COMMONWEALTH OF MASSACHUSETTS
ENERGY FACILITIES SITING BOARD

NSTAR Electric Company d/b/a Eversource Energy and New England Power Company d/b/a National Grid, EFSB 15-04/D.P.U. 15-140/15-141	EFSB15-04/D.P.U. 15-140/15-141

PRE-FILED TESTIMONY OF DONALD HAES, Ph.D., CHP

Q. Please state your name, position and business address.

A. My name is Donald L. Haes. I am a Radiation Safety Officer for BAE Systems, Inc. and I also work as a Certified Health Physicist with a specialty in ionizing and nonionizing radiation. My business address is PO Box 198, Hampstead, NH 03841.

Q. On whose behalf are you testifying?

A. I am testifying on behalf of intervenor towns of Winchester and Stoneham ("Winchester and Stoneham"), MA, which have retained me as an expert with respect to electromagnetic fields and transmission and distribution power lines.

Q. Please summarize your professional and educational background.

A. I received my bachelor's degree in Health Physics from University of Massachusetts at Lowell in 1987. I received a master's degree in Radiological Sciences and Protection from University of Massachusetts at Lowell in 1988, and I was awarded my Ph.D. in Radiation Protection from Hamilton University in 2000.

I began my formal training for my career in the field of radiation safety in the United States Navy Nuclear Power Program in the mid-1970s, achieving qualifications as a mechanical operator / engineering laboratory technician (MO/ELT) and serving on board a fast attack nuclear submarine. Upon completion of active duty in 1981, I began working with and supervising the manufacturing of radio-isotopes at DuPont/NEN Products, routinely with vast quantities. Working second and third shifts afforded me the opportunity to continue my education in radiation safety and I completed undergraduate and graduate programs in radiological sciences and protection at the University of Lowell, Massachusetts. In 1988, I accepted a position at MIT as an assistant Radiation Safety Officer (RSO). While at MIT, I gained knowledge in non-ionizing radiation and joined the IEEE committees for RF safety, known today as the International Committee on Electromagnetic Safety (ICES), and have served as secretary on several subcommittees. In addition to RF safety, I became responsible for the safe use of RF/UV/IR and lasers by MIT students and faculty and joined the Laser Institute of America (LIA). While working at MIT, I also completed a graduate program in Radiation Safety earning a Ph.D. in 2000. I left full-time employment at MIT in 2001 and worked as an independent consultant specializing in non-ionizing radiation. I achieved certification by the ABHP in 1994. I am also an HPS Journal peer-reviewer for non-ionizing radiation papers, and have served 10 years on the Part 2 panel of examiners.

I achieved certification by the Board of Laser Safety in 2008, and accepted a position of Commissioner in 2012. I also serve on several subcommittees of the laser safety standards-setting organization Z136 including SC-1, SC-6, and SC-8. I have been accepted as a voting member on the Committee On Man And Radiation (COMAR).

In 2005 I accepted the position of Corporate RSO/LSO at BAE Systems with headquarters in New Hampshire. I serve in that capacity today, with radiation safety oversight of ~19,000 employees in 12 states and five countries. In the capacity of RSO, I oversee all radiation safety issues relating to BAE Systems. The facilities include state-of-the-art radiation laboratories and indoor and outdoor radiation ranges.

My particular experience in electromagnetic fields (EMF) includes work at MIT's High Voltage Research Laboratory, Lincoln Laboratory (Lexington and Westford/Groton, MA campuses, and the Kwajalein Atoll) and Draper Laboratory (Cambridge, MA). I have conducted investigations to discover sources of electromagnetic interference ("EMI") with sensitive equipment such as communications equipment, computers employing cathode ray tubes (CRTs), at the Francis Bitter Magnet Laboratory in Cambridge, MA. These investigations led to my publication of a research paper on the electromagnetic fields associated with Video Display Terminals (VDTs): (Haes, D.L., Fitzgerald, M.F.; VDT VLF Measurements: The Need for Protocols in Assessing VDT User "Dose", *Health Physics*, 68(4), 572-578, 1995). I have also investigated EMF and EMI from 60 Hz magnetic fields for numerous clients listed on my C.V. with respect to residential and industrial exposures. With the recent upsurge in usage of the electromagnetic spectrum, I have been asked to perform intermodulation studies for national providers of wireless services to ensure any primary electromagnetic signals and their generated harmonics are compatible; one notable example was ensuring that the installation of a full personal wireless services facility within the Comcast Center in Marshfield, MA did not interfere with the existing complicated wireless sound system.

A copy of my C.V. is attached as Exhibit A.

Q. Have you testified previously in any regulatory proceedings? If so, please list them.

A. I have testified in the following relevant proceedings:

1. Re: Julinska and Kniazev v. Vermont Transco, LLC and Vermont Elec. Power Co., Inc., No. 620-8-12 Rdcv (Vt. Super. Ct.);

2. Re: Burlington Broadcasters, Inc. d/b/a Charlotte Volunteer Rescue Services, Inc. and John Lane, No. 4C1004R-EB (Vt. Environmental Bd.);
3. Re: Burlington Broadcasters, Inc. d/b/a WIZN, Declaratory Ruling Request No. 322, (Vt. Environmental Bd.);
4. Re: NYNEX Mobile Limited Partnership 1 d/b/a Bell Atlantic NYNEX Mobile, Declaratory Ruling Request No. 323 (Vt. Environmental Bd.); and
5. Re: NSTAR Electric Company d/b/a Eversource Energy and New England Power Company d/b/a National Grid, EFSB14-04/D.P.U. 14-153/14-154.

In addition, I have also appeared before hundreds of siting boards and zoning boards in Massachusetts and several other states on issues, including EMF and EMI, relating to the installation of facilities and equipment for the telecommunications industry.

Q. What is your role with respect to Winchester and Stoneham's intervention in this proceeding?

A. Winchester and Stoneham retained me in response to their concerns that the proposed 345 kV underground transmission lines that Eversource seeks to install through Winchester and Stoneham would emit EMF that could affect the health and safety of Winchester and Stoneham's residents and visitors, as well as the functionality of sensitive electric equipment within residences and businesses along the route.

As part of my assessment, I reviewed the relevant submissions in this proceeding by Eversource and its EMF consultant, Gradient, concerning the project and its predicted EMF output. While my findings did not indicate an immediate concern with respect to human health and safety, I did observe that the Gradient report did NOT provide the real maximum magnetic field values that the residents of Winchester and Stoneham could be exposed to, as specified in their report on page 1: "…at peak loading, the maximum magnetic field values generated by the proposed underground line in an inverted-delta configuration will be 34 mG, and this will fall to 3.6 mG at a horizontal distance of ±20 feet away from the centerline of the conductors."

Q. How did the Gradient reports present the "maximum magnetic fields" that residents and visitors in Winchester and Stoneham could experience? And why aren't these the true values?

A. The Gradient reports calculate magnetic field levels "at a horizontal distance of ±20 feet away from the centerline of the conductors." However, after review of the plans for the physical location of the proposed 345 kV transmission lines, I observed the center of the conductors is not always planned to be in the center of the street. Therefore, a horizontal distance of ±10 feet away from the centerline of the conductors would be more appropriate. At this closer distance, the resulting magnetic fields would be much higher, up to four times higher. In fact, Eversource admits to the 10 foot value in response to EFSB-MF-10. In the original Gradient report, Eversource represented that would represent magnetic field values generated by the proposed underground line in an inverted-delta configuration of about 11-12 mG at a horizontal distance of ±10 feet away from the centerline of the conductors.

The original Gradient report presented calculated magnetic fields as outlined in "Section 3.4 EMF Modeling Results" (page 7) to produce the results in the graphs on page 8 (Figure 3.3) and page 9 (Figure 3.4). It appears from the shape of the curves that a straight line conductor was assumed. The magnetic field of an infinitely long straight wire can be obtained by applying Ampere's law, and for a circular path centered on the wire, the magnetic field is everywhere parallel to the path. Thus, the shape of the curve for predicted magnetic fields intensities over distance present the bell-shaped curves as shown. However, the Biot-Savart Law (which relates magnetic fields to the currents which are their sources) requires finding the magnetic field resulting from a current distribution involving the vector product, and is inherently different when the distance from the current to the field point is continuously changing. There are areas along the route (specifically the intersection of Cross and Washington Streets in Winchester-- is there a similar location in Stoneham you can reference?) where the proposed route would make a 90° bend. At locations within the bend, the resultant magnetic fields would be greater than the values predicted by Gradient.

The Gradient report provides resultant magnetic field values for a 345-kV, 3,500-kcmil, XPLE carrying a "peak load" of 206 Amps. However, in response information request TOS-MF-4, the actual "maximum" loading would be 1much higher. While the two graphs appear similar in shape and size, the scale of the actual peak fields is ten times higher. The actual value along the centerline of the road would be closer to 250 mG, not the 35 mG reported. While not readily comparable because of differences in scaling, at a horizontal distance of ±10 feet away from the centerline of the conductors the value appears to be closer to 80 mG, and not the 3.6 mG reported. At all locations, the resultant magnetic fields would be greater than the values predicted by Gradient during peak loading times. It is well-documented that unshielded sensitive electric equipment (medical/research diagnostic equipment, metal detectors, some office equipment, etc.) may be susceptible to EMF interference at levels as low as 2 mG. Certainly, at times of peak loads, even a temporary spike at 80 mG would likely cause interference in sensitive electronic equipment.

Another Gradient report (EFSB 15-04/D.P.U. 15-140/15-141 - TOW-PA-2) provides a comparison of predicted versus resultant magnetic field values, which included similar underground 345-kV lines in CT. Within that report, I read that the resulting magnetic fields based on their own measured values are not always "in very good agreement with each other". In one instance, the resultant values were found to be 23% HIGHER than predicted. In other instances, the magnetic fields values were higher due to a design changes post calculation submittal. The resultant magnetic fields predicted are only as accurate as the parameters used to perform them; any changes or variations from those used in the predictions will change the resultant field values. We can expect to find magnetic field values greater those values predicted by Gradient.

Q. What are the existing magnetic field levels like along the proposed routes in Winchester and Stoneham on a typical hot summer day?

