December 22, 2009

Mr. Daniel Caruso, Chairman
Connecticut Siting Council
Ten Franklin Square
New Britain, CT 06051

RE: Docket 272: Post-construction EMF Monitoring Report

Dear Chairman Caruso:

The Connecticut Light and Power Company and The United Illuminating Company hereby file the enclosed original and twenty copies of the Post-construction EMF Monitoring Report for the Middletown to Norwalk Project.

If you need any further information, please call me at 860-665-2771.

Sincerely,

Anne Bartosewicz
Middletown-Norwalk Project Director

Attachment

cc: Fred Cunliffe – Supervisory Siting Analyst, Connecticut Siting Council
Service list (w/o attachment)

POST-CONSTRUCTION EMF MONITORING REPORT FOR THE MIDDLETOWN-NORWALK TRANSMISSION PROJECT

DECEMBER 18, 2009

Measurements and Report By:

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APPENDICES

Notes Concerning Frequently Used Terms

Pre-construction Data	
Pre-construction measurements	Prior to Project construction, electric and magnetic fields were measured at each of 42 Monitoring Sites. (Note: During pre-construction measurements, some transmission lines were out of service in preparation for construction. Out-of-service lines are noted for particular Monitoring Sites in Appendices C and D.)
Pre-construction monitored system load	Prior to Project construction, actual New England system loading was recorded on the date and at the time electric and magnetic field measurements were taken.
Pre-construction monitored currents	Prior to Project construction, actual circuit currents were recorded on the date and at the time electric field and magnetic field measurements were taken.
Post-construction Data	
Projected or predicted field levels	Estimated electric and magnetic field levels based on modeling assumptions were provided to the Council during the Docket 272 siting proceedings. These estimated field levels were calculated using established modeling techniques and assumptions. The calculations provide an estimate of post-construction fields from Docket 272 facilities for average loading conditions on the New England system.
Post-construction measurements	Magnetic and electric fields were measured after the Project was constructed and energized. Magnetic fields were measured on two different days at each of the 42 monitoring sites, and are referred to as Post Construction Set 1 and Post Construction Set 2. Electric fields were measured at a subset of the 42 sites on a single day after the Project was constructed and energized.
Post-construction monitored system load	After the Project was constructed and energized, actual system loading was recorded on the date and at the time electric and magnetic field measurements were taken. These data were recorded at each of the two times that post-construction measurements were taken at a given site, and are referred to as Monitored Set 1 and Monitored Set 2.
Post-construction monitored currents	After the Project was constructed and energized, actual circuit currents recorded on the date and at the time measurements were taken. These data were recorded at each of the two times that post-construction measurements were taken at a given site, and are referred to as Monitored Set 1 and Monitored Set 2.

1.0 Introduction

In their Application to the Connecticut Siting Council (the "Council") in Docket 272, The Connecticut Light & Power Company ("CL&P") and The United Illuminating Company ("UI") (together, the "Companies") provided an assessment of electric and magnetic fields ("EMF") for the Middletown-Norwalk Transmission Project. During the course of the siting proceedings, the Companies were asked to provide additional electric and magnetic field calculations for a variety of overhead and underground transmission line configurations, some of which were ultimately selected by the Council for the design of the Project. [1]

The Council's Decision and Order in Docket 272 included the condition that the Companies submit a post-construction EMF Monitoring Plan as part of the Development and Management Plan ("D&M") process prior to the commencement of operations.[2] An EMF Monitoring Plan for electric and magnetic fields along the Project route and at the substation perimeters was submitted to the Council on February 16, 2007 and is attached as Appendix A.

At a public meeting held on November 5, 2007, the Council considered and approved the EMF Monitoring Plan,[3] which identified 39 locations for magnetic field measurements. The Plan called for electric field measurements at a subset of locations where magnetic field measurements were made. To the list of 39 sites, the Council added measurement locations at Lyman Orchards Golf Course in Middlefield under the new 345-kV line; Old Farms Road in Cheshire above the new 115-kV underground cables; and Lincoln Street in Westport above the new 345-kV underground cables.

This report summarizes EMF measurements at the 39 monitoring sites originally proposed and the three sites added by the Council. As required by the Council, this report includes:

- comparisons between electric and magnetic field measurements taken after completion of the Project and electric and magnetic field values calculated during the siting proceedings.

- "true up" comparisons between: (i) field measurements taken after completion of the Project; and (ii) calculated field values using actual line conditions at the time these measurements were taken.

The measurements in this report show that the EMF levels projected during the siting proceedings provided a reasonable estimate of the actual EMF levels measured after the Project was energized, recognizing that such estimates depend upon assumed line conditions (i.e., line loading and conductor height). By replacing assumed line conditions with measured line conditions, "true-up" comparisons in this report demonstrate the accuracy of EMF modeling

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[1] See Companies' Exhibit 96a, which provided updated electric- and magnetic-field calculations as of July 20, 2004 for the overhead line segments ("the July 2004 Filing"), and Companies' Exhibit 162, magnetic-field calculations for XLPE transmission cables dated September 27, 2004.

[2] CSC Decision and Order, Docket No. 272, April 7, 2005.

[3] CSC Approval of EMF Monitoring Plan, January 4, 2008 (included in Appendix A).

methods used during the siting proceedings.

2.0 Sources of Electric and Magnetic Fields

Electric fields are the result of voltages applied to electrical conductors and equipment. Since utility installations are designed to operate at a specific voltage, electric fields from utility sources are stable over time. In addition to the Middletown-Norwalk transmission lines and the equipment added to substations, there are additional sources of power-frequency electric fields along the Project route, including distribution and transmission conductors not associated with the Project. Most conductive materials – including fences, shrubbery, buildings, soil, and the metallic sheaths of underground cables – block electric fields. For this reason, the underground lines constructed as part of the Project are not a source of electric fields above ground.

Magnetic fields are produced by the flow of electric currents and therefore vary over time as the demand for electric power fluctuates. Unlike electric fields, most materials do not readily block magnetic fields. The level of the magnetic field at any point depends on characteristics of the source, including the arrangement of conductors, the amount of current flowing, and the source's distance from the point of measurement. As for electric fields, the intensity of magnetic fields diminishes with increasing distance from the source.

Sources of magnetic fields not associated with the Project include transmission and distribution lines, as well as currents flowing on other conductors of electricity, such as communication cables and water pipes. The major sources of power-frequency magnetic fields associated with the Project are overhead transmission lines, cable systems below grade, and the transformers and other equipment within the associated substations. Section 6.0 summarizes measurements for these Project-related sources, including measurements of:

(1) electric and magnetic fields beneath new sections of 345-kV and 115-kV overhead transmission lines;

(2) electric and magnetic fields over each new set of 345-kV and 115-kV underground transmission cables; and

(3) electric and magnetic fields around the perimeters of the Scovill Rock and Beseck Switching Stations, and around the perimeters of the East Devon, Singer, and Norwalk Substations.

It is important to remember that measurements of magnetic fields present a snapshot of power demand at a point in time. Within an hour, a day, or over the course of months and seasons, the magnetic field changes depending upon the amount and the patterns of power demand within the state and surrounding region. Moreover, measurements at any specific location can include the contribution from time-varying sources that are not associated with the Project.

3.0 Measurement and Calculation Methods

Electric and magnetic field measurements were recorded at a height of one meter (3.28 feet) above ground in accordance with standard methods for measuring EMF near power lines

(Institute of Electrical and Electronics Engineers, IEEE Std. 644-1994a). Both electric and magnetic fields were expressed as the total field computed as the resultant of field vectors measured along vertical, transverse, and longitudinal axes.[4] 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) manufactured by Enertech Consultants. Along substation perimeters before construction, the magnetic field was measured in units of mG in x, y and z-axes by orthogonally mounted sensing coils whose output was logged by a digital recording meter (Dexsil Corp) at one-foot intervals.

Prior to the Project, electric fields were measured in units of kilovolts per meter ("kV/m") with a single-axis field sensor and meter manufactured by Electric Field Measurements, Inc. After Project construction and energization, electric fields were measured in units of kV/m with a single-axis sensor accessory for the Emdex II meter at ten-foot intervals. The sensitive axis of the electric-field sensors was successively oriented in the vertical, transverse, and longitudinal directions to measure the total electric field at particular points. These instruments meet the IEEE instrumentation standard for obtaining accurate field measurements at power-line frequencies (IEEE Std.1308-1994b). The meters and the electric field probes were calibrated by the manufacturer by methods like those described in IEEE Std. 644-1994a.

CL&P and UI reported power flows and voltage on the transmission lines at the time of electric and magnetic field measurements. Exponent used these monitored conditions to assess the stability of readings, and included monitored loads in calculations of site-specific magnetic fields. Site-specific magnetic field levels were calculated using computer algorithms developed by the Bonneville Power Administration (BPA, 1991). The inputs to the BPA program include data regarding voltage, current flow, circuit phasing, and conductor position. The resultant magnetic fields associated with a particular loading were then calculated along transects perpendicular to the transmission line conductors. For the CL&P portions of the underground line route where underground cable sheaths were not cross-bonded, the effect of ground continuity conductors ("GCCs") was included in the calculations. Induced currents on the GCCs were calculated with the ENVIRO program using algorithms developed at the Electric Power Research Institute ("EPRI") Power Delivery Center.

