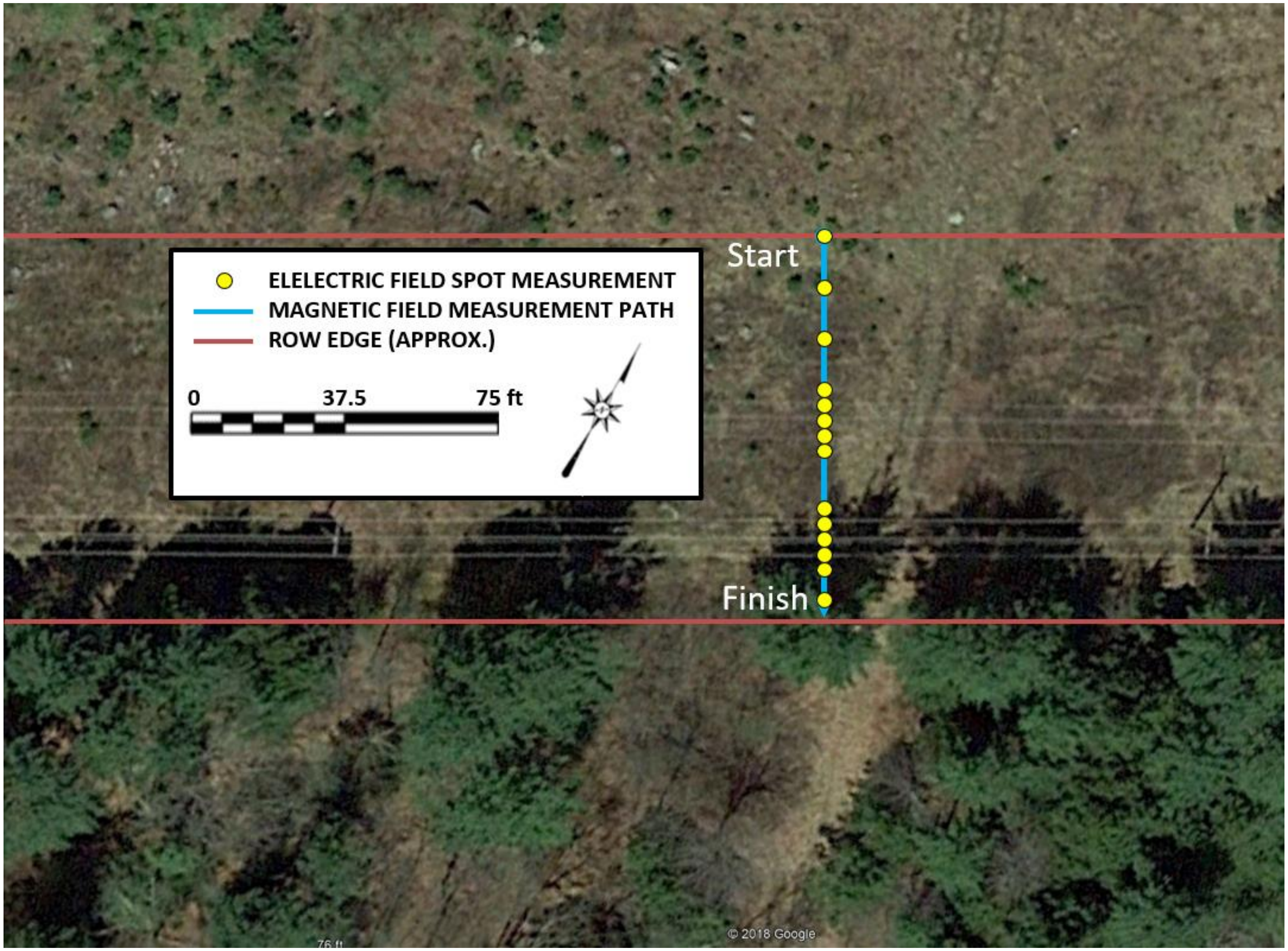

Figure C-4. Aerial photograph of measurement Site 4 (north of Bennett Rd.) showing the approximate location of the magnetic-field measurement path and electric-field spot measurements performed on June 3, 2019.