A. I inspected the proposed route along Winchester and Stoneham, and chose 10 (ten) individual locations to obtain magnetic field measurements on a typical hot summer day. The measurements were made perpendicular to the route, at a distance of 1 meter above the ground for comparison with the calculated magnetic field results provided in Gradient's reports. The baseline measurements I obtained within Winchester and Stoneham, MA, along the proposed route and my analyses related thereto, are summarized in the report attached as Exhibits B and C.

Based on my own measurements and my review of EMF modelling conducted by Eversource's consulting firm Gradient, it is my opinion that the proposed 345 kV underground transmission lines will cause sensitive equipment in Winchester and Stoneham's to be exposed to EMF levels WELL above 2 mG. Consequently, it is my opinion that EMF from the proposed 345 kV underground transmission lines could pose a threat to the functionality of sensitive equipment in Winchester and Stoneham, and thus, their residents' and visitors' ability to rely on their equipment for daily operations.

Q. Were the documents attached hereto as <u>Exhibit B</u> and <u>Exhibit C</u> prepared by you or under your supervision and control?

A. Yes, they were.

Q. Are there ways to reduce the magnetic fields in Winchester and Stoneham assuming the project proceeds along the proposed route?

A. Yes, they are. Besides those already submitted to be employed by Eversource (e.g. phase cancellation, buried lines, conductor spacing minimized for field conditions) it is well documented that the magnetic fields produced by "pipe-type cable" (HPFF-PTC) are much lower than the purposed cross-linked polyethylene (commonly abbreviated XLPE).

Q. Does this complete your testimony?

A. Yes.

SIGNED UNDER THE PAINS AND PENALTIES OF PERJURY THIS 22ND DAY OF AUGUST 2016.

Donald L. Haes, Ph.D., CHP

CURRICULUM VITAE

Donald L. Haes, Jr., Ph.D., CHP †, CLSO ‡

Radiation Safety Specialist
PO Box 368, Hudson, NH 03051
Voice: 603-303-9959
Email: donald_haes_chp@myfairpoint.net

† Board Certified by the American Board of Health Physics 1994; renewed 1998, 2002, 2006, 2010, 2014 (exp 12/31/2018).
‡ Board Certified by the Board of Laser Safety 2008; renewed 2011, 2014 (exp 12/31/2017).

Academic Training -

- Ph.D. in Radiation Protection,04/2000; MS in Radiological Sciences and Protection, 05/1988; BS in Health Physics, 06/1987.
- Naval Nuclear Prototype Training Unit, Knolls Atomic Power Laboratory, Windsor, Connecticut, 01-9/1977. Qualification - Nuclear Reactor Plant Mechanical Operator and Engineering Laboratory Technician (MO/ELT).
- Naval Nuclear Power School, 06/1976.

Continuing Education –

- *Profession Enrichment Program [PEP],* American Academy of Health Physics:

07/10-14/15, Indy, IN	07/25-29/06, Providence, RI	06/12-13/01, Cleveland, OH
07/13-17/14, Balt, MD	07/10-13/05, Spokane, WA	06/26-29/00, Denver, CO
07/7-11/13, Mad, WI (chair)	02/12-14/05, N Orleans, LA	06/27-29/99, Phil, PA
06/26-30/11, P Beach, FL	07/11-15/04, Wash, DC	07/12-16/98, Mpls, MN
06/27-1 07//10, SL City, UT	05-07/04, Augusta, GA	06/29-07-02/97, S Ant, TX
07/12-16/09, Mpls, MN	07/20-24/03, San Diego, CA	07/22-27/95, Boston, MA
07/13-17/08, Pittsburgh, PA	01/26-27/03, San Ant, TX	07/23-28/ 94; San Fran, CA
07/08-12/07, Portland, OR	02/15-18/02, Orlando, FL	07/25-30/93; Atlanta, GA

- *Annual DOE LSO Workshops; 2012-present;* Lecturer and attendee.
- *Laser Safety Officer With Hazard Analysis;* LIA Inc.; November 3-7 2008; Boston, MA
- *Laser Safety Officer Training;* Laser-Professionals Inc.*;* November 1-4, 2006; Austin, TX.
- *Prepare for and Pass the ABHP Exam*; TMS, Inc.; March 7-11, 1994; New Orleans, LA.
- *EPRI Power System Magnetic Field Measurement Workshop*; Conducted by G.E. Company at the High Voltage Transmission Research Center, April 13-16, 1992; Lenox, MA
- *Advanced Laser Safety*; Engineering Technology Institute, March 2-6, 1992; Waco, TX.
- *Laser Safety*; Engineering Technology Institute, June 10-1 4, 1991; Woburn, MA.
- *Non-ionizing Radiations: Health Physics & Radiation Protection*; MIT, July 23-27 1990; Cambridge, MA*;* Lecturer and attendee.
- *Assessing Non-Ionizing Radiation Hazards*; 1990 Health Physics Society Summer School, June 17-22, 1990; Fullerton, CA.
- *Certification Review for HPs*; Skrable Enterprises, Inc; March 19-24, 1989; Nashua, NH.
- *Hazardous RF Electromagnetic Radiation: Evaluation, Control, Effects, and Standards*; George Washington University, November 2-4, 1988; Washington, DC.

Employment History -

- Consulting Health Physicist; Ionizing/Nonionizing Radiation, 1988 - present.
  - **See Attached list of clients.**
- Radiation Safety Officer; Ionizing/Nonionizing Radiation - BAE SYSTEMS, Inc., 2005 - present.
- Radiation Safety Officer; Ionizing/Nonionizing Radiation - MIT, 1988 – 2005 (retired).
- Radiopharmaceutical Production Supervisor - DuPont/NEN, 1981 - 1988.
- United States Navy; Nuclear Power Qualifications, 1975 - 1981.

Professional Societies -

- Health Physics Society [HPS].
  - American Academy of Health Physics [AAHP]
    - **Part II Panel of Examiners**, 2001-2006; 2010-2015.
  - National Chapter: HPS Journal peer reviewer, non-ionizing radiation.
  - New England Chapter [NECHPS].
- Institute of Electrical and Electronics Engineers [IEEE];
  - Standards Association [SA] voting member.
  - International Committee on Electromagnetic Safety [ICES] (ANSI C95 series).
    - Technical Committee 95 [TC95].
    - Subcommittee SC-2 **{Secretary}**: Terminology and Units of Measurement.
    - SC-3/4: Safety Levels With Respect to Human Exposure, 0-3 300 GHz.
- Laser Institute of America [LIA].
  - Board of Laser Safety [BLS]; **Board of Commissioners**; 2011-present.
  - American National Standards Institute Accredited Standards Committee (ASC Z136).
    - SSC-1: Safe Use of Lasers.
    - SSC-6: Safe Use of Lasers Outdoors.
    - SSC-8 Safe Use of Lasers in Research, Development & Testing.
    - TSC5 **{Vice Chair}**: Technical Scientific Committee on *Non-Beam Hazards*
- Committee on Man and Radiation [COMAR].
  - Contributing member; 2014-present.

Pertinent Publications -

- **Haes, D.L.**; *Subjugating Technical Imperfections in the Composition of Wireless Cellular Telephone Radio-frequency [RF] Environmental Assessments.* Dissertation for Ph.D.; 2000.
- **Haes, D.L.**, McCunney, R. (ed); *Medical Center Occupational Health & Safety*. Chap 14 Nonionizing Radiation Including Lasers, pp. 219-230. Lippincott Williams & Wilkins, Philadelphia, 1999.
- **Haes, D.L.**, Galanek, M, DiBerardinis, L. (ed); *Handbook of Occupational Safety and Health*. Chap 24 Radiation: Nonionizing & Ionizing Sources, 987-1016. John Wiley & Sons, Inc., 1999.
- **Haes, D.L.**, Fitzgerald, M.F.; VDT VLF Measurements: The Need for Protocols in Assessing VDT User "Dose". *Health Physics*, 68(4), 572-578, 1995.
- Ducatman, A., **Haes, D.L.**.; *Textbook of Clinical Occupational and Environmental Medicine*. Chap 23 Nonionizing Radiation, 646-657. W.B. Saunders Company, 1993.
- **Haes, D.L.**; ELF Magnetic Field Measurements: Units of bedlam. *Health Physics*, 63(5), 591, 1992.
- **Haes, D.L.**; VDT _Radiation_ Protection Products - Protection or Pacification?. *Health Physics Newsletter*, Vol XIX, No 12, 19-21, December 1991.
- **Haes, D.L.**; Are VDTs Safe?. *Information Display*, Vol 7, No 6, 17-27, June 1991.
- Heath Physics Society ***Ask the Expert***: Contributing expert, non-ionizing radiation.

Standards Setting Organizations Involvement: Cited as Author and/or Reviewer -

- **ANSI® Z136.1 – 2014 (Revision of ANSI Z136.1-2007)**: American National Standard for Safe Use of Lasers
- **ANSI® Z136.2–2012**: American National Standard for Safe Use of Optical Fiber Communication Systems Utilizing Laser Diode and LED Sources
- **ANSI® Z136.3–2012**: American National Standard for Safe Use of Lasers in Health Care
- **ANSI® Z136.6 – 2005**: American National Standard for Safe Use of Lasers Outdoors
- **ANSI® Z136.8–2012**: American National Standard for Safe Use of Lasers in Research, Development, or Testing
- **ANSI® Z136.9 – 2013**: American National Standard for Safe Use of Lasers in manufacturing Environments
- **IEEE Std C95.1™-2005 (Revision of IEEE Std C95.1-1991)**: IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz
- **IEEE PC95.1a™-2010**: Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz—Amendment 1: Specifies Ceiling Limits for Induced and Contact Current, Clarifies Distinctions between Localized Exposure and Spatial Peak Power Density
- **IEEE PC95.1-2345™-2013**: Standard for Military Workplaces - Force Health Protection Regarding Personnel Exposure to Electric, Magnetic and Electromagnetic Fields, 0 Hz to 300 GHz
- **IEEE Std C95.2™-1999 (Revision of IEEE Std C95.2-1982)**: IEEE Standard for Radio-Frequency Energy and Current-Flow Symbols
- **IEEE Std C95.4™-2002**: IEEE Recommended Practice for Determining Safe Distances from Radio Frequency Transmitting Antennas When Using Electric Blasting Caps During Explosive Operations
- **IEEE Std C95.6™-2002**: IEEE Standard for Safety Levels with Respect to Human Exposure to
- Electromagnetic Fields, 0–3 kHz
- **IEEE Std C95.7™-2005**: IEEE Recommended Practice for Radio Frequency Safety Programs, 3 kHz to 300 GHz