4.0 Measurement Locations

The Middletown-Norwalk Transmission Project comprises 69 miles of 345-kV transmission line construction between the Scovill Rock Switching Station in Middletown and the Norwalk Substation (see Index of EMF Measurement Locations in Appendix B). The Project includes approximately 45 miles of new overhead 345-kV line construction and 24 miles of new underground double-circuit 345-kV cable construction, as well as the reconstruction of existing 115-kV and 345-kV overhead transmission facilities. The overhead line portion of the Project extends from the Scovill Rock Switching Station to the East Devon Substation in Milford. The underground cable portion extends from the East Devon Substation to the Norwalk Substation.

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[4] Magnetic field measurements along the vertical, transverse, and longitudinal axes were recorded as root-mean-square ("rms") magnitudes. RMS refers to the common mathematical method of defining the effective voltage, current, or field of an alternating current ("AC") system.

Table 1 identifies the 42 monitoring sites which are depicted on the Index of EMF Measurement Locations in Appendix B. The overview map in Appendix B is followed by 42 aerial photographs marking the measurement location for each site.

Table 1. Measurement Sites identified by the EMF Monitoring Plan and recommended by the Council

Site	Cross Section[5]	Segment	Municipality	Location	400 Scale Aerial Segment[6]
			Overhead Route		
1	—	1a	Middletown	Scovill Rock Switching Station	1
2	1 LEMF	1a	Middletown	Bartholomew Road	3
3	2 LEMF	1a	Durham	Arbutus Street	5
4	2 ROB	1b	Middletown/ Middlefield	South Main Street (Rt 17) (Royal Oaks Bypass)	6
5	2 LEMF	1a	Durham/ Middlefield	Durham Landfill	7
CSC-1	2 LEMF	1a	Middlefield	Lyman Orchards Golf Course	8
6	3 LEMFB	1a	Meriden	Meriden PBA – Birsdey Avenue	12
7	3	1a	Meriden	High Hill Road	12
8	4	1a	Wallingford	Gravel Operation	13
9	—	2a	Wallingford	Beseck Substation	10,14
10	5 LEMF	2a	Wallingford	Cornfield Road off Tamarac Swamp Road	18
11		2a	Wallingford	Harrison Road	19
12	6 EAST	2a	Wallingford	Pond Hill Road	19
13	6 WEST	2a	Wallingford	South Cherry Street	20
14	7A	2a	Wallingford	Blue Hill Orchard	21
15	7B	2a	Cheshire	Old Farms Road	24
CSC-2	7B	2a	Cheshire	Old Farms Road above 115-kV UG line	24
16	8A	2a	Cheshire	Old Lane Road	24
17	8B	2b	Hamden	Brooksvale Avenue	25
18	8B	2b	Bethany	Hatfield Hill Road	29
19	8B	2b	Woodbridge	Dillon Road	31
20	8B LEMF	2b	Woodbridge	JCC Parking Lot	33
21	8B LEMF	2b	Woodbridge	Congregation B'nai Jacob	34
22	8B	2b	Orange	Dogburn Road	36
23	8B LEMF	2b	Orange	Orange Center Road (Route 152)	40
24	8B LEMF	2b	Milford	Eisenhower Park Parking Lot and Equestrian Field	42

[5] Cross-section designation in Table 1 refers to the drawing designation from the various D&M Plans

[6] Docket 272 CSC Application Volume 9 of 12, Route Maps - Overview of Route on USGS Map; Aerial Photographs - 400 Scale

Site	Cross Section[5]	Segment	Municipality	Location	400 Scale Aerial Segment[6]
25	—	2b	Milford	East Devon Substation	45
26	8D	2b	Milford	Off Caswell Avenue	46
27	8E	2b	Milford	Access road off Naugatuck Avenue	47
			Underground Route		
28	9 East	3a	Milford	Naugatuck Avenue	47
29	9 East	3b	Stratford	1895 Barnum Avenue	50
30	9 East	3b	Stratford	Thompson Street and Soundview Avenue	50
31	9 East	3b	Bridgeport	Bishop Avenue and Sage Avenue	50
32	9 East	3b	Bridgeport	510 Barnum Avenue	51
33	9 East	3b	Bridgeport	Noble Avenue and Barnum Avenue	52
34	—	3b	Bridgeport	Singer Substation	53
35	9 West	4a	Bridgeport	Melrose Avenue	55
36	9 West	4a	Fairfield	Ruane Street	57
CSC-3	9 West	4b	Westport	Lincoln Street	61
37	9 West	4b	Westport	599 Post Road West	62
38	9 West	4c	Norwalk	Grand Street	66[7]
39	—	4c	Norwalk	Norwalk Substation	66

5.0 Right-of-Way Configurations

The monitoring sites are representative of all major right-of-way ("ROW") configurations, identified by the "Cross Section" column in Table 1 above. These cross sections comprise the various Project segments along the overhead and underground portions of the Project (*cf.*, "Segment" column in Table 1). This portion of the report provides a description of the configurations that make up each of the Project Segments.

5.1 Overhead Transmission Line Route

The overhead line portion of the Project encompasses Segments 1a, 1b, 2a, and 2b.

5.1.1 Segment 1a

Segment 1a consists of three sub-segments, each adding a new 345-kV line section to the existing 345-kV system in central Connecticut. In the D&M Plan for Segment 1a, the ROW configuration is represented by Sections 1 LEMF, 2 LEMF, 3, 3 LEMFB, and 4:

[7] Note: This portion of the route is not depicted in the 400-scale aerial maps filed with the CSC Application. See Figure F-2 of the Companies Filing dated 7-21-06 re: Norwalk Route Change.

- Cross Section 1 LEMF: From the Scovill Rock Switching Station to Chestnut Junction in Middletown, where the ROW width was expanded by 60 feet to accommodate a new 345-kV line section using a compact delta design.
- Cross Section 2 LEMF: From Oxbow Junction in Haddam to the new Beseck Switching Station in Wallingford, where a new 345-kV line section was constructed on new steel monopoles that also support replacement conductors for an existing 115-kV line.
- Cross Sections 3 LEMF, 3 and 4: From Black Pond Junction in Meriden to the Beseck Switching Station, where two new 345-kV line sections were added on steel monopoles, and replacement conductors for the existing 115-kV lines were installed on two of the new steel monopoles.

5.1.2 Segment 1b

Segment 1b comprises a 1.2-mile segment of the 345-kV overhead transmission line that is routed away from an existing CL&P 115-kV line corridor (Cross Section 2 ROB in Segment 1a) and onto a bypass route around the Royal Oak Subdivision. In the Segment 1b D&M Plan, the new 345-kV line is supported in a delta configuration on tubular steel monopoles on a new 125-foot-wide ROW.

5.1.3 Segment 2a

Segment 2a consists of one continuous path for a new 345-kV transmission line (part of circuit 3827) from the new Beseck Switching Station in Wallingford to the Cheshire/Hamden Town Line, south of Cook Hill Junction. In the D&M plan for Segment 2a, the major ROW configurations are represented by Sections 5 LEMF, 6 EAST, 7A, 7B, and 8A:

- Cross Section 5 LEMF: From Beseck Switching Station to East Wallingford Junction in Wallingford, in which the new single-circuit 345-kV line was built using a delta design, with only minor modifications to an existing, parallel 345-kV line.
- Cross Section 6 EAST: From East Wallingford Junction to Wallingford Junction in Wallingford, where an existing 115-kV line was replaced with a new 345/115-kV double-circuit line.
- Cross Section 7A: From Wallingford Junction in Wallingford to a new line-transition structure west of the Wallingford/Cheshire Town Line in Cheshire. Along this sub-segment, a new single-circuit 345-kV line was constructed with delta-configured line structures with only minor modifications to an existing double-circuit 115-kV line.
- Cross Section 7B: From a new line-transition structure west of the Wallingford/Cheshire Town Line to Cook Hill Junction in Cheshire. In this sub-segment, the new 345-kV line was built using new double-circuit structures, shared by replacement conductors for an existing 115-kV line.

One other existing 115-kV line was relocated to an underground duct-bank within the street at Old Farms Road.

- Cross Section 8A: Cook Hill Junction to the new line-transition structure south of the Cheshire/Hamden Town Line in Hamden. In this sub-segment, new 345/115-kV lines were constructed vertically on double-circuit structures and the other existing 115-kV line continued underground along Old Lane Road to the transition structure.

5.1.4 Segment 2b

Segment 2b consists of one continuous path for a new 345-kV transmission line within an existing transmission line corridor. Segment 2b begins at the Cheshire/Hamden Town Line south of Cook Hill Junction in Hamden and continues through the towns of Hamden, Bethany, Woodbridge, Orange, West Haven and Milford to the new East Devon Substation in Milford. Two of the three existing 115-kV transmission lines were rebuilt within this corridor; the third 115-kV circuit was removed.

In the D&M plan for Segment 2b, the major ROW configurations are represented by the Sections 8B, 8B LEMF, 8D, and 8E:

- Cross Section 8B: From the new line-transition structure south of the Cheshire/Hamden Town Line in Hamden to the East Devon Substation (with the exception of 8B LEMF sub-segments, discussed below). In this Section, one existing 115-kV line was removed, and the remaining two 115-kV lines were rebuilt on one line of double-circuit structures. The new 345-kV line was constructed on compact delta structures near the center of the ROW.

- Cross Section 8B LEMF: In certain areas along Segment 2b, the 345-kV line design in Section 8B was modified to a split-phase design.

- Cross Sections 8D and 8E: The 115-kV lines in Section 2b, and the 115-kV Milford Power Generation connection lines, continue beyond the new East Devon Substation to the Devon Generation Substation in Milford. These 115-kV lines were reconfigured to support the Project, and the ROW in these Sections converges with other transmission corridors in Milford.

5.2 Underground Cable Route

The underground cable portion of the Middletown-Norwalk Project extends approximately 24 miles from the East Devon Substation to Singer Substation in Bridgeport and then continues to Norwalk Substation in Norwalk.