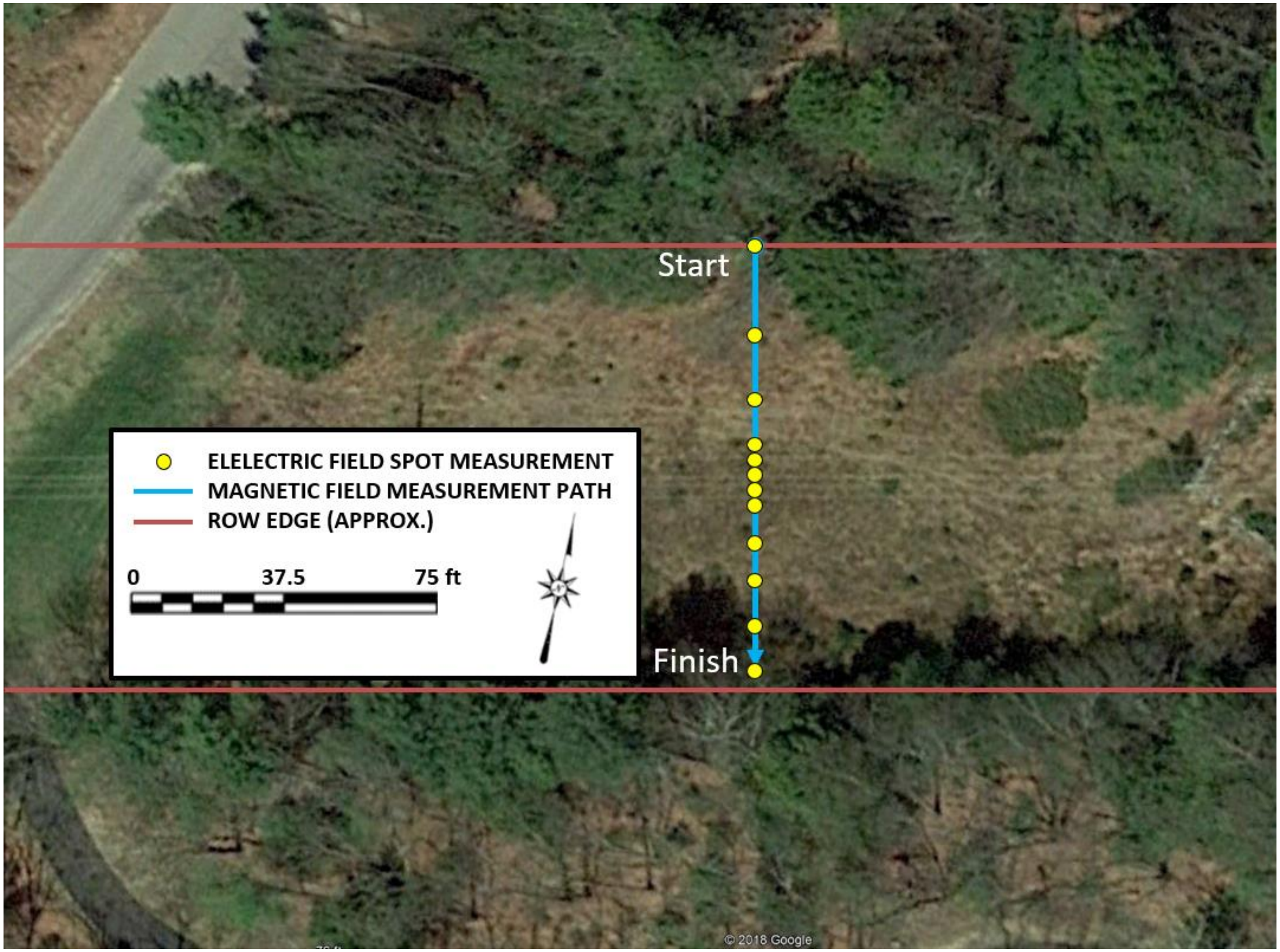

Figure C-5. Aerial photograph of measurement Site 5 (east of Sandy Brook Rd.) showing the approximate location of the magnetic-field measurement path and electric-field spot measurements performed on June 3, 2019.