Below is a listing of Clients by category:

Academia / Research
Center for Blood Research
Boston College
Boston University
Harvard University
MIT
New England College of Optometry
Tufts University
University of Connecticut
University of Massachusetts
University of Texas
Woods Hole Oceanographic Institute

Bio-Tech
Alpha Gene
BioGen
Cell Signaling Technology
CytoMed
Enzytech
Ergo Sciences
Genetics Institute
Genzyme
NeoGenesis
Osteo Arthritis Sciences
Peptimed
Peptimune
Procept
ProScript
Weyth

Government Organizations & Services
City of Peabody, MA DPH
City of Quincy, MA DPH
City of Watertown, MA DPH
Malden, MA Fire Department
Massachusetts State Police
Massachusetts Radiation Control Program
NASA
Swampscott, MA Police & Fire Departments
USN
Wellesley Municipal Light Plant
Worcester Housing Authority

City/Town Permitting Boards
Candia, NH
Duxbury, MA
Edgartown, MA
Freeport, ME
Foxborough, MA
Lancaster, MA
Lincoln, MA
Maynard, MA
North Andover, MA
Needham, MA
Newington, CT
Reading, MA
Tewksbury, MA

Consulting/Law
Amec Foster Wheeler
Anderson & Kreiger
Arthur D. Little
Atlantic Western
Bailey Associates
D.L. Haes, Sr.
DRM PLC
Duval & Klasnick LLC
Environmental Heath & Engineering
Environmental Training
F.X. Massé Associates
Gehring Associates
Hunter Inc.
J. Lee Consulting
Kilpatrick Townsend & Stockton LLP
Network Building & Consulting, LLC
Network Development Consulting
S.B.A.
SeaCoast LLP
Tectonics
Terracord LLC
Wenstrup Consulting
Wireless Facilities

Health Care
Addison Gilbert Hospital
Dana Farber Cancer Institute
Fallon Clinic
Health Resources
MDPH Lead Lab
Merrimack Valley Hospital
New England Medical Center
Rhode Island Hospital
St. Vincent's Hospital
Tufts Medical Center
Worcester Medical Center

Industry
Agilent Technologies
American Holographic
American Saw
Analog Devices
Anthony's Building Company
ASML
BAE Systems

Becton-Dickenson
Channel Fish Co.
Compugraphics
Draper Laboratory
Display Components
DuPont/NEN Products
Federal-Mogul
Focal
Gillette
GTE Products
Harris
Hewlett Packard
Ingold
Kopin
Kraft General Foods
Landis + Gyr
Lockheed Martin
Loral Microwave
Lucent Technologies
Mettler-Toledo
MIT Lincoln Laboratory
MRM, Inc.
Muro Pharmaceutical
Narda
Northrop
Osram-Sylvania
Phasex
Philips Medical Systems
Polaroid
Portsmouth Naval Shipyard
Questek
Sanofi Pasteur
Senior Flexonics
Skyworks
Spire
SVG Lithography
The Money Store
Varian
Visidine
W.R. Grace
Wearguard
Wyman-Gordon

Wireless/Broadcast/Paging

5-State Tower
American Tower Co.
American Tower Corp.
AT&T Wireless
Bay Communications
Berkshire Wireless
Centerline Communications LLC
Cingular Wireless
Clear Wire, LLC
Cricket Communications
Crown Castle International
Direct Network Services
DRT Enterprises
FiberTower
General Dynamics Network Systems, Inc.
Independent Wireless One
Industrial Communications
Infinigy Engineering
Light Squared
Lighttower
MetroPCS
Mid-Hudson Communications
Nextel Communications
Northeast Paging/UCOM
Northeast Wireless Services, LLC
Northern Telecom
NY Cellular
OmniPoint Communications
Pyramid Network Services
RCC
SAI Communications
Sprint PCS
Telecorp
Telegent
Tower Resource Management
Ultranet
US Cellular
Varsity Wireless
Verizon Wireless
Vermont Public Radio
Vermont Public Television
Videolink TV
Voice Stream
WCVB-TV
WEBK-FM
WFLY-TV
WGNA-TV
WIZN-FM
WMHT-TV
WPYX-FM
WVPS-FM

Elaboration of Localities Where the Following Services Have Been Provided:
RF Environmental Assessments, RF Field Measurements, and/or Public Testimony

Colorado
Englewood
Littleton
Thornton

Connecticut
Avon
East Hartford
Guilford
Hartford
Middletown
Putum
Stamford
Westerly

Florida
Miami

Maine
Baldwin
Cornish
Fort Kent
Freeport
Orono
Poland
Standish
Tremont
Winthrop

Massachusetts
Abington
Acton
Amesbury
Amherst
Andover
Arlington
Ashland
Athol
Attleboro
Auburn
Avon
Barnstable
Barre
Bedford
Bellingham
Belmont
Billerica
Boston
Bourne
Boxborough
Boylston
Braintree
Bridgewater
Brimfield
Brockton
Brookline
Brookline Village
Burlington
Cambridge
Canton
Carver
Charlestown
Charlton
Chelmsford
Chelsea
Cheshire
Chester
Chestnut Hill
Cohasset
Concord
Cotuit
Cummington
Dalton
Danvers
Dartmouth
Dedham
Deer Island
Dighton
Dorchester
Douglas
Dover
Dracut
Dudley
Dunstable
Duxbury
East Bridgewater
East Fairhaven
Eastham
Easton
Edgartown
Everett
Exeter
Fairhaven
Fall River
Falmouth
Foxborough
Framingham
Franklin
Freetown
Georgetown
Gloucester
Grafton
Great Barrington
Greenfield
Groveland
Hamden
Hamilton
Hanover
Harvard
Haverhill
Hingham
Holbrook
Holden
Holliston
Hopkinton
Hudson
Huntington
Hyannis
Ipswich
Jamaicaway
Kingston
Lakeville
Lancaster
Lanesborough
Lawrence
Leominster
Lexington
Lincoln
Littleton
Lowell
Lunenburg
Lynn
Lynnfield
Malden
Manchester-by-the Sea
Mansfield
Marblehead
Marlborough
Marshfield
Marston Mills
Martha's Vineyard
Mattapan
Maynard

Moultonborough
Nashua
New Boston
Newbury
New Hampton
Newington
Newmarket
Northfield
North Hampton
Pelham
Pembroke
Portsmouth
Salem
Sandwich
Seabrook
Spofford
Troy
Wakefield
Warner
Weare
Webster
Winchester
Windham
Wolfeboro

New Jersey

Alpine

New York

Antwerp
Barneveld
Buffalo
Clifton Park
Conewango
Darien Center
Deposit
East Syracuse
Glencove
Goshen
Harpursville
Honeoye
Lake Placid
Lindley
Lockport
Macedon
Malone
Marbletown
Middleton
Olean
Oneida
Pavilion
Pearl River
Penfield
Philadelphia
Pittsford
Port Crane
Rochester
Rome
Rye Brook
Sand Lake
Smethport
Sodus
Spencerport
Syracuse
Troy
Tupper Lake
Vestal
Yonkers
Watertown
Webster
West Sand Lake
Wolcott

Pennsylvania

Caroline
Lansdale
Philadelphia

Rhode Island

Barrington
Block Island
Burrillville
Bristol
Charlestown
Chepachet
Coventry
Cranston
East Greenwich
Exeter
Foster
Glocester
Hopkinton
Jamestown
Johnston
Lincoln
Marieville
Middletown
North Providence
Pawtucket
Perryville
Portsmouth
Providence
Richmond
Riverside
Smithfield
Tiverton
Warwick
West Greenwich
West Warwick
Woonsocket

Vermont

Burlington
Charlotte
Killington
Stowe
West Windsor
Windsor

DONALD L. HAES, JR., PH.D., CHP
Radiation Safety Specialist
MA Radiation Control Program Health Physics Services Provider Registration #65-0017
PO Box 198, Hampstead, NH 03841 603-303-9959 Email: donald_haes_chp@myfairpoint.net

June 27, 2016

Re: Electromagnetic Field Measurements within Winchester, MA.

EXECUTIVE SUMMARY

An electromagnetic field (EMF) survey was performed at ten (10) individual locations along the proposed Woburn-to-Wakefield Junction Underground 345-kV running through sections of Winchester, MA. These readings were performed to verify that exposure limits and/or guidelines would not be exceeded post site work, and memorialized baseline conditions. The results of the surveys demonstrate that existing electromagnetic fields strengths were well below established limits and/or guidelines for public exposure, and below interference thresholds for implanted medical devices. Average estimated alternating current (AC) magnetic field levels within homes are approximately 1 mG (0.001 G) (0.1 μT), and measured values range from 9 to 20 mG (0.009 to 0.020 G) (0.9 to 2 μT) near appliances.

A total of 70 EMF measurements were made. The maximum measured value was **1.70 mG**. Based on my extensive experience in the field of non-ionizing radiation safety, and the results and examination of the measured ambient electromagnetic fields, I can render the following expert opinions:

- Existing measured electromagnetic field strengths are below the established limits and/or guidelines for public exposure.
- The measured values indicate existing EMF levels present a negligible impact on personnel health and safety.

PURPOSE

The following report presents the results of the physical measurements of electromagnetic field (colloquially known as "EMF") survey requested at ten (10) individual locations along the proposed Woburn-to-Wakefield Junction Underground 345-kV running through sections of Winchester, MA. The survey was were performed to verify that exposure limits and/or guidelines would not be exceeded post site work, and memorialized baseline conditions. These baseline values may be used later to superimpose on modeled values of EMF for the proposed transmission lines and electrical components to assess expected health based exposure limits, and the reliability of any implanted medical devices (IMDs) in members of the public.