5.2.1 Segments 3a and 3b

Segments 3a and 3b include two underground 345-kV cross-linked polyethelene ("XLPE") transmission cable circuits and corresponding splice vaults from the East Devon Substation, Milford to the Singer Substation in Bridgeport. The Companies' D&M Plans for Segment 3 included several duct-bank configurations of varying burial depth. Details of the duct-bank section at each measurement location are included in Appendix C. The predominant duct-bank configuration along this portion of the route is a double-circuit vertical design with no spare ducts and varying burial depth. Details of the duct-bank section are included in Appendix C for each measurement location.

5.2.2 Segments 4a, 4b, and 4c

Segments 4a, 4b, and 4c include two underground 345-kV XLPE transmission-cable circuits and corresponding splice vaults extending from the Singer Substation, Bridgeport to the Norwalk Substation, excluding major water crossings between these locations. The underground cable system is installed primarily within existing public road ROWs. The majority of the splice-vaults are located on new easements off of the existing public road ROWs. The predominant duct-bank configuration in these segments is a double-circuit horizontal configuration with no spare ducts and varying burial depth. Details of the duct-bank section in Segments 4a, 4b, and 4c are included in Appendix C for each measurement location.

6.0 Post-Construction EMF Measurements

6.1 EMF Measurements along Overhead Line Portion of the Project Route

6.1.1 Magnetic Fields

Table 1 above includes 25 monitoring sites beneath new sections of 345-kV and 115-kV overhead transmission lines. At each of these locations, magnetic field measurements were recorded along a transect perpendicular to the Project route once before and twice after the in-service date. These measurements are presented in Appendix C alongside line height and loading data recorded at the time of the measurements. Where possible, the measurement path traversed the entire width of the ROW, and the locations of overhead line conductors are noted on the transect.

For purposes of making "true up" comparisons between calculated and measured fields, calculated magnetic field profiles are superimposed on the measured profiles in Appendix C for the following locations:

- Monitoring Site 2: Bartholomew Road, Middletown
- Monitoring Site 6: Meriden Police Benevolent Association ("PBA"), Meriden

- Monitoring Site 8: Gravel Operation, Wallingford
- Monitoring Site 12: Field off of Pond Hill Road, Wallingford
- Monitoring Site 14: Blue Hill Orchard, Wallingford
- Monitoring Site 17: Brooksvale Avenue, Cheshire
- Monitoring Site 23: Orange Center Road, Orange
- Monitoring Site 26: off Caswell Avenue, Milford

These sites were chosen for "true up" comparisons between calculated and measured fields for several reasons. At these sites, the terrain is relatively flat, conductor configurations are longitudinally uniform, conductor heights are typical and representative, and there are few EMF sources extraneous to the Project. Induced currents on shield wires are negligible and were not included in the modeling. As shown by the profiles in Exhibit C, the agreement between the calculated and measured field profiles at these locations demonstrates the accuracy of the modeling methods, and is discussed further in Section 7.3.

6.1.2 Electric Fields

Electric field profiles were recorded at a subset of 8 sites within the overhead line monitoring sites, once before and once after the in-service date:

- Monitoring Site 2: Bartholomew Road, Middletown
- Monitoring Site 3: Arbutus Road, Durham
- Monitoring Site 6: Meriden PBA, Meriden
- Monitoring Site 8: Gravel Operation, Wallingford
- Monitoring Site 13: South Cherry Street, Wallingford
- Monitoring Site 20: Jewish Community Center, Woodbridge
- Monitoring Site 21: Congregation B'nai Jacob, Woodbridge
- Monitoring Site 24: Eisenhower Park, Milford

The three orthogonal components of the electric field were measured directly below conductors and at the ROW edges or at 10-foot intervals along the path of the magnetic field measurements. The three orthogonal measurements at each distance were combined to yield the resultant electric field as a function of distance measured perpendicular to the conductors. The resultant electric field profiles are presented in Appendix D, with calculated profiles based upon the measured conductor heights superimposed at Monitoring Sites 2, 8 and 24. These profiles illustrate the accuracy of the electric field modeling methods.

6.2 EMF Measurements along Underground Line Portion of the Project Route

6.2.1 Magnetic Fields

Table 1 includes 12 monitoring sites over new sets of 345-kV and 115-kV underground transmission cables. At each of these locations, magnetic field measurements were recorded along a transect perpendicular to the Project route once before and twice after the in-service date. These readings are presented in Appendix C alongside line loading data recorded at the time of the measurements. The measurement path crosses roadways at these locations, extending down adjacent roads, sidewalks, or driveways where possible. Since duct-bank configuration and burial depth varies along underground routes, the duct-bank section at each site is included with the measured profiles in Appendix C.

A calculated magnetic field profile is superimposed on the measured profile at Monitoring Site CSC-3, Lincoln Street, for a "true-up" comparison. At this monitoring site, the duct-bank configuration is longitudinally uniform, and there are only weak magnetic field sources in the vicinity. Generally in urban areas, as confirmed by pre-construction measurements, there are numerous magnetic field sources extraneous to the Project beneath and adjacent to roadways.

6.2.2 Electric Fields

Disregarding extraneous sources, typically there is no electric field from the underground transmission cables. To confirm this anticipated result, the electric field was measured above the underground transmission cables located under the commuter parking lot on the east bank of the Saugatuck River, near the intersection of Imperial Avenue and Thomas Road in Westport. (See last sheet of Appendix D.) At all locations within one hundred feet of the duct-bank centerline at this location, the measured electric field was 0.00 kV/m.

6.3 Substation Measurements

The Project includes the construction of two new electric substations (the East Devon Substation in Milford and the Singer Substation in Bridgeport) and one new switching station (the Beseck Switching Station in Wallingford). In addition, the existing Norwalk Substation and Scovill Rock Switching Station were modified with new line terminals, switchgear, and transformers. Appendix E summarizes EMF readings collected along the perimeter of substations and switching stations before and after commencement of operation.

6.3.1 Scovill Rock Switching Station

New switching station equipment was installed within the fenced area of the existing Scovill Rock Switching Station, including four 345-kV circuit breakers, nine 345-kV

isolating disconnect switches, and associated equipment. (See Scovill Rock Switching Station D&M Plan.)

An aerial photograph of Scovill Rock Switching Station and key locations around its perimeter is provided in Appendix B, Measurement Site 1. Pre-construction electric and magnetic fields were measured around the perimeter of Scovill Rock Switching Station on January 31, 2003 and submitted to the Council as a part of the October 2003 Application. Post-construction measurements along the same path were taken on April 13, 2009 and May 12, 2009 and are included in Appendix E alongside the pre-construction readings.

The electric and magnetic fields are reported in Appendix E proceeding clockwise around the station perimeter from the northwest corner. The highest pre-construction magnetic field measured around the perimeter of the substation was 70 mG and occurred near the northeast corner of the substation, beneath an existing 345-kV transmission line.

After the Project's in-service date, the highest magnetic field was 83 mG, again near the northeast corner. The highest measured magnetic field level on the western perimeter beneath the new 345-kV lines was 60 mG. These results indicate what is commonly observed in magnetic field measurements along a substation perimeter, namely, that the highest magnetic field levels occur where transmission and distribution lines cross over or under the facility's fence line.

The electric fields were measured at locations around the perimeter of the facility and are reported in Appendix E beneath the magnetic field profiles. The electric fields were measured at the four corners of the substation and at the approximate midpoints on each side. Measurements were also made under the center phase of each transmission line entering the station. The highest pre-construction electric field measured was 1.32 kV/m and occurred along the east side of the station, beneath a 345-kV transmission line passing into the station. After construction, the highest electric field readings were between 0.54 and 0.56 kV/m, recorded under the existing 345-kV transmission line on the east side of the substation, and under the new 345-kV transmission line on the west side of the substation, respectively.

6.3.2 Beseck Switching Station

The new Beseck 345-kV Switching Station includes four line-terminal structures, seven 345-kV circuit breakers, twenty 345-kV disconnect switches, and associated equipment. (See Beseck Switching Station D&M Plan). An aerial photograph of the Beseck Switching Station and key locations around its perimeter is provided in Appendix B, Measurement Site 9. The site is part of a larger tract of land owned by Northeast Utilities, north of Carpenter Lane and east of High Hill Road. Before construction, existing transmission lines were located on the north and east sides of the facility.

Pre-construction measurements of magnetic fields were taken at the site of the then-proposed Beseck Switching Station on January 31, 2003. The magnetic fields were measured around the path indicated in Appendix B, Measurement Site 9. The measurement path began at point A on the southwest corner of the site and proceeded clockwise around the site from point A to B to C to D, and back to point A. The highest value, measured at point D, was influenced by the nearby 115-kV and 345-kV lines that meet at Carpenter Lane Junction.

Post-construction measurements at the Beseck Switching Station perimeter were recorded on April 13, 2009 and May 13, 2009 and are included in Appendix E alongside the pre-construction readings. After the in-service date, the highest magnetic-field reading was 110 mG on the northern perimeter, beneath the point where 345-kV lines pass over the station fence line. The post-construction measurements were not recorded at the same elevation as the pre-construction measurements, since the grading of the Beseck Switching Station site was changed during construction.

The pre-construction electric field was measured at the four corners of the then-proposed facility, labeled A, B, C and D on Appendix B and the results are reported in Appendix E beneath the magnetic field profiles. Nearby trees on the site and along its perimeter perturbed the electric field measurements, which were highest (1.67 kV/m) near the corner of the site adjacent to Carpenter Lane Junction. After the in-service date, the highest measured electric field was 4.18 kV/m, beneath the newly constructed 345-kV line.