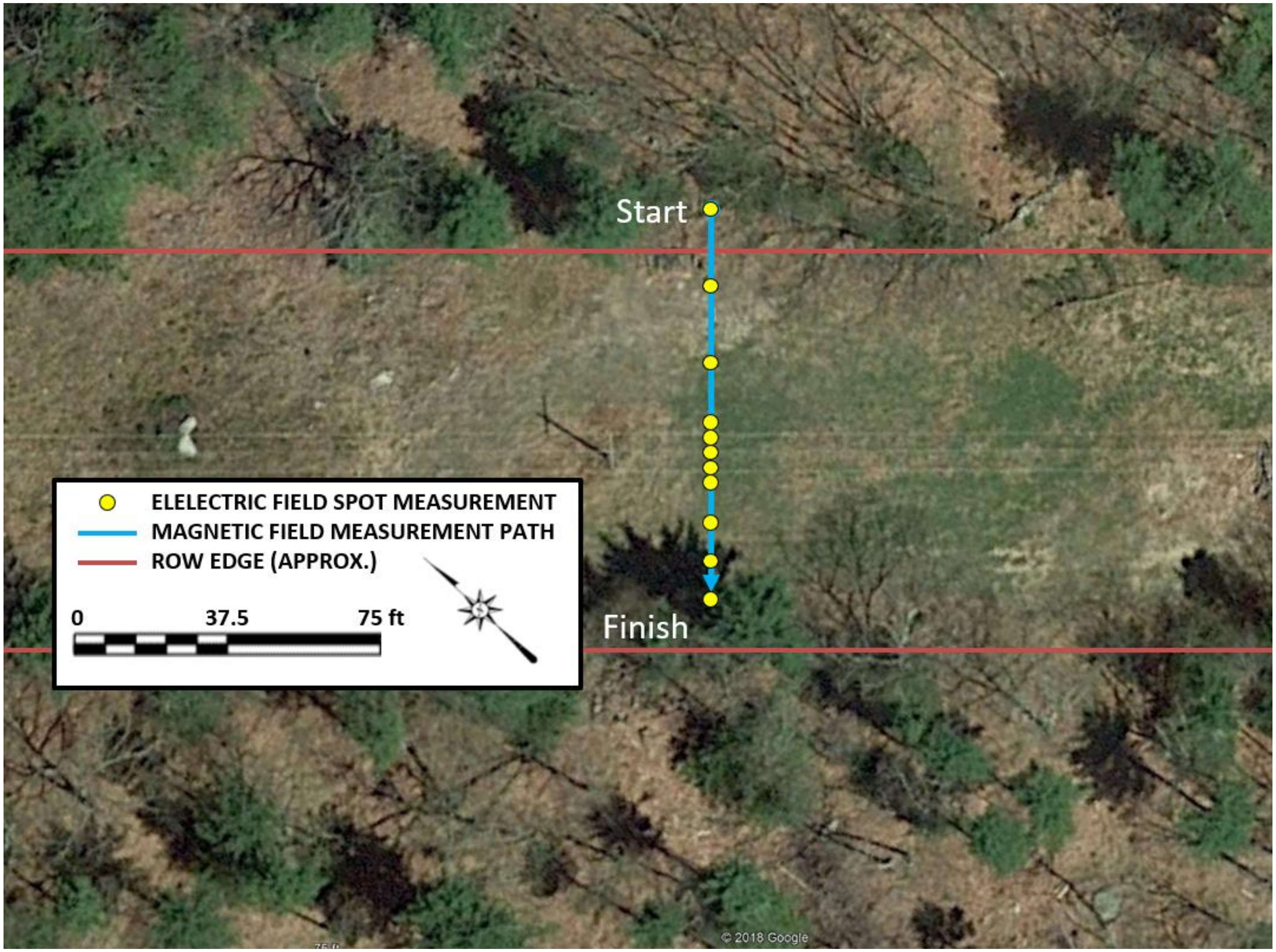

Figure C-6. Aerial photograph of measurement Site 6 (north of Durham Point Rd.) showing the approximate location of the magnetic-field measurement path and electric-field spot measurements performed on June 3, 2019.

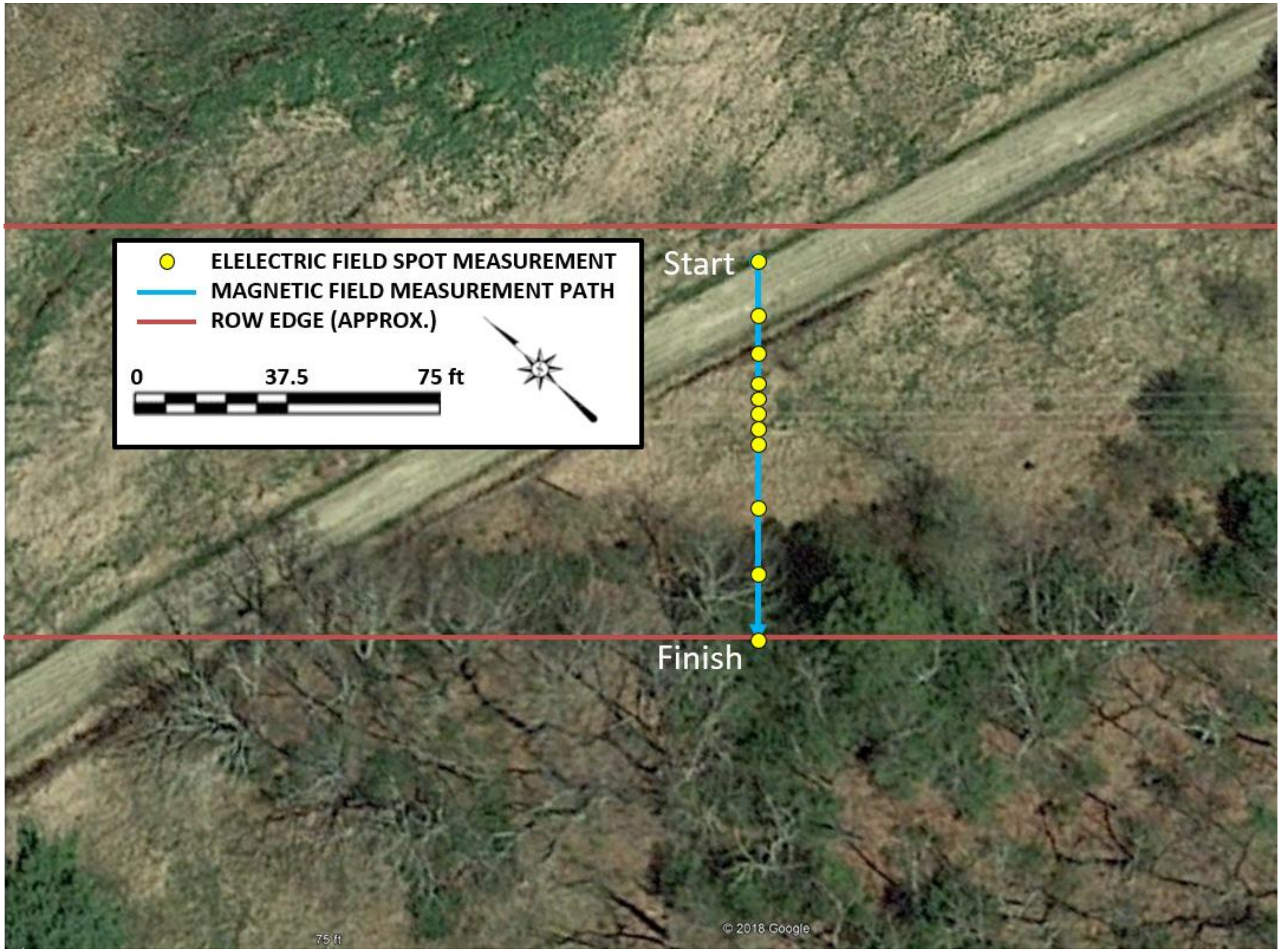

Figure C-7. Aerial photograph of measurement Site 7 (south of Durham Point Rd.) showing the approximate location of the magnetic-field measurement path and electric-field spot measurements performed on June 4, 2019.