PHYSICAL CONDITIONS

An electromagnetic field (EMF) survey was performed at ten (10) individual locations along the proposed Woburn-to-Wakefield Junction Underground 345-kV running through sections of Winchester, MA. During the survey, the following environmental conditions were noted: Sunny skies; Temperature 82-84°F (85-87°F "Real Feel™); Humidity 24%-26%; Winds 9-10 W; Visibility 10 miles; Barometric pressure 1009-1010 mbar.[1]

DISCUSSION OF UNITS

The nomenclature for expressing the ***intensity*** of magnetic fields varies with frequency. Below listed are customary units and symbols used to express magnetic field intensities:

Magnetic Field Strength: H => A/m or A^2/m^2
Magnetic Flux Density: B => Gauss (G) or Tesla (T) (10,000 G = 1 T)

To covert to units of field strength (A/m), divide by the permeability of free space (4π X 10^{-7} henry/meter); or simply multiply by 0.08 (80 A/m = 1000 mG).

EXPOSURE LIMITS AND GUIDELINES

Neither the Federal Government nor the Commonwealth of Massachusetts regulates the electric/magnetic field intensities associated with the transmission or distribution of electric power. However, electromagnetic field exposure limit values, often referred to as "Maximum Permissible Exposure" limits (MPEs), have been published by standard-setting agencies. Established electromagnetic field exposure limits that relate to the potential fields from common electricity, i.e. 60± Hz, are listed below:

- International Commission on Non-Ionizing Radiation Protection (ICNIRP) *Guidelines For Limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields (Up to 300 GHz).* [i, ii]
- ANSI/IEEE C95.6-2002; *Standard for Safety Levels With Respect to Human Exposure to Electromagnetic Fields, 0 to 3 kHz.* [iii]
- American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLV); Subfrequency (30 kHz and below) Magnetic Fields, Subfrequency (30 kHz and below) and Static Electric Fields, and Static Magnetic Fields. [iv]

[1] Source: Weather.com

SUMMARY: The Maximum Permissible Exposure (MPE) limit published by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines (1998; Tables 6 and 7) for 60-Hz magnetic fields for the instantaneous exposure of the general public is 0.833 G (83.3 μT), and the MPE for controlled environments where only employees work is 4.2 G (420 μT). For comparison, the magnetic field ranges from 500 to 700 mG (0.5 to 0.7 G; 50 to 70 μT) which are non-time-varying (or DC) at the surface of the earth. Average estimated alternating current (AC) magnetic field levels within homes are approximately 1 mG (0.001 G) (0.1 μT), and measured AC values range from 9 to 20 mG (0.009 to 0.020 G) (0.9 to 2 μT) near appliances. The intensity of the electric and/or magnetic field ("EMF") rapidly decreases with distance away from the source; therefore it makes sense then to find higher than background levels close to potential sources such as motors (hence the equipment and/or appliances that house them), wiring and breakers, and transformers. Sources [v] suggest typical interference levels for common types of sensitive equipment occur above 2 mG.

Table 1 list the established electromagnetic field exposure limit values. Note that "Public" limits have not been listed by the ACGIH as it relates to "worker" exposures only.

Table 1: Electromagnetic Field Exposure Limits from Modulated Magnetic Fields that Include 60 Hz

Limit Setting Agency	Frequency Range	Field Intensity Limit: Members of the Public	Field Intensity Limit: Workers
ICNIRP (Reference levels)*	0.025–0.82 kHz (25–820 Hz)	$5/f^{\dagger}$ mT (833 mG)	$25/f^{\dagger}$ mT (4167 mG)
ANSI/IEEE C95.6‡	20 – 759 Hz	0.904 mT (9,400 mG)	2.71 mT (27,100 mG)
ACGIH	≤ 10 MHz	*N/A*	80 A/m (1,000 mG)

Table Notes:
*: Reference levels of exposure are provided for comparison with measured values of physical quantities; compliance with all reference levels will ensure compliance with basic restrictions.
†: *f* as indicated in the frequency range column.
‡: For the head and torso

MEASUREMENT PROTOCOL

Electromagnetic field measurements were obtained on June 23, 2016, using currently accepted scientific procedures. [vi] The measuring equipment was within manufacturer's recommended calibration intervals (calibrated 4/8/15; due 12/3/16) and included the following:

- NARDA model 8532-60 *Precision ELF/VLF Gaussmeter*; S/N 2572. The *Precision ELF/VLF Gaussmeter* has a single-axis detector which can be selected to respond accurately to magnetic fields in the following frequency range: 57-63 Hz. The 57 - 63 Hz range allowed for data analysis of the 60± 3 Hz fields as the primary source. Note: 1 kHz = 1,000 cycles per second.

The electromagnetic field measurements were obtained at each location by continuously scanning an area approximately 1 meter by 1 meter at a height of 1 meter above ground level. The **highest reading in each of the three orthogonal axes** was observed with the *Precision ELF/VLF Gaussmeter* in the 57 - 63 Hz range, and recorded in tabular form. For root-sum-square (RSS) values, peak readings in each of the three axes are evaluated by taking the square root of the sum of the squares of the means (See Equation below). The recorded values represent the "worst case" values. Care was exercised not to move the probe to within 20 cm of the any surface to minimize probe-proximity errors. The results of the electromagnetic field survey are included in tabular form.

$$\boldsymbol{RSS} = \sqrt{\boldsymbol{Z}^2 + \boldsymbol{X}^2 + \boldsymbol{Y}^2}$$

Locations & Results

Figure 1: Locations & Results for Electromagnetic Field Survey
#1: Middle of Sidewalk, #2: Edge of Sidewalk, #3: Middle of Near Lane, #4: Middle of Road, #5: Middle of Far Lane, #6: Edge of Sidewalk, #7: Middle of Road Lane
Intersection of Border & Pickering Streets; Winchester, MA

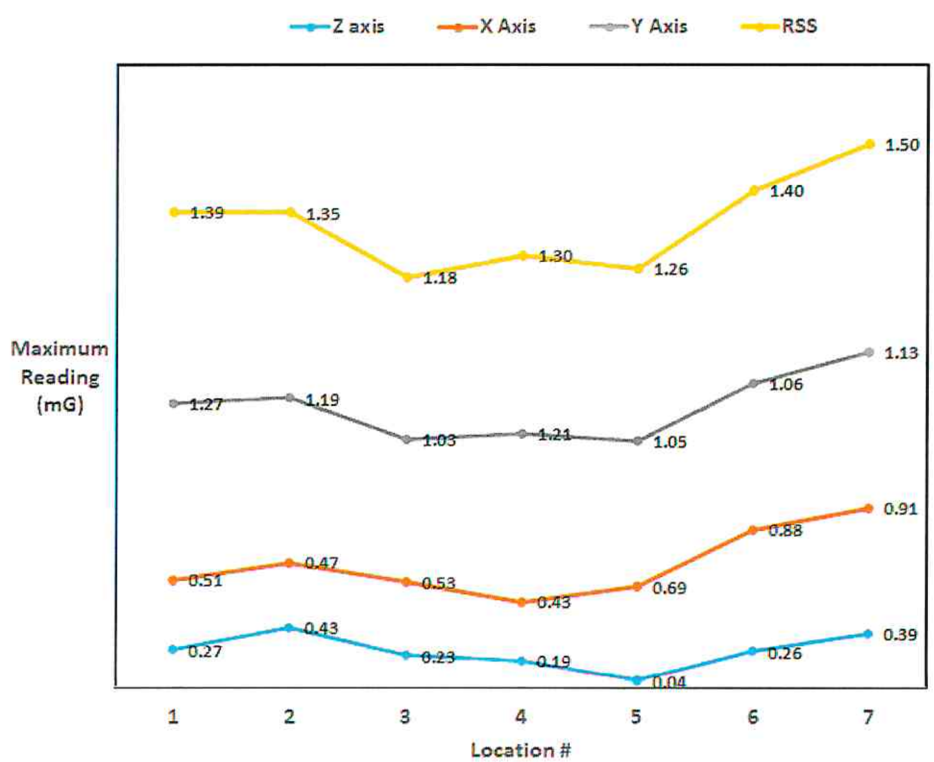


Figure 2: Locations & Results for Electromagnetic Field Survey
#1: Middle of Sidewalk, #2: Edge of Sidewalk, #3: Middle of Near Lane, #4: Middle of Road, #5: Middle of Far Lane, #6: Edge of Sidewalk, #7: Middle of Road Lane
Intersection of **Cross & Wendel**l Streets; Winchester, MA

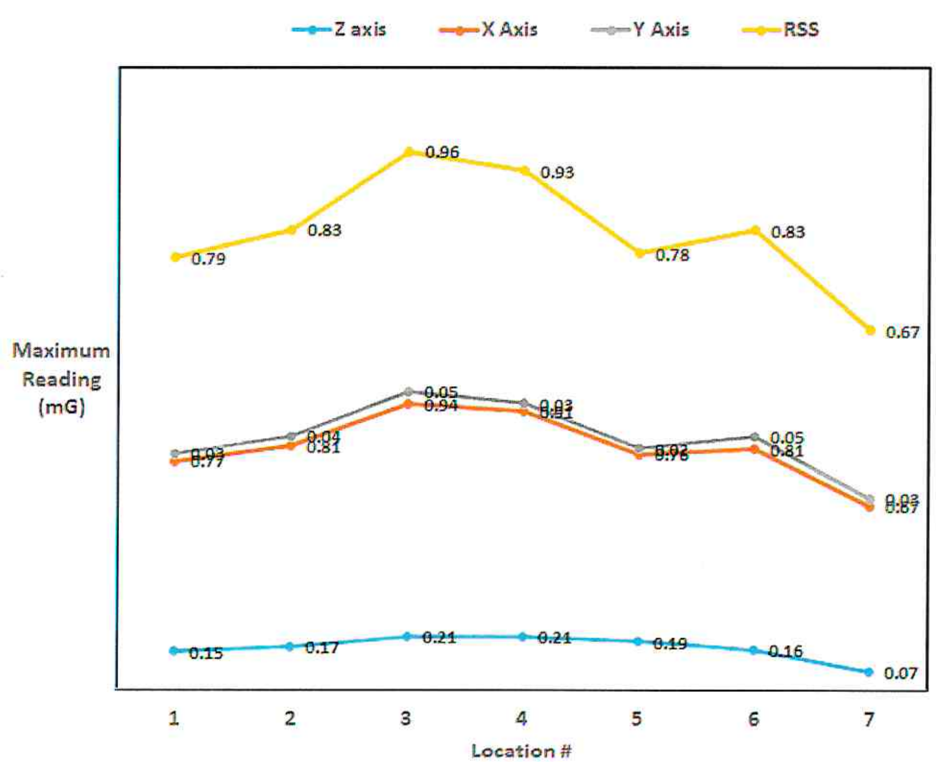


Figure 3: Locations & Results for Electromagnetic Field Survey#1: Middle of Sidewalk, #2: Edge of Sidewalk, #3: Middle of Near Lane, #4: Middle of Road, #5: Middle of Far Lane, #6: Edge of Sidewalk, #7: Middle of Road Lane
Intersection of **Cross & Kirk** Streets; Winchester, MA