6.3.3 East Devon Substation

The new East Devon Substation includes one 345-kV line-terminal structure, seven 345-kV circuit breakers, sixteen 345-kV switches, three single-phase 345/115-kV autotransformers, three 115-kV line-terminal structures, seven 115-kV circuit breakers, twenty-five 115-kV disconnect switches, six single-phase 115-kV current-limiting series reactors, and associated equipment (East Devon Substation D&M Plan).

An aerial photograph of the East Devon Substation and key locations around its perimeter is is provided in Appendix B, Measurement Site 25. The site is north of the Milford Power generating plant and east of Oronoque Road. Before construction, existing transmission lines were located parallel to the east side of the proposed site.

Pre-construction measurements of magnetic fields were taken at the site of the then-proposed East Devon Substation on September 22, 2003 around the path indicated in the inset of Appendix B, Measurement Site 25. The perimeter profile started at point A and proceeded clockwise around the site from A to B to C and back to point A. The magnetic field profile is plotted in Appendix E, Monitoring Site 25. The highest pre-construction magnetic field level was 6.7 mG, and was measured on the east side of the site in the vicinity of 115-kV overhead lines.

Post-construction measurements along the perimeter of the facility were recorded on April 14, 2009 and May 14, 2009 and are included in Appendix E alongside pre-construction readings. After the in-service date, the highest measured magnetic field was 235 mG over the underground 345-kV transmission cables that exit the substation near Shelland Street. Magnetic fields on the eastern substation perimeter were between 25 mG and 110 mG in the vicinity of reconstructed 115-kV lines and new 345-kV overhead lines.

Pre-construction electric field measurements were recorded at points near the corners of the facility and are reported under the magnetic field profiles in Appendix E. Nearby trees on the site and along the fence perimeter perturbed the electric field and the highest reading was 0.25 kV/m at the northeast corner of the facility. After the in-service date, the highest measured electric field was 2.59 kV/m, beneath the newly constructed 345-kV lines at the northeast corner of the facility.

6.3.4 Singer Substation

The new Singer Substation comprises 345-kV and 115-kV line terminations, two 345/115-kV autotransformers, four 345-kV variable shunt reactors, and a new Gas Insulated Switchgear ("GIS") enclosure housing the 345-kV GIS. (See D&M Plan for the Construction of Singer Substation and 115kV Generation Interconnections.) An aerial photograph of the Singer Substation and key locations around its perimeter is provided in Appendix B, Measurement Site 34. The substation is located to the east of Main Street in Bridgeport, and is bounded by Atlantic and Henry Streets. PSEG property abuts the site to the east, and no measurements were made on the east side of the site due to restricted access.

Pre-construction magnetic field measurements were taken on April 3, 2007 along accessible roads. The measurement path started at point A and proceeded clockwise around the site from A to B to C. The magnetic field profile is plotted in Appendix E, Monitoring Site 34, alongside the post-construction readings. The highest measured magnetic field before construction was 1.9 mG, and was recorded along Main Street. Post-construction measurements along the same path were taken on April 14, 2009 and May 14, 2009. After the in-service date, the highest measured magnetic field was 113 mG over the underground 115-kV transmission cables that exit the substation on Atlantic Avenue. Over the underground 345-kV transmission cables that exit the substation on Main Street the highest measured magnetic field level was 55 mG.

Electric fields were measured at the corners of the substation before and after construction. The highest measured values were 0.1 kV/m on the sidewalks adjoining the site.

6.3.5 Norwalk Substation

New equipment was installed within the enclosing fence of the Norwalk Substation. The equipment includes three gas-insulated switchgear positions, three new 345/115-kV, 200-MVA single-phase autotransformers and ancillary devices, one spare single-phase transformer, one spare three-phase reactor, two three-phase 100-MVA shunt reactors, two new 345-kV circuit switchers, a new 345-kV underground cable duct-bank, and associated equipment. (See Norwalk Substation D&M Plan).

An aerial photograph of the Norwalk Substation and key locations around its perimeter is provided in Appendix B, Measurement Site 39 (see inset). The substation is located on the west side of Route 7 at the junction with Route 123. Since the time of the Application in 2003, the northern perimeter of the substation was extended to accommodate the Bethel-Norwalk project additions to the Norwalk Substation (CSC Docket 217).

The pre-construction magnetic fields were measured on April 3, 2007 around the extended perimeter of the substation starting at the southeast corner. The highest measured magnetic field was 43 mG, recorded at the northern perimeter beneath the Plumtree-Norwalk 345-kV line. Post-construction measurements along the substation perimeter were recorded on April 15, 2009 and June 12, 2009 and are included in Appendix E alongside pre-construction readings. After construction, the highest measured magnetic fields were between 140 mG and 150 mG, and were recorded on the eastern substation perimeter over the new 345-kV transmission cables between the Singer and Norwalk Substations. Near this location, individual ducts branch off from the 345-kV double-circuit duct-bank and proceed toward separate termination structures. Since duct and line spacing increases where individual ducts branch off, magnetic field cancellation between the 3280 and 3291 circuits decreases and the measured magnetic fields increase. It should be noted, however, that the eastern perimeter of the Norwalk Substation adjoins the Route 7 off-ramp, and there are no sidewalks on this side of the substation.

Electric fields were measured near the passage of transmission lines over the substation perimeter, before and after construction. The highest measured electric field level was 1.69 kV/m beneath overhead transmission lines on the western perimeter of the substation not associated with the Project. The highest measured electric field level in the vicinity of Project-related construction on the eastern perimeter of the site was 0.12 kV/m.

7.0 Discussion of EMF Values

The purpose of this section is to compare EMF calculations provided during siting proceedings and EMF measurements taken after completion of the Project. In addition, "true-up" comparisons of calculated EMF levels are provided to show the accuracy of the modeling methods.

Differences between post-construction EMF values measured at the edge of the ROW and EMF calculations provided to the Council during the siting proceedings are attributable to differences between the assumptions underlying the calculations made in 2004 and actual conditions at the time the measurements were taken. These differences include:

(1) differences between actual conductor heights above ground at measurement sites and the typical minimum conductor heights that were modeled in the calculations;

(2) differences between the power flows over each circuit modeled in the magnetic field calculations and actual power flows at the time measurements were taken in 2009; and,

(3) differences between the underground duct-bank configuration modeled in the siting proceedings and the duct-bank configurations approved during the D&M Plan process.

Items (2) and (3) are discussed in Sections 7.1.1 and 7.1.2 below.

7.1 Differences between Field Modeling in Siting Proceedings and 2009 Conditions

7.1.1 Power Flow

In July 2004, the Companies calculated magnetic field levels based upon a 15-Gigawatt ("GW") system-wide New England load level and dispatch case for the various ROW configurations ultimately chosen by the Council. This "15-GW Case" was designed to represent "typical system conditions," i.e., a load level in which the system operates most of the time as determined using data for the hourly distribution of loads for the years 1999-2002. (See Companies' Exhibit 156, Direct Testimony of John Prete Concerning Magnetic Field Modeling.) The 15-GW Case modeled 52nd-percentile loads on substations, and assumed an average or typical generation dispatch. The 15-GW Case also corresponded to the actual average load during 2002.

The intent of the 15-GW Case was to facilitate a comparison of the existing and proposed ROW configurations under "typical system conditions." In the 15-GW Case, the power flows on elements of the transmission system differ from the planning loads, which represent stressed conditions during a single hour of the year or less.

With this background, the actual currents observed on transmission circuits over any given 5-minute interval – which are reported in Appendix C at the time of magnetic field measurements – differed from those modeled in the15-GW Case for several reasons:

(1) the actual system demand at the time of some post-construction measurements in 2009 exceeded the extrapolated demand in the 15-GW Case;

(2) the actual generation dispatch in some cases differed from that assumed for the 15-GW Case[8]; and

(3) the 15-GW Case assumed that all lines were in service, which was not the case during all magnetic-field readings.[9]

A comparison of projected circuit currents used in the July 2004 calculations with actual circuit currents during measurement periods, both before and after construction, is presented in Table 2 for overhead line sections. A similar comparison for the underground line portion of the route is presented in Table 3.

In the case of an isolated single-circuit transmission line – assuming the same conductor heights above ground – measured magnetic fields at a particular location can be scaled by the ratio of the projected and actual circuit current to compare measured fields to predicted fields. In the presence of multiple overhead lines on the reconfigured ROWs, however, the ratio between projected and actual circuit current is different for each transmission line. For such a case, the measured magnetic fields at a particular location cannot be scaled to compare predicted magnetic fields to measurements. In Table 2, therefore, no adjustment for loading has been made in comparisons of predicted and measured magnetic field levels for the overhead route.

Unlike the overhead line ROWs, the measured magnetic fields at a particular location over the new 345-kV underground cables can be scaled by the ratio of projected and actual loading to compare predicted magnetic fields to measurements. Such correction for load is possible, in the absence of pre-existing sources and nearby transmission lines, because the currents in each of the two underground circuits are approximately equal in both Segments 3 and 4. In the comparison of predicted and measured magnetic field levels in Table 3, below, adjustment for circuit currents was made in comparisons for the underground route.

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[8] On the dates of the post-construction measurements between April 13, 2009 and June 12, 2009, the maximum system load ranged between 15.0 GW and 16.4 GW, which shows that the 15-GW load level is a reasonable load basis for comparison. However, changes in generation dispatch based on ISO-NE market system and inter-area transfers affected the current on particular transmission circuits. For instance, the 15-GW annual average load case assumed 350 MW generation on at the New Haven Harbor Generating Station. Projected current on the 387 circuit based on this assumption was 614 amperes. During post-construction readings on April 13, 2009, the New Haven Harbor Generating Station was off line. The actual current on the 387 circuit with New Haven Harbor off line was approximately 900 amperes, even though maximum system load on this day was 15.5 GW.