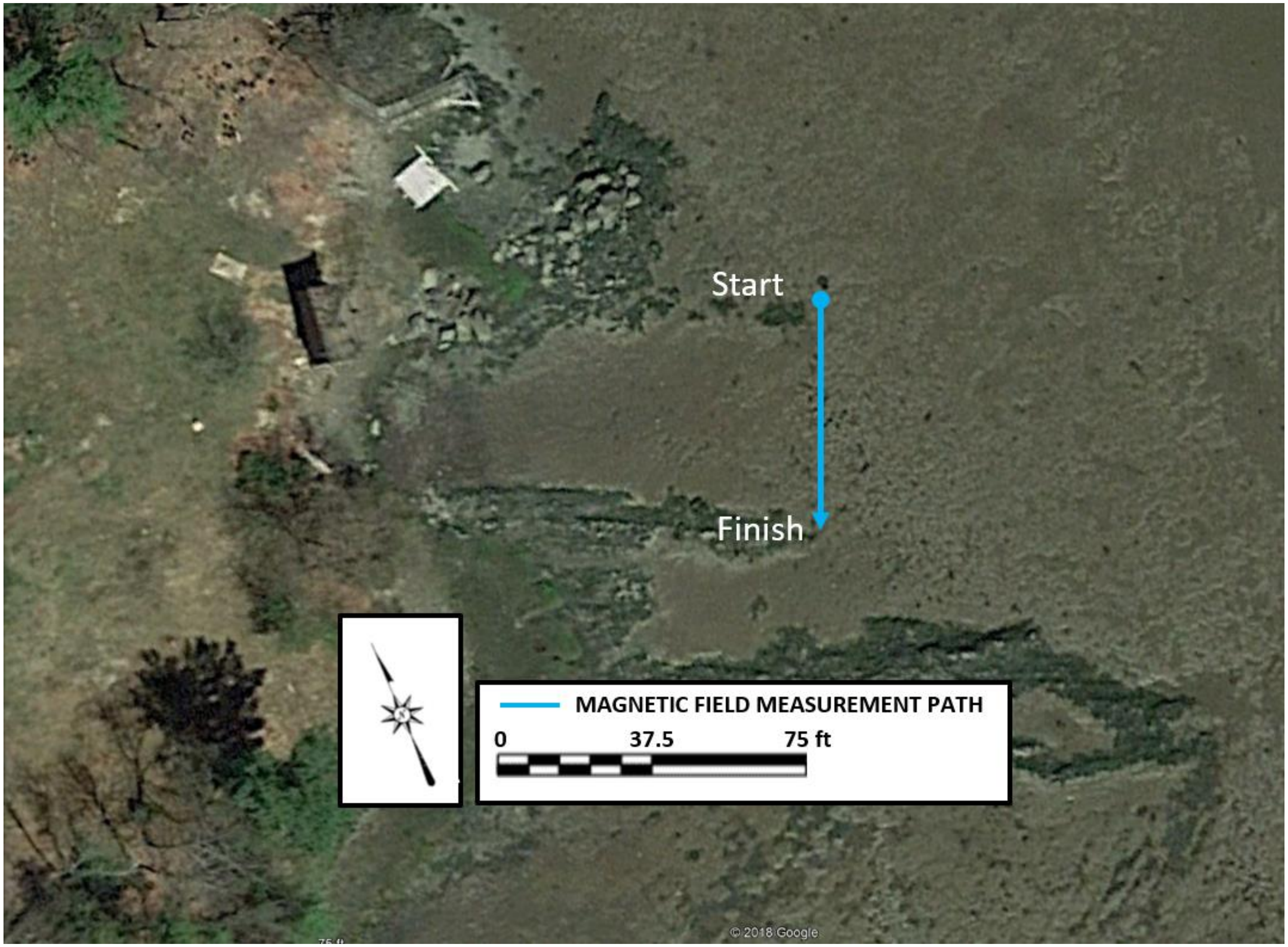

Figure C-8. Aerial photograph of measurement Site 8 (west side of Little Bay) showing the approximate location of the magnetic-field measurement path performed on June 4, 2019.