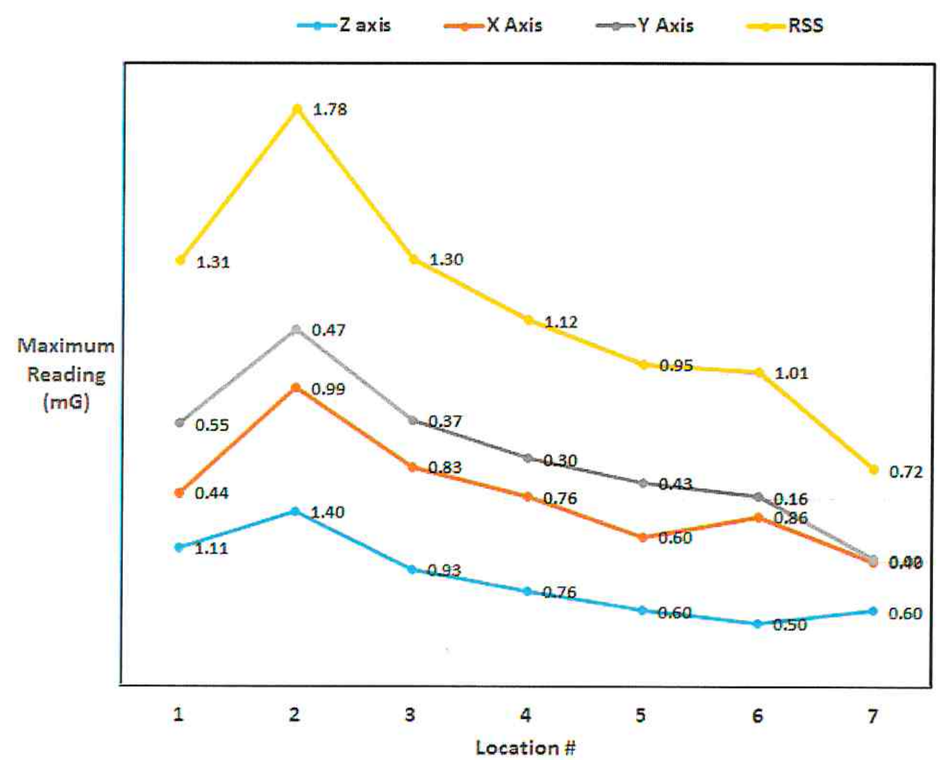


Figure 4: Locations & Results for Electromagnetic Field Survey#1: Middle of Sidewalk, #2: Edge of Sidewalk, #3: Middle of Near Lane, #4: Middle of Road, #5: Middle of Far Lane, #6: Edge of Sidewalk, #7: Middle of Road Lane
Intersection of **Cross & River** Streets; Winchester, MA

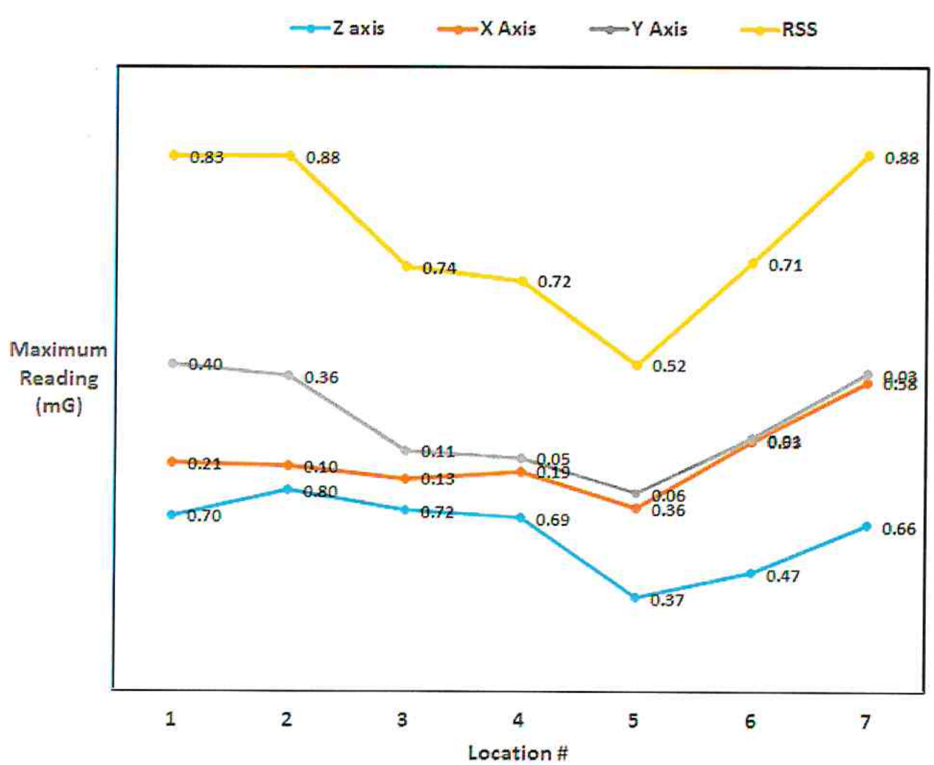


Figure 5: Locations & Results for Electromagnetic Field Survey#1: Middle of Sidewalk, #2: Edge of Sidewalk, #3: Middle of Near Lane, #4: Middle of Road, #5: Middle of Far Lane, #6: Edge of Sidewalk, #7: Middle of Road Lane

Intersection of **Cross & Lowell** Streets; Winchester, MA

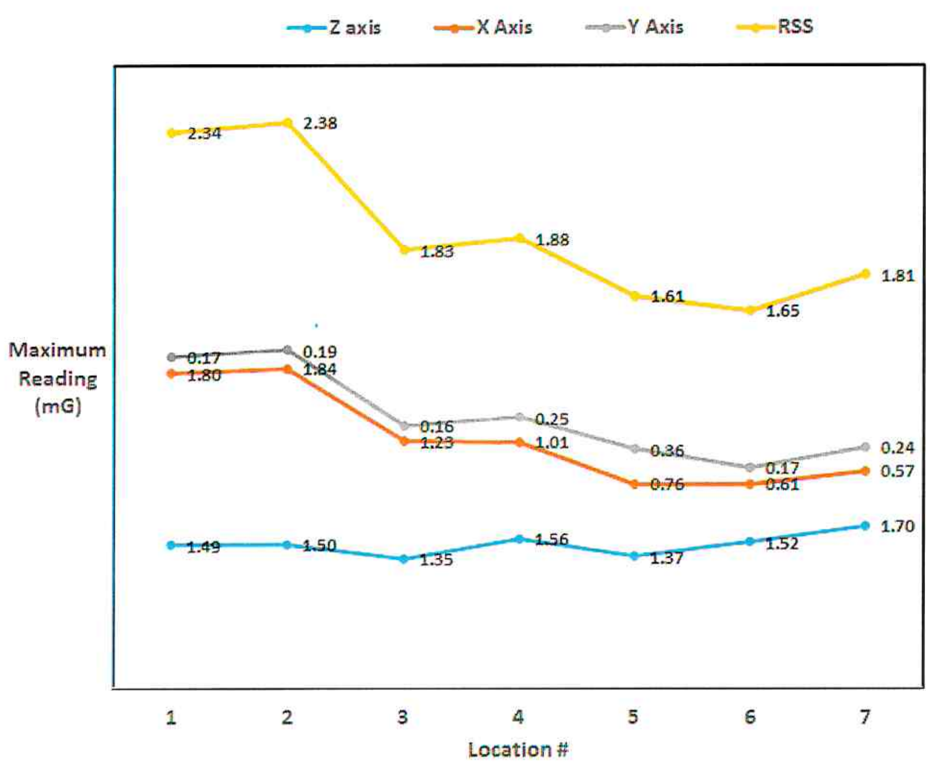


Figure 6: Locations & Results for Electromagnetic Field Survey#1: Middle of Sidewalk, #2: Edge of Sidewalk, #3: Middle of Near Lane, #4: Middle of Road, #5: Middle of Far Lane, #6: Edge of Sidewalk, #7: Middle of Road Lane
Intersection of **Cross & Cardinal** Streets; Winchester, MA