[9] As noted in Appendix C for particular cross-sections, the 345-kV 362 circuit was out of service when pre-construction measurements were made on January 11, 2007. Likewise, circuit 1690 was removed from service on November 3, 2006, before pre-construction measurements on November 9, 2006.

Table 2. Comparison of 15-GW annual average load-case currents used in July 2004 Filing for Overhead Line Segments with currents recorded during magnetic field measurements

Cross Section	Circuit	Pre-construction case[+]	Current or current range (amperes)	Post-construction case[++]	Current or current range (amperes)
1	387	Monitored	899	Projected	614
				Monitored set 1	881
				Monitored set 2	481
	362	Monitored	0*	Projected	285
				Monitored set 1	487
				Monitored set 2	381
	3041 (new)	Monitored	—	Projected	579
				Monitored set 1	715
				Monitored set 2	684
2	1975	Monitored	248-254	Projected	253
				Monitored set 1	274-280
				Monitored set 2	267-276
	348 (new)	Monitored	—	Projected	852
				Monitored set 1	1414-1458
				Monitored set 2	1224-1290
3	387	Monitored	860-869	Projected	614
				Monitored set 1	893-897
				Monitored set 2	514-520
	362 (new)	Monitored	—	Projected	285
				Monitored set 1	524-533
				Monitored set 2	402-433
	3754 (new)	Monitored	—	Projected	711
				Monitored set 1	770-772
				Monitored set 2	851-870
4	387	Monitored	860	Projected	614
				Monitored set 1	884
				Monitored set 2	515
	1975	Monitored	239	Projected	253
				Monitored set 1	285
				Monitored set 2	267
	1466	Monitored	121	Projected	130
				Monitored set 1	150
				Monitored set 2	142
	362 (new)	Monitored	—	Projected	285
				Monitored set 1	493
				Monitored set 2	403
	3754 (new)	Monitored	—	Projected	711
				Monitored set 1	748
				Monitored set 2	853

Cross Section	Circuit	Pre-construction case[+]	Current or current range (amperes)	Post-construction case[++]	Current or current range (amperes)
5	387	Monitored	863	Projected	614
				Monitored set 1	885
				Monitored set 2	412
	3827 (new)	Monitored	—	Projected	425
				Monitored set 1	869
				Monitored set 2	327
6	1630/1655	Monitored	39-112	Projected	35
				Monitored set 1	15-96
				Monitored set 2	17-46
	3827 (new)	Monitored	—	Projected	425
				Monitored set 1	874-876
				Monitored set 2	336-340
7A/7B	1640	Monitored	30-35	Projected	40
				Monitored set 1	117-120
				Monitored set 2	81-85
	1208	Monitored	243-247	Projected	171
				Monitored set 1	178-186
				Monitored set 2	178-184
	3827 (new)	Monitored	—	Projected	425
				Monitored set 1	808-884
				Monitored set 2	426-430
8/8B	1610	Monitored	112-245	Projected	90
				Monitored set 1	19-58
				Monitored set 2	45-55
	1640	Monitored	24-169	Projected	40
				Monitored set 1	112-133
				Monitored set 2	48-94
	1690	Monitored	0**	Projected	line no longer in service in this ROW
				Monitored set 1	
				Monitored set 2	
	3827 (new)	Monitored	—	Projected	425
				Monitored set 1	771-940
				Monitored set 2	375-540

* The 345-kV 362 circuit was out of service when pre-construction measurements were made on January 11, 2007

** Circuit 1690 was removed from service on November 3, 2006, before pre-construction measurements on November 9, 2006.

[+] Projected values were calculated in 2004 using the 15-GW Case. Pre-construction currents were recorded in 2006 and 2007.

[++] Projected values were calculated in 2004 using the 15-GW Case. Post-construction currents were recorded in 2009.

Table 3. Comparison of 2007 projected circuit currents used in September 2004 Filing for Underground Cable Segments with circuit currents recorded during magnetic field measurements

Cross Section	Line	Post-construction case	Current or current range (amperes)
9E	3165 (new)	Projected	285
		Monitored set 1	519
		Monitored set 2	253-262
	3619 (new)	Projected	285
		Monitored set 1	516
		Monitored set 2	254-262
9W	3280 (new)	Projected	665
		Monitored set 1	527-544
		Monitored set 2	591-655
	3921 (new)	Projected	665
		Monitored set 1	531-550
		Monitored set 2	593-655

7.1.2 Duct-bank Configuration

For the underground cable route, as-built duct-bank configurations differ from conceptual designs initially presented by the Companies during the siting proceedings. The 345-kV XLPE duct-bank design submitted in the Application and depicted in Figure 1 below was a compact double-circuit design with 1-foot separation between phase ducts and one GCC. While preparing their D&M Plans, the Companies completed final engineering review and made modifications to the conceptual design of the duct-banks. Changes to the duct-bank design were required to meet the required impedances and ratings of the underground cable systems. The final duct-bank design was reviewed and approved by the Council during the D&M Plan approval process.

The typical as-built duct-bank configuration constructed in the UI portions of Segment 3 (in Stratford and Bridgeport) is depicted in Figure 2 below. This design differs from the conceptual design both in its vertical double-circuit arrangement, and the larger spacing (19.375 inches) between the two cable circuits. In addition, the UI duct-bank design does not contain any GCCs, the induced currents on which alter calculated magnetic field profiles above ground.

The typical as-built duct-bank configuration constructed by CL&P in Segment 4 between the Singer and Norwalk Substations is depicted in Figure 3, below. This design differs from the conceptual design in terms of the cable configuration, as illustrated by Figure 3. Additionally, because of differences in cable length, three cable sections in Segment 4 had to be single-point-bonded (rather than cross-bonded like the rest of the circuit), which required CL&P to install two GCCs in ducts abutting the phase ducts. Unlike shield wires

in overhead transmission lines, the induced currents on the GCCs can significantly affect magnetic fields above the underground cables.

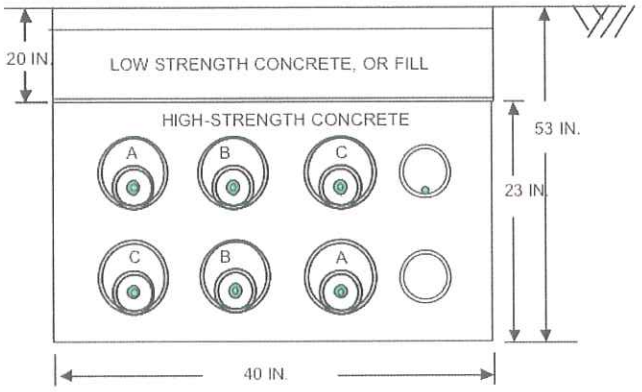

Figure 1. Horizontal double-circuit duct-bank for 345-kV XLPE transmission cables, proposed as an underground design in the Application

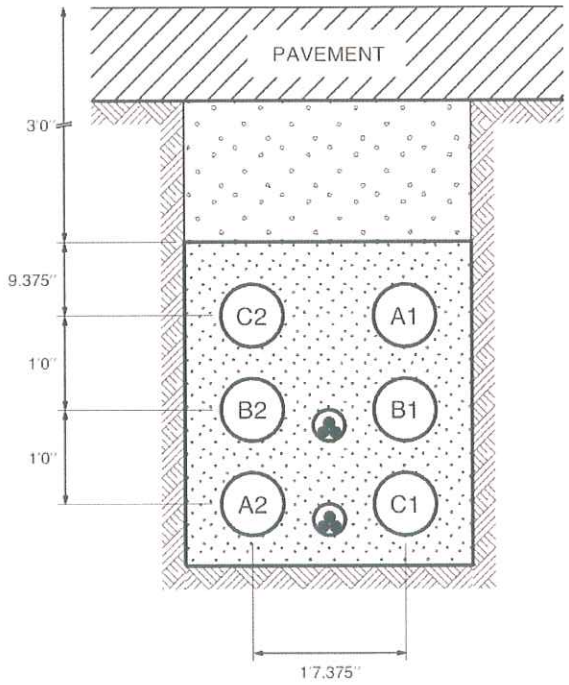

Figure 2. Typical vertical double-circuit design of the UI duct-bank in Segment 3.

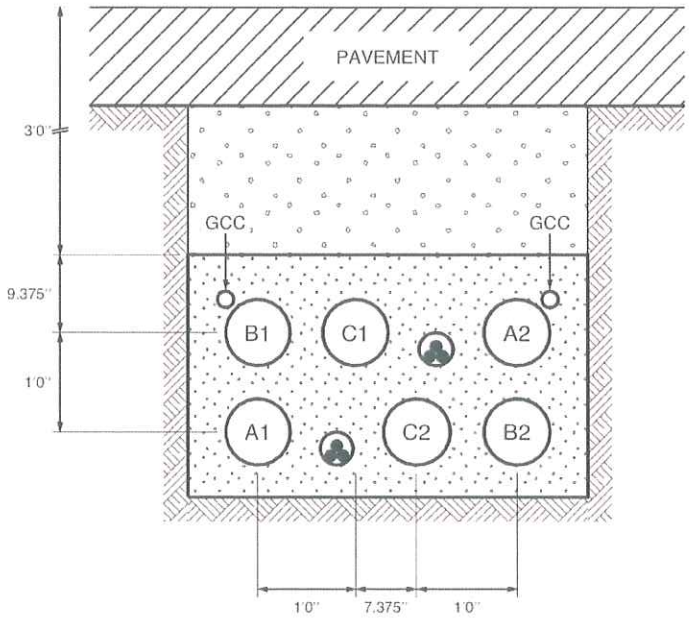

Figure 3. Typical horizontal double-circuit design of the CL&P duct-bank in Segment 4. GCCs in ducts adjoin the phase conductors in the last two cable lengths into the Norwalk Substation and the last cable length into the Singer Substation. GCCs are not present in other portions of the Segment 4 duct-bank.