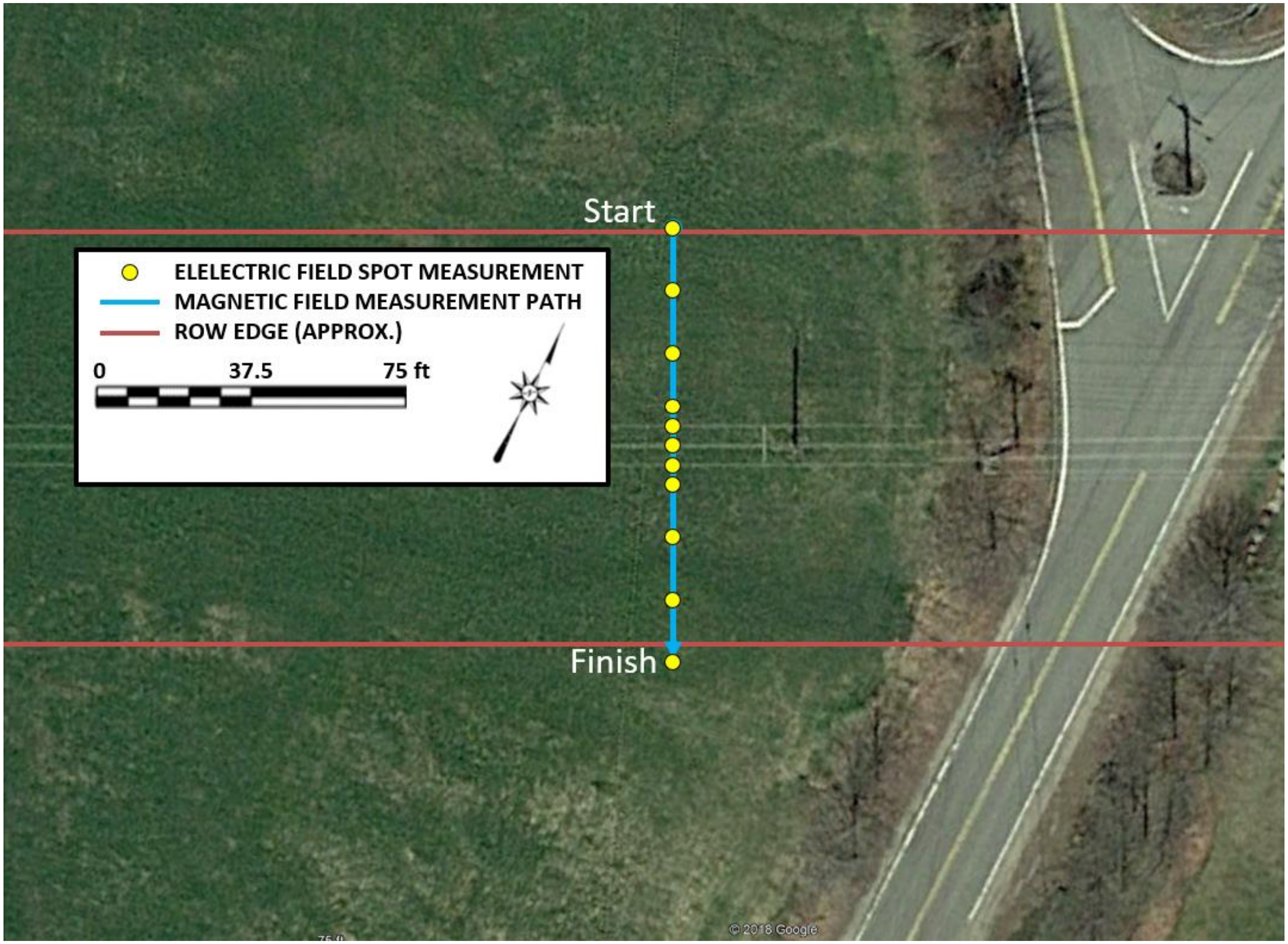

Figure C-9. Aerial photograph of measurement Site 9 (west of Nimble Hill Rd.) showing the approximate location of the magnetic-field measurement path and electric-field spot measurements performed on June 4, 2019.

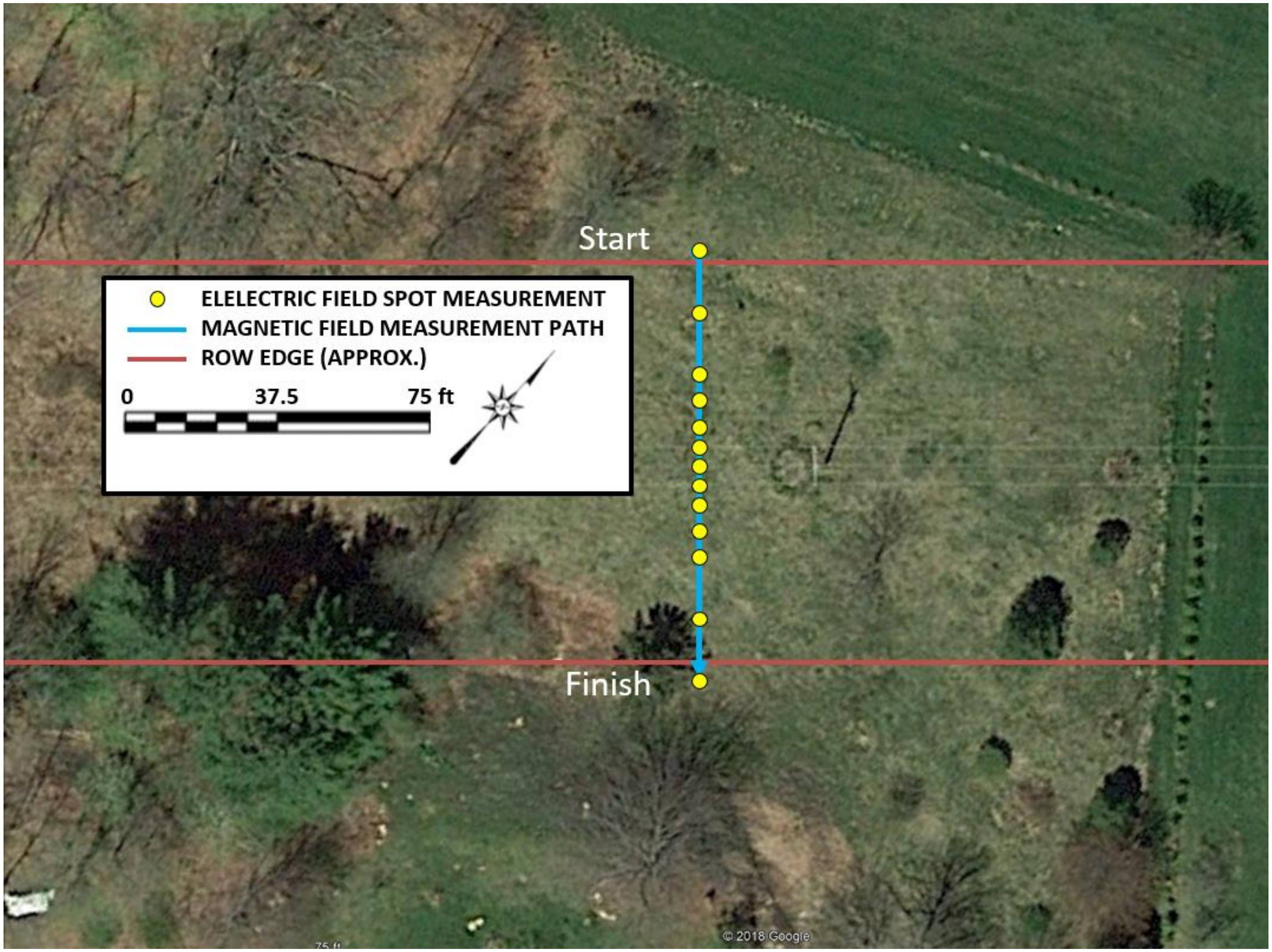

Figure C-10. Aerial photograph of measurement Site 10 (north of Fox Point Rd.) showing the approximate location of the magnetic-field measurement path and electric-field spot measurements performed on June 4, 2019.