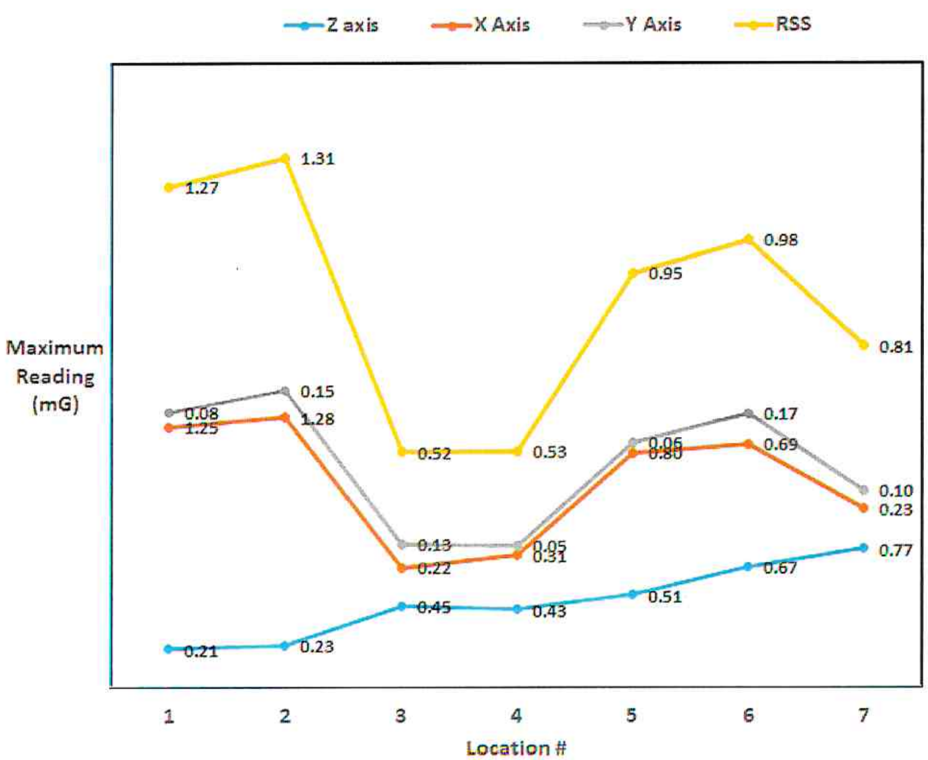
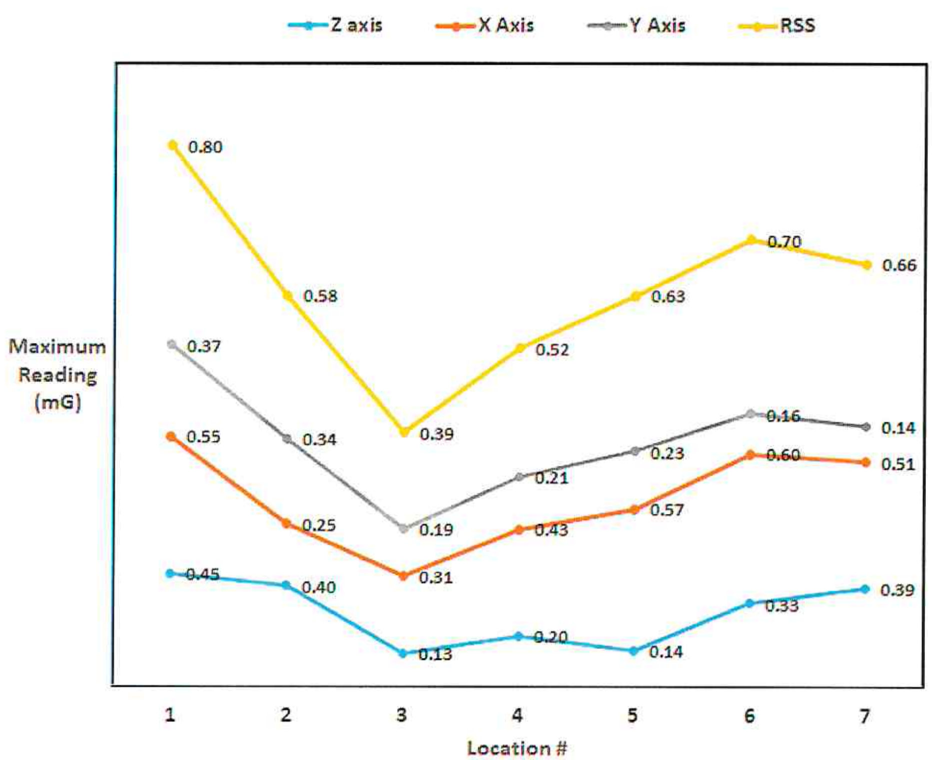


Figure 7: Locations & Results for Electromagnetic Field Survey#1: Middle of Sidewalk, #2: Edge of Sidewalk, #3: Middle of Near Lane, #4: Middle of Road, #5: Middle of Far Lane, #6: Edge of Sidewalk, #7: Middle of Road Lane
Intersection of Cross & Washington Streets; Winchester, MA



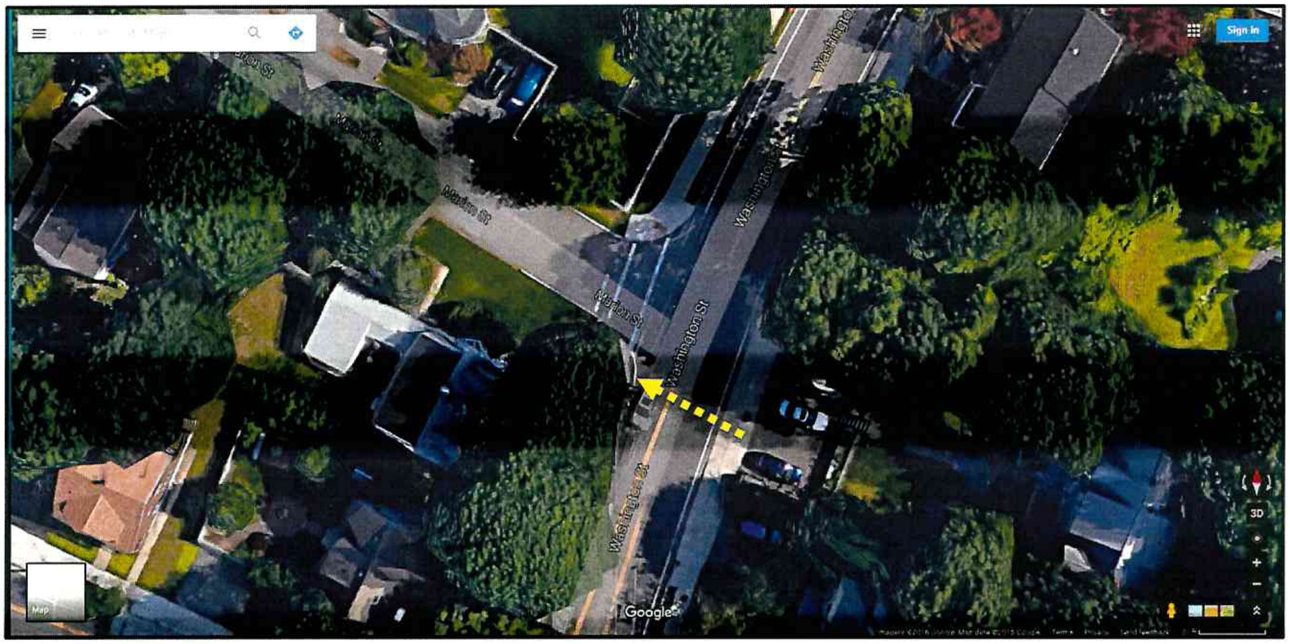


Figure 8: Locations & Results for Electromagnetic Field Survey#1: Middle of Sidewalk, #2: Edge of Sidewalk, #3: Middle of Near Lane, #4: Middle of Road, #5: Middle of Far Lane, #6: Edge of Sidewalk, #7: Middle of Road Lane
Intersection of Washington & Marion Streets; Winchester, MA

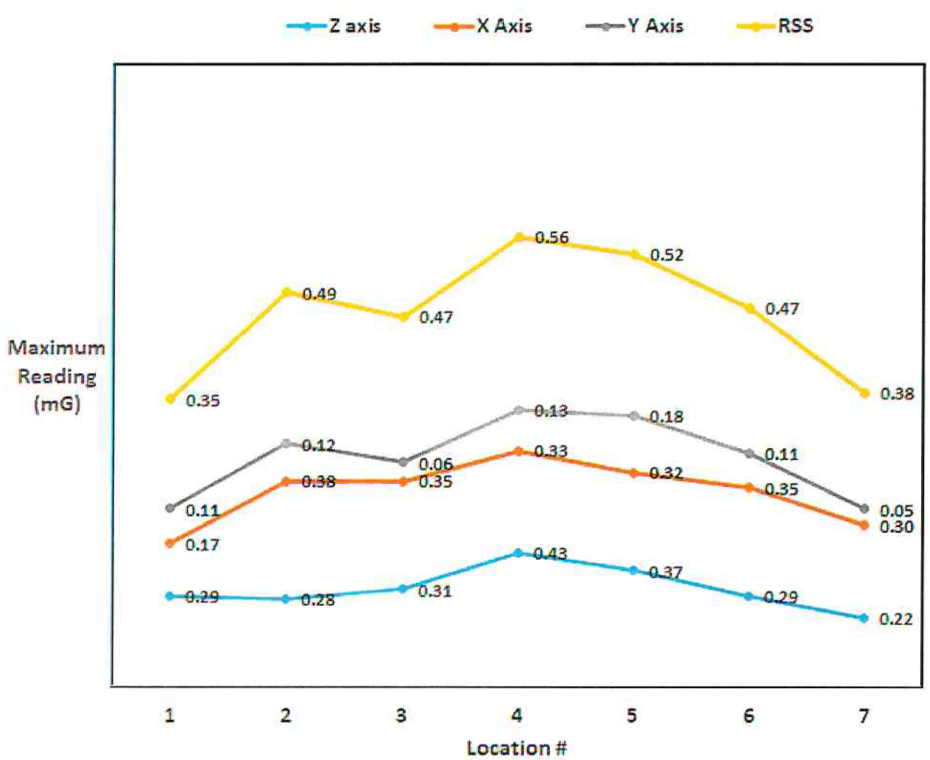


Figure 9: Locations & Results for Electromagnetic Field Survey#1: Middle of Sidewalk, #2: Edge of Sidewalk, #3: Middle of Near Lane, #4: Middle of Road, #5: Middle of Far Lane, #6: Edge of Sidewalk, #7: Middle of Road Lane
Intersection of **Washington &** Forest Streets; Winchester, MA