7.2 Comparison of Calculated EMF Levels Provided during the Siting Proceedings and Measured EMF Levels

The projected magnetic fields for the overhead line configurations ultimately chosen by the Council were provided in the Companies' July 2004 filing. For the proposed route and proposed line configurations, the Companies calculated magnetic fields that ranged from 2.6 mG to 28.8 mG at the edges of the ROW. The calculated electric fields were between 0.09 kV/m and 1.48 kV/m at the ROW edges. The electric field values and the magnetic field values from the July 2004 Filing are compared with measured electric and magnetic fields along the overhead line route in Table 4 and Table 5, respectively.

In Table 5, measured magnetic fields are reported as the edge-of-ROW values at monitoring sites that are representative of all sites sharing the same ROW cross-section. Comparisons of measurements of magnetic field levels before and after Project construction are complicated by the fact that power flows over the lines within a reconfigured ROW can vary significantly at the times of pre-construction and post-construction readings. At some ROW edges in Table 5, such as the west/north ROW edge at Site 2, Bartholomew Road, the highest encountered magnetic field was elevated by the proximity of a 345-kV line with a loading higher than that projected in the July 2004 filing for the 15-GW case. Generally, the measured magnetic field levels at the ROW edge lie between 5.3 mG and 31.5 mG, and are reasonably consistent with the calculations in the July 2004 Filing.

For the underground line route, Power Delivery Consultants ("PDC") modeled the magnetic fields from the double-circuit duct-bank containing XLPE transmission cables depicted in Figure 1. Between the East Devon and Singer Substations, calculated magnetic fields directly over the duct-bank were approximately 12.0 mG for 3-foot depth of cover, while magnetic fields at a distance of 20 feet from the duct-bank centerline were 3.8 mG. Between the Singer and Norwalk Substations, calculated magnetic fields directly over the duct-bank were approximately 27.0 mG for 3-foot depth of cover, and 8.1 mG at a distance of 20 feet. Table 6 provides a comparison of these calculated magnetic field values with magnetic field measurements along the underground line route, corrected for actual circuit currents.. Measured magnetic fields are reported 20 feet from the duct-bank centerline at monitoring sites with representative configuration and burial depth. These sites are relatively free of magnetic field sources identified during pre-construction readings.

Table 4. Edge of right-of-way electric field values for pre-construction and post-construction line configurations on the overhead line portion of the Project

Cross Section	Representative Monitoring Site	Pre-construction Electric field (kV/m) (measured values)		Post-construction Case	Post-construction Electric Field (kV/m)	
		East/South ROW	West/North ROW		East/South ROW	West/North ROW
1	Bartholomew Road (Site 2)	<0.95[+]	<0.10[◊+]	Predicted	0.75	1.39
				Measured	<0.61[+]	<0.82[+]
2	Arbutus Street (Site 3)	0.24	<0.38[+]	Predicted	0.57	0.20
				Measured	0.15	<0.09[+]
3	Meriden PBA (Site 6)	<0.02[+]	<0.05	Predicted	0.07	0.24
				Measured	<0.60[+]	<0.14
4	Gravel Operation (Site 8)	<0.03[+]	0.35	Predicted	0.09	0.21
				Measured	<0.05[▽]	<0.90
6 West	South Cherry Street (Site 13)	0.03	0.26	Predicted	0.25	0.20
				Measured	0.48	0.23
8 Middle LEMF	JCC Parking Lot (Site 20)	0.56	0.08[×]	Predicted	0.34	0.62
				Measured	0.50	0.23
8 South LEMF	Eisenhower Park (Site 24)	0.65	0.04[×]	Predicted	0.44	0.62
				Measured	0.66	0.73

◊ The 345-kV 362 circuit on the north ROW edge was out of service when pre-construction measurements were made on January 11, 2007.

+ Electric field levels at this location were measured near the edge of the clearing, and reflect shielding by the presence of vegetation. Electric field levels at the ROW edge, outside of the clearing, are lower than the tabulated values.

× Circuit 1690 closest to the west/north ROW edge was removed from service on November 3, 2006, before pre-construction measurements on November 9, 2006.

▽ Edge-of-ROW values taken from calculated regression lines at the ROW edge that exceed measured values at locations within the ROW.

Table 5. Edge of right-of-way magnetic field values for pre-construction and post-construction line configurations on the overhead line portion of the Project

Predicted values calculated for the 15-GW Case were included in the July 2004 filing with the Council. See Appendix C for the loads corresponding to the measured magnetic field values at representative monitoring sites.

Cross Section	Representative Monitoring Site	Pre-construction Magnetic Field (mG) (measured values)		Post-construction Case	Post-construction Magnetic Field (mG)	
		East/South ROW	West/North ROW		East/South ROW	West/North ROW
1	Bartholomew Road (Site 2)	34.1	8.5	Predicted	6.2	28.8
				Measured set 1	14.7	31.3
				Measured set 2	16.1	31.3+
2	Durham Landfill (Site 5)	5.2	13.6	Predicted	17.6	12.2
				Measured set 1	24.1	17.9
				Measured set 2	22.5	16.7
3	Meriden PBA (Site 6)	11.6	8.0	Predicted	>5.9	<12.9
				Measured set 1	14.1	16.3
				Measured set 2	13.7	16.3
4	Gravel Operation (Site 8)	5.5	8.9	Predicted	5.3	11.5
				Measured set 1	6.1+	8.5
				Measured set 2	6.3+	16.5
5	Tamarac Swamp Road (Site 10)	5.7	23.9	Predicted	4.2	21.2
				Measured set 1	16.7	24.6+
				Measured set 2	7.8	11.3+
6 East	Pond Hill Rd. (Site 12)	0.8	1.3	Predicted	4.5	9.4
				Measured set 1	8.3	18.1
				Measured set 2	6.2	7.0
7	Blue Hill Orchard (Site 14)	1.0	7.1	Predicted	11.9	10.2
				Measured set 1	14.8	10.9
				Measured set 2	11.7	7.6
7b	Old Farms Road	0.7	3.1	Predicted	6.2	17.9

Cross Section	Representative Monitoring Site	Pre-construction Magnetic Field (mG) (measured values)		Post-construction Case	Post-construction Magnetic Field (mG)	
		East/South ROW	West/North ROW		East/South ROW	West/North ROW
	(Site 15)			Measured set 1	<12.0	9.5
				Measured set 2	<8.7	13.4
				Predicted	1.8	6.0
8a	Old Lane Road (Site 16)	4.6	1.5	Measured set 1	28.3[V]	20.5
				Measured set 2	7.5[V]	8.1
				Predicted	8.7	15.7
8 North	Brooksvale Avenue (Site 17)	4.6	1.5	Measured set 1	11.6	18.5
				Measured set 2	5.3	8.0
				Predicted	8.7	15.7
8 Middle	Dillon Road (Site 19)	4.6	1.5	Measured set 1	16.7°	31.5°
				Measured set 2	12.1°	16.3°
				Predicted	2.7	5.8
8 Middle LEMF	JCC Parking Lot (Site 20)	4.6	1.5	Measured set 1	6.3	<15.3
				Measured set 2	2.5	<6.7
				Predicted	11.2	16.0
8 South	Dogburn Road (Site 22)	4.6	1.5	Measured set 1	15.3	26.1
				Measured set 2	7.9	15.7
				Predicted	1.7	5.9
8 South LEMF	Eisenhower Park (Site 24)	4.6	1.5	Measured set 1	3.0	5.9
				Measured set 2	2.8	3.1

+ Edge-of-ROW values taken from calculated regression lines at the ROW edge that exceed measured values at locations within the ROW.

[V] The underground 1640 line segment crosses the east ROW edge obliquely at this measurement location, elevating fields on the east ROW edge, before assuming its position within the ROW.

° Uneven terrain at this measurement location.

Table 6. Magnetic field values for pre-construction conditions and post-construction line configurations on the underground cable portion of the Project

Predicted values calculated for the 15-GW Case based on the September 2004 filing with the Council. See Appendix C for the loads corresponding to the measured magnetic field values at representative monitoring sites

Cross Section	Representative Monitoring Site	Pre-construction Magnetic Field (mG) (measured values 20 feet from duct-bank centerline)		Post-construction Case	Post-construction Magnetic Field (mG) (measured values 20 feet from duct-bank centerline)	
		East/South	West/North		East/South	West/North
9 East	Noble Ave. and Barnum Ave. (Site 33)	1.0	0.9	Predicted	3.8	3.7
				Measured set 1	5.0	5.3
				Measured set 2	5.5	5.4
9 West	Melrose Ave. (Site 35a)	2.8	1.8	Predicted	8.1	8.1
				Measured set 1	9.5	8.1
				Measured set 2	8.1	6.5

7.3 Comparison of Calculated Magnetic Field Levels Using Actual Line Loading Data ("True-Ups") and Measured Magnetic Field Levels

To confirm the accuracy of modeling methods, the EMF Monitoring Plan calls for a comparison of measured magnetic field values with calculated values at particular monitoring sites. Calculated or "true-up" comparisons in this section account for transmission-line conductor heights at the time the measurement is made, and model magnetic fields using synchronously recorded line currents. "True-up" comparisons for three representative overhead line monitoring sites and one underground line measurement location are presented below:

- Monitoring Site 2: Bartholomew Road, Middletown
- Monitoring Site 17: Brooksvale Avenue, Cheshire
- Monitoring Site 23: Orange Center Road, Orange
- Monitoring Site CSC-3: Lincoln Street, Westport

7.3.1 Monitoring Site 2: Bartholomew Road, Middletown

Figure 4 depicts calculated and measured magnetic field levels at Site 2, Bartholomew Road, before and after construction of the new 345-kV line (circuit 3041). The cross-section in Figure 4 depicts the ROW transect from the vantage point of an observer standing in the ROW looking west, toward Chestnut Junction and away from the Scovill Rock Switching Station. The pre-existing 362 circuit segment on this ROW, which was supported on the line of horizontal H-frame structures closest to the north ROW edge, was relocated to new compact delta structures closest to the south ROW edge, where the ROW was expanded by 60 feet. After construction, the existing H-frame structures closest to the north ROW edge support the new 3041 circuit.