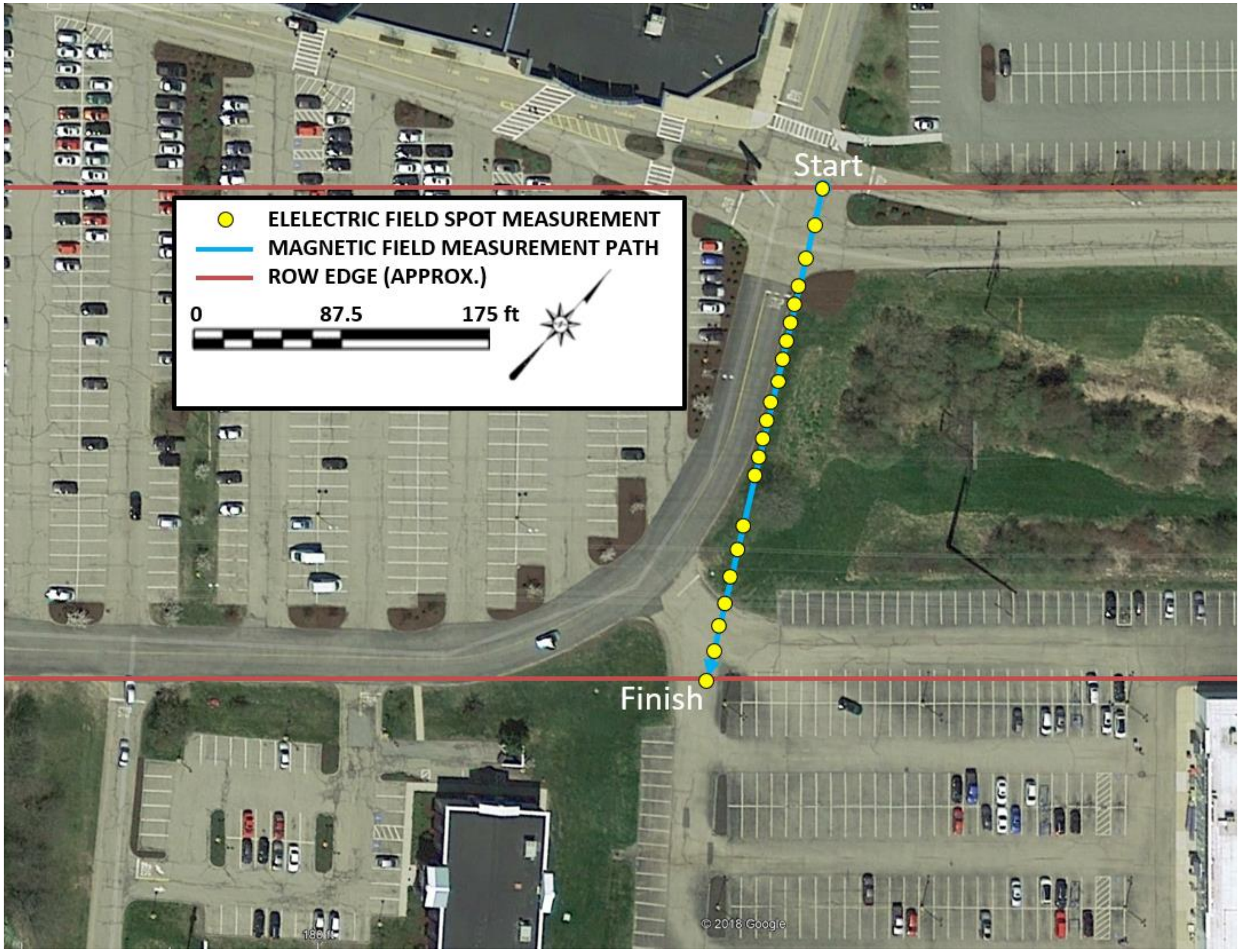

Figure C-11. Aerial photograph of measurement Site 11 (Mall parking lot) showing the approximate location of the magnetic-field measurement path and electric-field spot measurements performed on April 29, 2019.

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)	Application (Peak Loading) Amperes	Measurement Loading Amperes	Minimum Conductor Height (ft) Application	Minimum Conductor Height (ft) Measurement
Site 1	Madbury Substation to Route 4 Crossing	380	34.5	417	244.5	25	30.2
Site 2	Underground through UNH Parking Lot	380	34.5	417	263.5	25	41.2
		UNH 12	12	n/a	22	n/a	41.6
Site 3	UNH to Durham Substation	380	34.5	260	190	25	25.6
Site 4	Packers Falls Substation to Newmarket Rd.	3162	34.5	20	10.4	25	34.7
		3152	34.5	256	0	25	29.8
Site 5	Timber Brook Ln. to Sandy Brook Dr.	3162	34.5	20	10.7	25	33.7
Site 6	Sandy Brook Dr. to Durham Point Rd.	3162	34.5	20	12.3	25	39.6
Site 7	Durham Point Rd. to Little Bay Launch	3162	0	n/a	11.4	n/a	36.8
		1-φ	19.9 (L-N)	n/a	0*	n/a	26.8
Site 8	Little Bay Crossing	n/a	n/a	n/a	n/a	n/a	n/a
Site 9	Underground through Frink Farm	3850	34.5	n/a	12*	n/a	43.8
		Neutral	0	n/a	6.5*	n/a	28.4
Site 10	Fox Point Rd. to Spaulding Turnpike Crossing	3850	34.5	357	12*	25	37.1
		Neutral	0	n/a	5.5*	n/a	30.1
Site 11	Crossing at Fox Run to Portsmouth Substation	E194	115	213	51.6	30	33.8
		E181	115	52	47.1	30	39.1
		3135	345	1141	360.1	35	66

* Loading not available during measurements. This is an assumed value based on reasonable match with measured values.