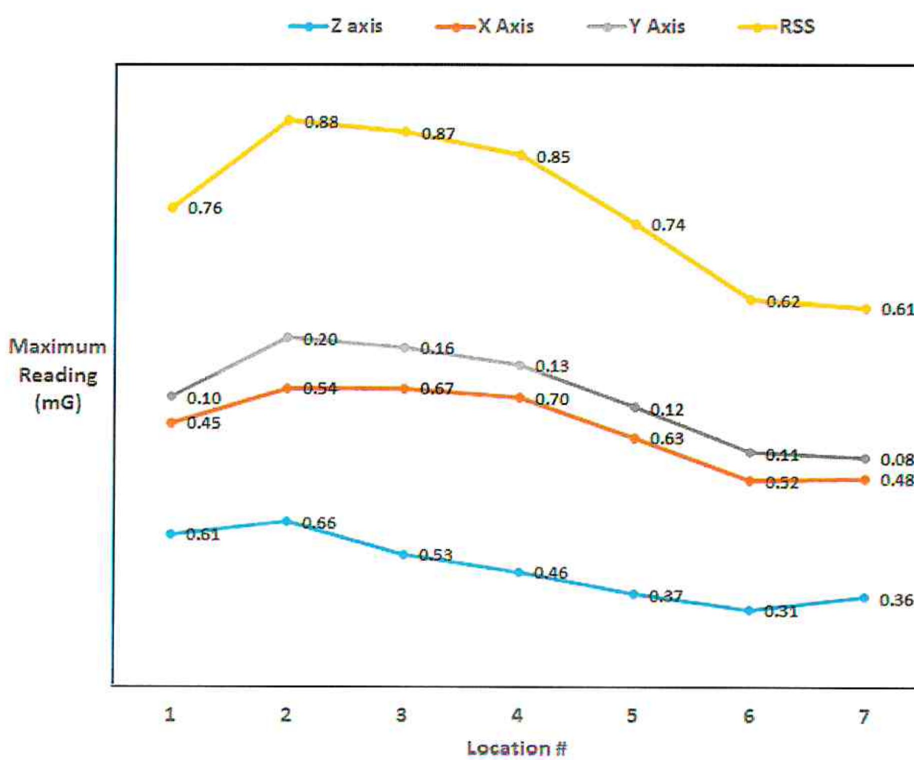
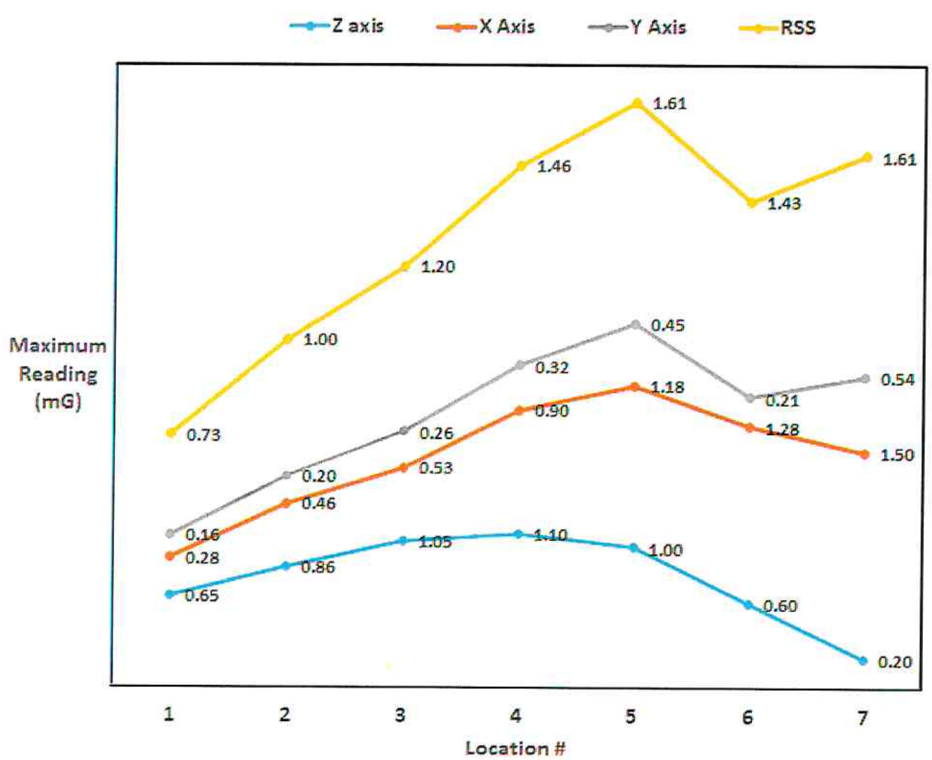


Figure 10: Locations & Results for Electromagnetic Field Survey#1: Middle of Sidewalk, #2: Edge of Sidewalk, #3: Middle of Near Lane, #4: Middle of Road, #5: Middle of Far Lane, #6: Edge of Sidewalk, #7: Middle of Road Lane
Intersection of Washington & Sunset Streets; Winchester, MA



RESULTS

The results of the EMF survey are included in Tables 2a-2j.

Table 2a: EMF Magnetic Field Survey Results Location #1: Border St & Pickering St Intersection							
Axis/mG	1	2	3	4	5	6	7
Z	0.27	0.43	0.23	0.19	0.04	0.26	0.39
X	0.51	0.47	0.53	0.43	0.69	0.88	0.91
Y	1.27	1.19	1.03	1.21	1.05	1.06	1.13
RSS	**1.39**	**1.35**	**1.18**	**1.30**	**1.26**	**1.40**	**1.50**
STATISTICS							
Axis/mG	**Stats**	**MAX**	**MIN**	**AVE**	**MEAN**	**STD**	
	Z	**0.43**	**0.04**	**0.26**	**0.26**	**0.13**	
	X	**0.91**	**0.43**	**0.63**	**0.53**	**0.20**	
	Y	**1.27**	**1.03**	**1.13**	**1.13**	**0.09**	
	RSS	**1.50**	**1.18**	**1.34**	**1.35**	**0.11**	

Table 2b: EMF Magnetic Field Survey Results Location #2: Cross St & Wendell St Intersection							
Axis/mG	1	2	3	4	5	6	7
Z	0.15	0.17	0.21	0.21	0.19	0.16	0.07
X	0.77	0.81	0.94	0.91	0.76	0.81	0.67
Y	0.03	0.04	0.05	0.03	0.02	0.05	0.03
RSS	**0.79**	**0.83**	**0.96**	**0.93**	**0.78**	**0.83**	**0.67**
STATISTICS							
Axis/mG	**Stats**	**MAX**	**MIN**	**AVE**	**MEAN**	**STD**	
	Z	**0.21**	**0.07**	**0.17**	**0.17**	**0.05**	
	X	**0.94**	**0.67**	**0.81**	**0.81**	**0.09**	
	Y	**0.05**	**0.02**	**0.04**	**0.03**	**0.01**	
	RSS	**0.96**	**0.67**	**0.83**	**0.83**	**0.10**	

Table 2c: EMF Magnetic Field Survey Results Location #3: Cross St & Kirk St Intersection							
Axis/mG	1	2	3	4	5	6	7
Z	1.11	1.40	0.93	0.76	0.60	0.50	0.60
X	0.44	0.99	0.83	0.76	0.60	0.86	0.40
Y	0.55	0.47	0.37	0.30	0.43	0.16	0.02
RSS	**1.31**	**1.78**	**1.30**	**1.12**	**0.95**	**1.01**	**0.72**
STATISTICS							
Axis/mG	**Stats**	**MAX**	**MIN**	**AVE**	**MEAN**	**STD**	
	Z	**1.40**	**0.50**	**0.84**	**0.76**	**0.32**	
	X	**0.99**	**0.40**	**0.70**	**0.76**	**0.22**	
	Y	**0.55**	**0.02**	**0.33**	**0.37**	**0.19**	
	RSS	**1.78**	**0.72**	**1.17**	**1.12**	**0.34**	

Table 2d: EMF Magnetic Field Survey Results Location #4: Cross St & River St Intersection							
Axis/mG	1	2	3	4	5	6	7
Z	0.70	0.80	0.72	0.69	0.37	0.47	0.66
X	0.21	0.10	0.13	0.19	0.36	0.53	0.58
Y	0.40	0.36	0.11	0.05	0.06	0.01	0.03
RSS	**0.83**	**0.88**	**0.74**	**0.72**	**0.52**	**0.71**	**0.88**
STATISTICS							
Axis/mG	**Stats**	**MAX**	**MIN**	**AVE**	**MEAN**	**STD**	
	Z	**0.80**	**0.37**	**0.63**	**0.69**	**0.15**	
	X	**0.58**	**0.10**	**0.30**	**0.21**	**0.19**	
	Y	**0.40**	**0.01**	**0.15**	**0.06**	**0.16**	
	RSS	**0.88**	**0.52**	**0.75**	**0.74**	**0.13**	

Table 2e: EMF Magnetic Field Survey Results Location #5: Cross St & Lowell Ave Intersection							
Axis/mG	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Z	1.49	1.50	1.35	1.56	1.37	1.52	1.70
X	1.80	1.84	1.23	1.01	0.76	0.61	0.57
Y	0.17	0.19	0.16	0.25	0.36	0.17	0.24
RSS	**2.34**	**2.38**	**1.83**	**1.88**	**1.61**	**1.65**	**1.81**
STATISTICS							
Axis/mG	**Stats**	**MAX**	**MIN**	**AVE**	**MEAN**	**STD**	
	Z	**1.70**	**1.35**	**1.50**	**1.50**	**0.12**	
	X	**1.84**	**0.57**	**1.12**	**1.01**	**0.53**	
	Y	**0.36**	**0.16**	**0.22**	**0.19**	**0.07**	
	RSS	**2.38**	**1.61**	**1.93**	**1.83**	**0.31**	

Table 2f: EMF Magnetic Field Survey Results Location #6: Cross St & Cardinal St Intersection							
Axis/mG	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Z	0.21	0.23	0.45	0.43	0.51	0.67	0.77
X	1.25	1.28	0.22	0.31	0.80	0.69	0.23
Y	0.08	0.15	0.13	0.05	0.06	0.17	0.10
RSS	**1.27**	**1.31**	**0.52**	**0.53**	**0.95**	**0.98**	**0.81**
STATISTICS							
Axis/mG	**Stats**	**MAX**	**MIN**	**AVE**	**MEAN**	**STD**	
	Z	**0.77**	**0.21**	**0.47**	**0.45**	**0.21**	
	X	**1.28**	**0.22**	**0.68**	**0.69**	**0.46**	
	Y	**0.17**	**0.05**	**0.11**	**0.10**	**0.05**	
	RSS	**1.31**	**0.52**	**0.91**	**0.95**	**0.32**	