The 345-kV 362 circuit near the north ROW edge was out of service when pre-construction measurements were made on January 11, 2007. The sole remaining source on the ROW was the 387 circuit, and the "true-up" magnetic field profile for this source is superimposed in green over the measured magnetic field in Figure 4. The mean deviation between the calculated and measured profiles is 4.0%, with a maximum edge-of-ROW deviation of 6.5%. Differences between the measured and calculated profiles can be attributed to uncertainty in the monitored current and measured magnetic field, as well as simplifications present in the modeling (namely the assumption of level terrain, steady-state currents, and longitudinally uniform geometry).

After construction, all three transmission lines (the 362, 387, and 3041 circuits) were in service. At the west/north ROW edge (the right side of Figure 4), the highest encountered magnetic field was elevated by the proximity of the 362 circuit, which had a loading higher than that projected in the July 2004 filing for the 15-GW Case (see Table

2). The "true-up" magnetic field profile accurately accounts for the higher currents, and deviates from measured values by a maximum of 5.3% at the ROW edges.

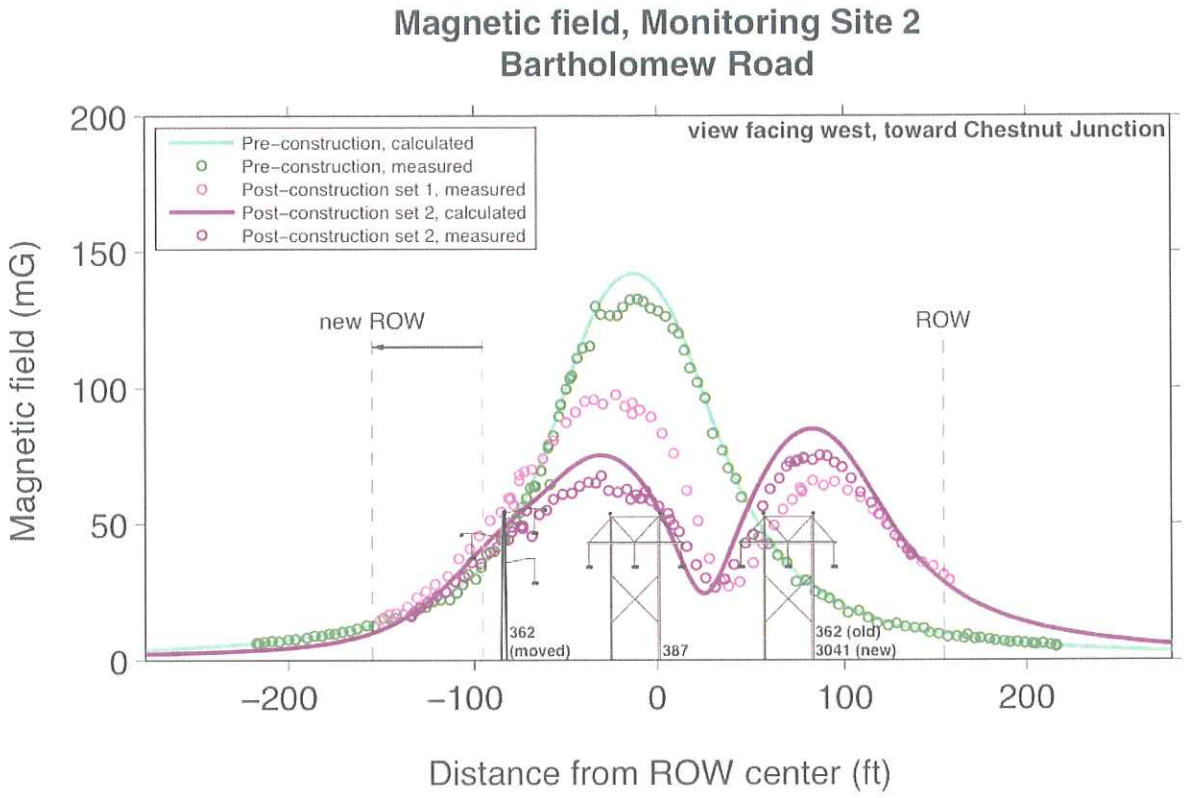

Figure 4. Comparison of calculated and measured magnetic field levels at Site 2, Bartholomew Road, Middletown. The 345-kV 362 circuit on the north ROW edge was out of service when pre-construction measurements were made on January 11, 2007.

7.3.2 Monitoring Site 17: Brooksvale Avenue, Hamden

Figure 5 depicts calculated and measured magnetic field levels at Site 17, between Brooksvale Avenue and Whitney Avenue, Hamden, before and after construction of the new 345-kV line (circuit 3827). The cross-section in Figure 5 depicts the ROW transect looking south, toward Glen Lake Junction and the East Devon Substation. The existing 1690 circuit was removed, and the remaining two 115-kV lines (circuits 1610 and 1640) were rebuilt on double-circuit structures. The new 345-kV line (circuit 3827) was constructed on compact delta structures near the center of the ROW.

The 115-kV 1690 circuit on the east ROW edge was out of service when pre-construction measurements were made on November 10, 2006. The "true-up" magnetic field profile for the two remaining 115-kV circuits is superimposed in green over the measured magnetic field in Figure 5. Even with the sloping terrain

that was encountered at this monitoring site, the maximum edge-of-ROW deviation is 0.8 mG.

After construction, all three transmission lines (the new 3827 circuit and the existing 1610 and 1640 circuits) were in service. During the first set of post-construction measurements on April 13, 2009 – when measured magnetic field levels were highest – the mean deviation between the calculated and measured profiles is 4.9%, with a maximum edge-of-ROW deviation of 6.1%.

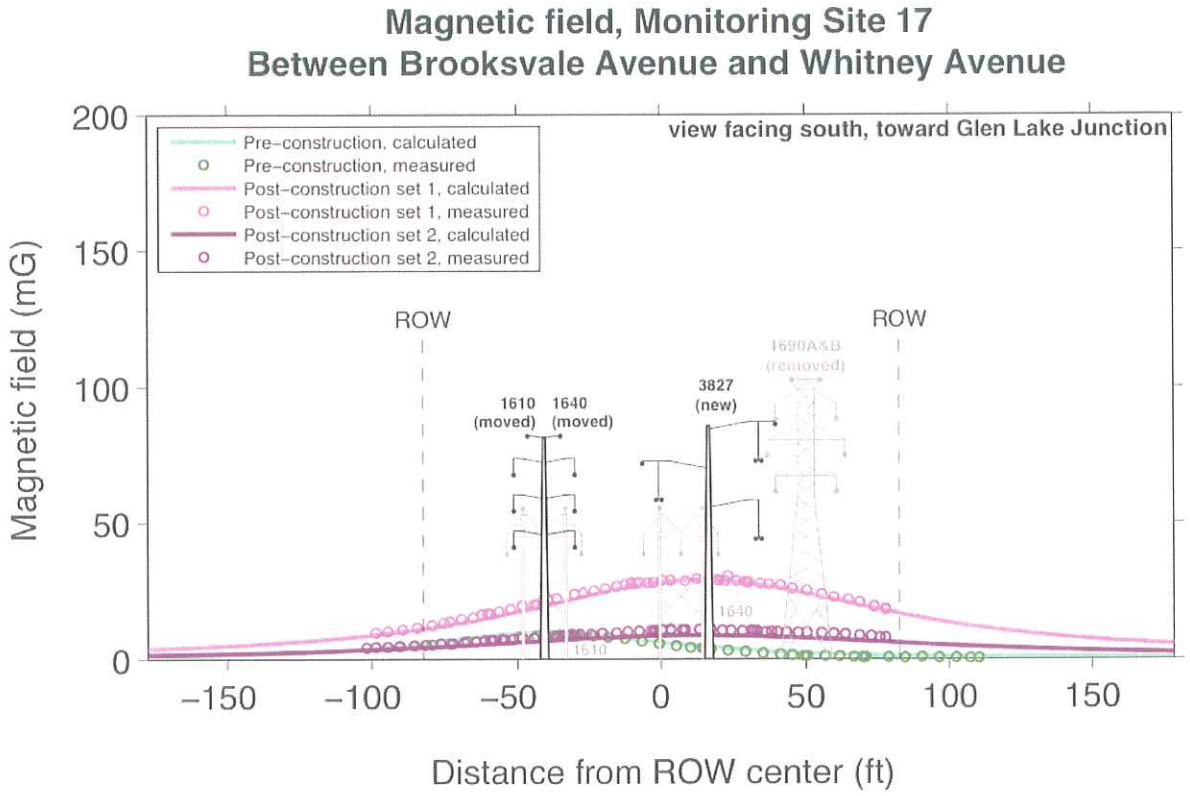

Figure 5. Comparison of calculated and measured magnetic field levels at Site 17, Brooksvale Avenue, Hamden.