Appendix E

Calibration Certificates

Certificate of Calibration

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

Instrument Model: EMDEX II

Frequency: 60 Hertz

Serial Number: 1134

Date of Calibration: 10/24/2018

Re-Calibration suggested at one year from above date.

EMDEX LLC

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

H. Christopher Hooper
Calibration Inspector

suparule

Calibration Certificate

Holland Road,
National Technology Park,
Limerick, Ireland.

Tel: +353 (0) 61 201030
Fax: +353 (0) 61 330812

Email: info@suparule.com
Web: www.suparule.com

MODEL	***600E***
Description	***Cable Height Meter***
Serial No.	***A41142***
Date of Calibration	***20th May 2019***
CHM Calibration Due Date	***20th May 2020***

Equipment used:

Model	Serial No.	Control No.	Calibration Due Date
SupaRule T30 Thermometer	8310412	CAL ID 041	8th May 2020
Leica Dista A2	4070150304		8th May 2020

Instrument calibrated to a national or international standards to better than ± 0.15°C (T30).

Method: After temperature stabilisation, readings taken are as follows:
Actual Temperature: 22.1°C
Temperature reading before adjustment: 22.2°C

Adjustment made.
Waveform calibrated.

Calibration accuracy:

After calibration the instrument will have an accuracy of ± 0.5% +/- 2digits provided that the displayed temperature is within ± 0.5°C of the ambient temperature. (Temperature range = 0°C to 35°C), as per its specification.

Eoin O'Loughlin

Approved Signatory
Eoin O'Loughlin

All the equipments used in this calibration are traceable to National or International standards.

ISO 9001:2008 EQA QUALITY ASSURED COMPANY

Directors: J. McDonnell, M.Meehan, B. O'Donoghue.
Suparule Systems Ltd., Registered in Ireland. Company No. 152205. Registered Office is at the above address

Kestrel®
Weather & Environmental Meters
by NK

Certificate of Conformity

This instrument was produced under rigorous factory production control and documented standard procedures. It was individually visually inspected, leak tested and function tested for display, backlight, button and software performance. The accuracy of each of its primary measurements was individually calibrated and/or tested against standards traceable to the National Institute of Standards and Technology ("NIST") or calibrated intermediary standards. This instrument is certified to have performed at the time of manufacture in compliance with the following specifications as they apply to this meter's specific model, measurements and features.

Methods Used in Calibration and Testing

Wind Speed:

The Kestrel Weather & Environmental Meter impeller installed in this unit was individually tested in a subsonic wind tunnel operating at approximately 300 fpm (1.5 m/s) and 1200 fpm (6.1 m/s) monitored by a Gill Instruments Model 1350 ultrasonic time-of-flight anemometer. The Standard's maximum combined uncertainty is +/–1.04% within the airspeed range 706.6 to 3923.9 fpm (3.59 to 19.93 m/s), and +/–1.66% within the airspeed range 166.6 to 706.6 fpm (0.85 to 3.59 m/s).

Temperature:

Temperature response is verified in comparison with a Eutechnics 4600 Precision Thermometer or a standard Kestrel 4000 Weather & Environmental Meter calibrated weekly against the Eutechnics 4600. The Eutechnics 4600 is calibrated annually and is traceable to NIST with a system accuracy of +/– 0.05 °C.

Direction / Heading

The sensitivity of the magnetic directional sensor is verified at the component level by applying a magnetic field to the sensor and measuring the signal output at 4 points, as well as after assembly by orienting the unit to the cardinal directions and measuring the magnetic field output. In both cases, the compass output must be accurate to within +/– 5 degrees.

Relative Humidity:

Relative humidity receives a two-point calibration in humidity and temperature controlled chambers at 75.3% RH and 32.8% RH at 25° C. The calibration tanks are monitored with an Edgetech Model 2002 DewPrime II Standard Chilled Mirror Hygrometer. Following calibration, performance is further verified at an RH of approximately 43.2% against the Edgetech Hygrometer. The Edgetech Hygrometer is calibrated annually and is traceable to NIST with a maximum relative expanded uncertainty of +/– 0.2% RH.

Barometric Pressure:

Pressure response is verified against a Vaisala PTB210A Digital Barometer or a standard Kestrel 4000 Weather & Environmental Meter calibrated weekly against the Vaisala Barometer. The Vaisala Barometer is calibrated annually and is traceable to NIST with an accuracy of +/-0.15 hPa at +20°C defined as the root sum of the squares (RSS) of end point non-linearity, hysteresis error, repeatability error and calibration uncertainty at room temperature.

Approved By:

Michael Naughton, Engineering Manager

The enclosed Kestrel Weather & Environmental Meter was manufactured by Nielsen-Kellerman Co. at its facilities located at 21 Creek Circle, Boothwyn, PA 19061 USA.