7.3.3 Monitoring Site 23: Orange Center Road, Orange

Figure 6 depicts calculated and measured magnetic field levels at Site 23, near the High Plains Community Center on Orange Center Road, Orange, before and after construction of the new 345-kV line (circuit 3827). The cross-section in Figure 6 depicts the ROW transect looking south, toward Glen Lake Junction and the East Devon Substation. As in other areas on Segment 2B, the Council directed the Companies to adopt a modified design for cross section 8 in the vicinity of the High Plains Community Center to reduce magnetic fields. The existing 115-kV lines were rebuilt as described above for Monitoring Site 17, but the new 345-kV line (circuit

3827) was constructed in a split-phase line design near the center of the ROW to reduce EMF levels.

The 115-kV 1690 circuit on the east ROW edge was out of service when pre-construction measurements were made on November 9, 2006. The "true-up" magnetic field profile for the two remaining 115-kV circuits is superimposed in green over the measured magnetic field in Figure 6. The maximum edge-of-ROW magnetic field level was 7.2 mG, 1.5 mG lower than the calculated value.

After construction, all three transmission lines (the new 3827 circuit and the existing 1610 and 1640 circuits) were in service. During the first set of post-construction measurements on April 14, 2009 – when measured magnetic field levels were highest – the maximum edge-of-ROW magnetic field level was 7.0 mG, 1.2 mG lower than the calculated value.

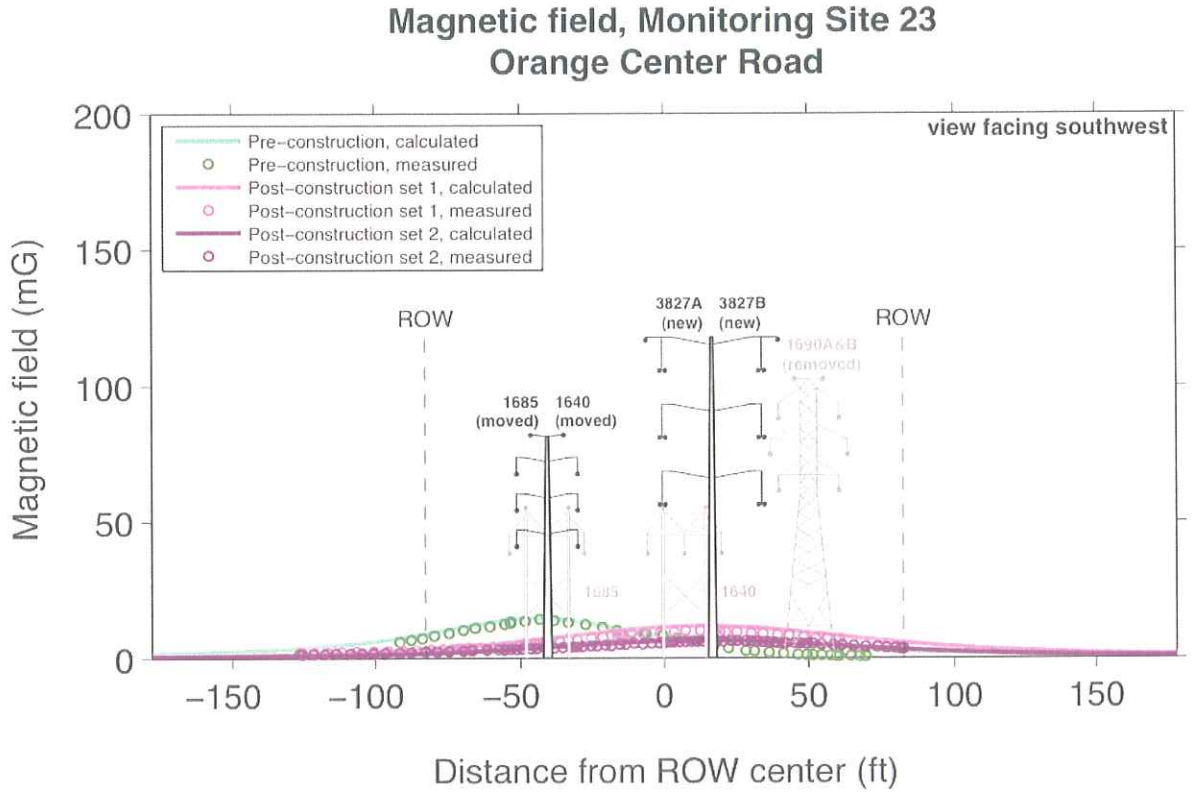

Figure 6. Comparison of calculated and measured magnetic field levels at Site 23, Orange Center Road, Orange, near the High Plains Community Center.

7.3.4 Monitoring Site CSC-3: Lincoln Street, Westport

Figure 7 depicts magnetic field levels at Site CSC-3, Lincoln Street, Westport, before and after the installation of two new 345-kV cable circuits in ducts buried to a depth of 5 feet below the pavement in the middle of Lincoln Street. The cables at this monitoring site are constructed with the horizontal configuration depicted in Figure 3, with cross-bonded cable sheaths and no GCCs. The cross-section in Figure 7 depicts the ROW transect looking west, toward Norwalk Substation. Before construction, there were no modeled magnetic field sources, and the maximum measured magnetic field was 1.0 mG in this area.

After construction, the measured profiles are 23% higher than the calculated "true up" profiles over the duct-bank centerline. While the magnetic field sources identified during pre-construction readings on February 18, 2008 account for some of this difference, the majority of the difference can be attributed to simplifications present in the modeling. The magnetic field calculation for cross-bonded cable segments assumes that minor sections of each cross-bonding triad are of approximately equal length which, in turn, means that induced sheath currents are negligible. In practice, induced sheath currents are not zero since the lengths of minor sections are constrained by the placement of splice vaults. Induced sheath currents, which were not included in the calculations for Figure 7, alter the magnetic field encountered over the roadway. In addition, variability in the in-field burial depth can increase or decrease the measured magnetic fields in the vicinity of a particular duct-bank transect, which is assumed to have a constant burial depth for purposes of calculation.

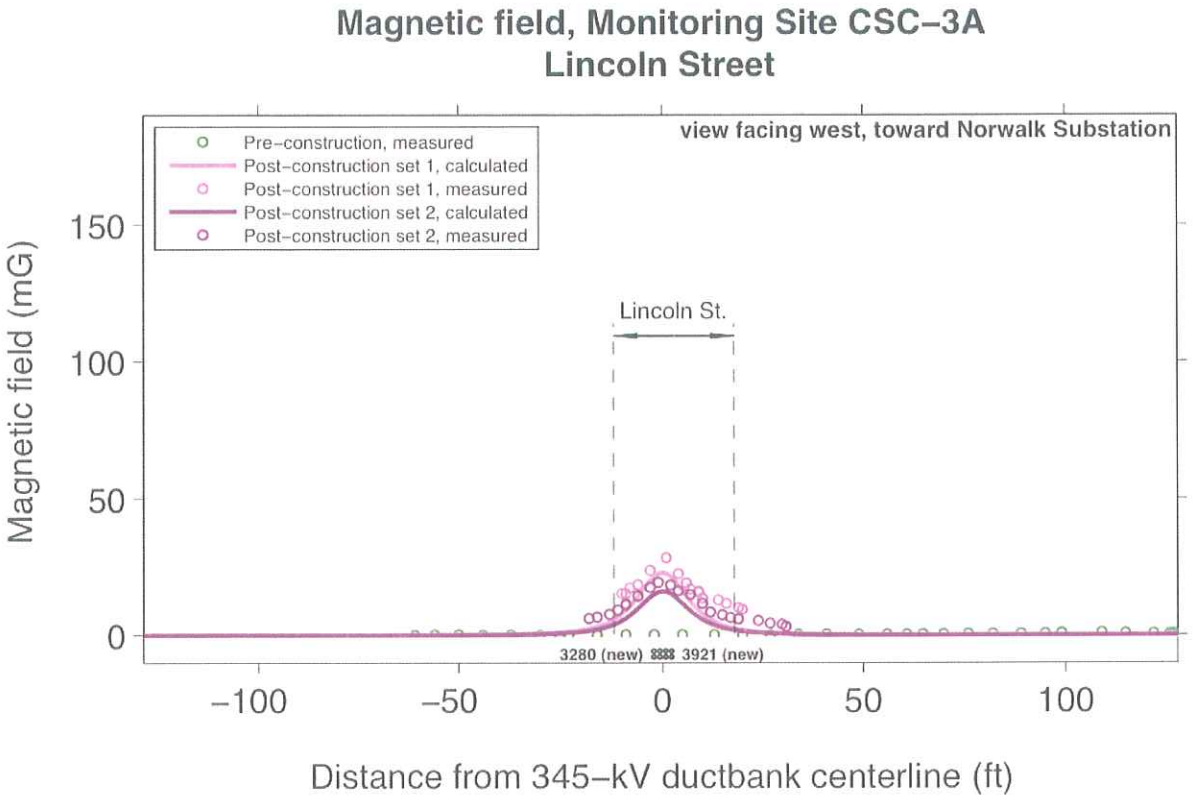

Figure 7. Comparison of calculated and measured magnetic field levels at Site CSC-2, Lincoln Street, Westport.