Appendix F

Measurement Protocol Sent to the PUC and NHSEC on April 18, 2019

Exponent®

MEMORANDUM

TO:	Pamela Monroe, Administrator, NH SEC
FROM:	Benjamin Cotts, Ph.D., P.E.
CC:	Paul Kasper, Assistant Director, Safety and Security, NH PUC Dena Champy, PMP, Eversource Energy, Christopher Soderman, P.E., Eversource Energy,
DATE:	April 3, 2019
PROJECT:	1501863.001 Seacoast Reliability Project (NH SEC Docket 2015-04)
SUBJECT:	Draft Protocol for 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 on January 31, 2019, Eversource requested Exponent to provide a draft protocol for performing measurements of electric and magnetic fields (EMF) both before and after the Project is placed into service in consultation with the Safety Division of the New Hampshire Public Utilities Commission (PUC).

Order and Certificate of Site and Facility Condition

The Order and Certificate of Site and Facility with Conditions issued by the New Hampshire Site Evaluation Committee (NHSEC) for the SRP dated January 31, 2019 states that it is:

> "Further Ordered that the Applicant, in consultation with the PUC 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; . . . ."

Proposed Measurement Protocol

The proposed measurement protocol is divided into several sections including Measurement Preparation, Measurement Procedure, and Reporting.

Measurement Preparation and Location Identification

Exponent and Eversource have reviewed in detail the configuration and the residential density along the route of the proposed F107 transmission line and have identified 11 segments of the proposed project route where measurements are proposed to be taken before and after construction of the Project. These 11 route segments cover all the proposed configuration types and are expected to conservatively evaluate electric and magnetic field (EMF) levels for the entire route.[1,2] The criterion for initial site selection was to evaluate all F107 structure types (e.g., delta, delta with underbuild, underground etc.) and to combine segments where similar configurations are proposed. Next, specific locations were selected where the F107 line would pass by a higher density of residences than other segments of the route with similar configurations. These 11 route segments for which measurements are proposed are described in Table 1 by the Line Section in the Application, structure type, and beginning and ending structure numbers.

Table 1. EMF measurement section proposal

Measure #	**Line Section** (Application Section)	**F107 Structure Type**	**Begin Segment Structure #**	**End Segment Structure #**
1	Madbury S/S to Route 4 Xing	Delta	Madbury S/S	9
2	Underground through UNH Parking Lot	Underground	23	24
3	UNH to Durham S/S	Delta w/ underbuild	25	32
4	Packers Falls S/S to Newmarket Rd.	Delta w/ underbuild & adjacent line	49	59
5	Timber Brook Ln. to Sandy Brook Dr.	Delta w/ underbuild	64	70
6	Sandy Brook Dr. to Durham Point Rd.	Delta & adjacent line	71	93
7*	Durham Point Rd. to Little Bay Launch	Delta	96	100
8	Little Bay Xing	Direct bury	Shoreline on west side of Bay	
9†	Underground through Frink Farm	Underground	109	113
10	Fox Point Rd. to Spaulding Turnpike Xing	Delta & adjacent line	115	137
11	Crossing at Fox Run to Portsmouth S/S	Vertical & adjacent lines	138	Portsmouth S/S

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

Within each of these 11 cross sections of the route Exponent and Eversource will select one measurement location (preferably with at least one alternate location), which is anticipated to be appropriate for measurements both before and after the Project is placed into service. These

[1] Spot measurements of magnetic field levels were previously performed on August 8, 2018 beneath the existing transmission line and at various points on the property and inside the Fitch residence at 291 Durham Point Rd.

[2] No measurements are proposed for the small portion of the route between structures 102 and 109 where the proposed configuration changes rapidly (from underground to vertical, to delta to H-frame and back to underground) over a relatively small area. Each of these configurations is measured elsewhere on the route except for the two spans where the F107 line is proposed in an H-frame configuration. No measurements are proposed for this configuration because it represents a very small (2 spans) portion of the route and because the nearest residence to this configuration is more than 400 feet away.

locations ideally will have the following characteristics that increase the likelihood of obtaining good quality measurements:

1) Free from other sources of EMF which may affect measured levels (e.g., overhead/underground distribution lines) or other facilities which can alter measured EMF levels (e.g., water or sewer pipes, gas or oil pipelines).
2) Flat, level surface beneath the transmission lines (or above underground transmission lines) that is away from transmission line structures (ideally near midspan of lines).
3) Free of underbrush, trees or other conductive objects which is necessary in order to match the conditions for which the modeled the electric field was calculated.

Additionally, foul weather, particularly precipitation, will interfere with the function of instruments and the valid measurement of electric field levels. Exponent will therefore coordinate with utility personnel and the Safety Division to identify a time-frame with anticipated favorable weather conditions. This timeframe (or timeframes) will be discussed with Eversource to confirm that there are no expected line outages, construction or system repairs, or other unusual line conditions scheduled for that period. Additionally, utility personnel will work with appropriate departments to ensure that necessary data (e.g., loading information of all transmission lines at the measurement locations) can be logged and available during the proposed measurement period. Post-construction measurements will be made during summer peak loading season.

Measurement Procedure

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

Engineers will then proceed to perform EMF measurements using measurement equipment and methodology outlined in Institute of Electrical and Electronics Engineers IEEE Standard 644-1994 (R2008) and IEEE Std. C95.3.1-2010. Measurements will be performed at a height of 1 meter above ground and will be performed for a transect perpendicular to the transmission line. If a transect other than perpendicular is necessary, the angle of the transect to the transmission lines will be noted and measurement distances will be adjusted accordingly.

Both electric fields and magnetic fields will be measured as the total field computed as the resultant of field vectors measured along vertical, transverse, and longitudinal axes.[3] 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 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. 644-1994. 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 measurements before the Project is placed into service are taken at line loadings lower than peak levels, 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.

Report

Exponent will prepare a report detailing the measurement methods and a summary of measurements taken before and after the Project is placed into service. These reports will include aerial maps from Google Earth 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 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 and as adjusted to the peak loading condition specified in the application.

[3] 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.