Table 2g: EMF Magnetic Field Survey Results Location #7: Cross St & Washington St Intersection							
Axis/mG	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Z	0.45	0.40	0.13	0.20	0.14	0.33	0.39
X	0.55	0.25	0.31	0.43	0.57	0.60	0.51
Y	0.37	0.34	0.19	0.21	0.23	0.16	0.14
RSS	**0.80**	**0.58**	**0.39**	**0.52**	**0.63**	**0.70**	**0.66**
STATISTICS							
Axis/mG	**Stats**	**MAX**	**MIN**	**AVE**	**MEAN**	**STD**	
	Z	**0.45**	**0.13**	**0.29**	**0.33**	**0.13**	
	X	**0.60**	**0.25**	**0.46**	**0.51**	**0.14**	
	Y	**0.37**	**0.14**	**0.23**	**0.21**	**0.09**	
	RSS	**0.80**	**0.39**	**0.61**	**0.63**	**0.13**	

Table 2h: EMF Magnetic Field Survey Results Location #8: Washington St & Marion St Intersection							
Axis/mG	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Z	0.29	0.28	0.31	0.43	0.37	0.29	0.22
X	0.17	0.38	0.35	0.33	0.32	0.35	0.30
Y	0.11	0.12	0.06	0.13	0.18	0.11	0.05
RSS	**0.35**	**0.49**	**0.47**	**0.56**	**0.52**	**0.47**	**0.38**
STATISTICS							
Axis/mG	**Stats**	**MAX**	**MIN**	**AVE**	**MEAN**	**STD**	
	Z	**0.43**	**0.22**	**0.31**	**0.29**	**0.07**	
	X	**0.38**	**0.17**	**0.31**	**0.33**	**0.07**	
	Y	**0.18**	**0.05**	**0.11**	**0.11**	**0.04**	
	RSS	**0.56**	**0.35**	**0.46**	**0.47**	**0.07**	

Table 2i: EMF Magnetic Field Survey Results Location #9: Washington St & Forest St Intersection							
Axis/mG	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Z	0.61	0.66	0.53	0.46	0.37	0.31	0.36
X	0.45	0.54	0.67	0.70	0.63	0.52	0.48
Y	0.10	0.20	0.16	0.13	0.12	0.11	0.08
RSS	**0.76**	**0.88**	**0.87**	**0.85**	**0.74**	**0.62**	**0.61**
STATISTICS							
Axis/mG	**Stats**	**MAX**	**MIN**	**AVE**	**MEAN**	**STD**	
	Z	**0.66**	**0.31**	**0.47**	**0.46**	**0.13**	
	X	**0.70**	**0.45**	**0.57**	**0.54**	**0.10**	
	Y	**0.20**	**0.08**	**0.13**	**0.12**	**0.04**	
	RSS	**0.88**	**0.61**	**0.76**	**0.76**	**0.11**	

Table 2j: EMF Magnetic Field Survey Results Location #10: Washington St & Sunset St Intersection							
Axis/mG	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Z	0.65	0.86	1.05	1.10	1.00	0.60	0.20
X	0.28	0.46	0.53	0.90	1.18	1.28	1.50
Y	0.16	0.20	0.26	0.32	0.45	0.21	0.54
RSS	**0.73**	**1.00**	**1.20**	**1.46**	**1.61**	**1.43**	**1.61**
STATISTICS							
Axis/mG	**Stats**	**MAX**	**MIN**	**AVE**	**MEAN**	**STD**	
	Z	**1.10**	**0.20**	**0.78**	**0.86**	**0.32**	
	X	**1.50**	**0.28**	**0.88**	**0.90**	**0.46**	
	Y	**0.54**	**0.16**	**0.31**	**0.26**	**0.14**	
	RSS	**1.61**	**0.73**	**1.29**	**1.43**	**0.33**	

CONCLUSION

An electromagnetic field (EMF) survey was performed at ten (10) individual locations along the proposed Woburn-to-Wakefield Junction Underground 345-kV running through sections of Winchester, MA. These readings were performed to verify that exposure limits and/or guidelines would not be exceeded post site work, and memorialized baseline conditions. The results of the surveys demonstrate that existing electromagnetic fields strengths were well below established limits and/or guidelines for public exposure, and below interference thresholds for implanted medical devices. Average estimated alternating current (AC) magnetic field levels within homes are approximately 1 mG (0.001 G) (0.1 μT), and measured values range from 9 to 20 mG (0.009 to 0.020 G) (0.9 to 2 μT) near appliances.

A total of 70 EMF measurements were made. The maximum measured value was **1.70 mG**. Based on my extensive experience in the field of non-ionizing radiation safety, and the results and examination of the measured ambient electromagnetic fields, I can render the following expert opinions:

- Existing measured electromagnetic field strengths are below the established limits and/or guidelines for public exposure.
- The measured values indicate existing EMF levels present a negligible impact on personnel health and safety.

Feel free to contact me with any questions.

Sincerely,

Donald L. Haes, Jr., Ph.D
Certified Health Physicist

Note: The analyses, conclusions and professional opinions are based upon the precise parameters and conditions of this particular site; **ten (10) individual locations along the proposed Woburn-to-Wakefield Junction Underground 345-kV running through sections of Winchester, MA.** Utilization of these analyses, conclusions and professional opinions for any other location, existing or proposed other than the aforementioned has not been sanctioned by the author, and therefore should not be accepted as evidence of regulatory compliance.

DONALD L. HAES, JR., PH.D., CHP
Radiation Safety Specialist
MA Radiation Control Program Health Physics Services Provider Registration #65-0017
PO Box 198, Hampstead, NH 03841 603-303-9959 Email: donald_haes_chp@myfairpoint.net

STATEMENT OF CERTIFICATION

1. I certify to the best of my knowledge and belief, the statements of fact contained in this report are true and correct.

2. The reported analyses, opinions, and conclusions are limited only by the reported assumptions and limiting conditions, and are personal, unbiased professional analyses, opinions and conclusions.

3. I have no present or prospective interest in the property that is the subject of this report and I have no personal interest or bias with respect to the parties involved.

4. My compensation is not contingent upon the reporting of a predetermined energy level or direction in energy level that favors the cause of the client, the amount of energy level estimate, the attainment of a stipulated result, or the occurrence of a subsequent event.

5. This assignment was not based on a requested minimum environmental energy level or specific power density.

6. My compensation is not contingent on an action or event resulting from the analyses, opinions, or conclusions in, or the use of, this report.

7. The consultant has accepted this assessment assignment having the knowledge and experience necessary to complete the assignment competently.

8. My analyses, opinions, and conclusions were developed and this report has been prepared, in conformity with the *American Board of Health Physics* (ABHP) statements of standards of professional responsibility for Certified Health Physicists.

Date: June 27, 2016

Donald L. Haes, Jr., Ph.D
Certified Health Physicist

ENDNOTES

[i]. ICNIRP *Guidelines For Limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields (Up to 300 GHz);* Published in: Health Physics 74 (4):494-522; 1998.

[ii]. ICNIRP Statement on the "*Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (Up to 300 GHz)*"; Published in: Health Physics 97(3):257-258; 2009.

[iii]. ANSI/IEEE C95.6-2002; *Standard for Safety Levels With Respect to Human Exposure to Electromagnetic Fields, 0 to 3 kHz;* The Institute of Electrical and Electronics Engineers, Inc., 3 Park Avenue, New York, NY 10016-5997, USA, October 2002. **This document is being combined with ANSI/IEEE C95.1; expected publication 2015/16.**

[iv]. ACGIH, Threshold Limit Values and Biological Exposure Indices; *ACGIH TLVs*, 2015.

[v]. FINAL California High-Speed Train Project Environmental Impact Report/Environmental Impact Statement and Final Section 4(f) Statement and Draft General Conformity Determination; Merced to Fresno Section; VOLUME I:REPORT. Prepared by: California High-Speed Rail Authority, 770 L Street, Suite 800, Sacramento, CA 95814. POC: Mr. Thomas Fellenz, 916-324-1541. USDOT Federal Railroad Administration, 1200 New Jersey Avenue SE, MS-20, W38-314, Washington, D.C. 20590. POC: Mr. David Valenstein, 202-493-6381.

[vi]. NIOSH (National Institute for Occupational Safety and Health) *Manual for Measuring Occupational Electric and Magnetic Field Exposures*; U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Division of Biomedical and Behavioral Sciences, October 1998.

DONALD L. HAES, JR., PH.D., CHP
Radiation Safety Specialist
MA Radiation Control Program Health Physics Services Provider Registration #65-0017
PO Box 198, Hampstead, NH 03841 603-303-9959 Email: donald_haes_chp@comcast.net

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Re: Electromagnetic Field Measurements within Stoneham, MA.

EXECUTIVE SUMMARY

An electromagnetic field (EMF) survey was performed at three (3) individual locations along the proposed Woburn-to-Wakefield Junction Underground 345-kV transmission lines running through sections of Stoneham, MA (See Figure 1). These readings were performed to verify that exposure limits and/or guidelines would not be exceeded post site work, and memorialized baseline conditions. The results of the surveys demonstrate that existing electromagnetic fields strengths were well below established limits and/or guidelines for public exposure, and below interference thresholds for implanted medical devices. Average estimated alternating current (AC) magnetic field levels within homes are approximately 1 mG (0.001 G) (0.1 μT), and measured values range from 9 to 20 mG (0.009 to 0.020 G) (0.9 to 2 μT) near appliances.

A total of 15 EMF measurements were made. The maximum measured value was **2.2 mG**. Based on my extensive experience in the field of non-ionizing radiation safety, and the results and examination of the measured ambient electromagnetic fields, I can render the following expert opinions:

- Existing measured electromagnetic field strengths are below the established limits and/or guidelines for public exposure.
- The measured values indicate existing EMF levels present a negligible impact on personnel health and safety.

PURPOSE

The following report presents the results of the physical measurements of electromagnetic field (colloquially known as "EMF") survey requested at three (3) individual locations along the proposed Woburn-to-Wakefield Junction Underground 345-kV running through sections of Stoneham, MA. The survey was were performed to verify that exposure limits and/or guidelines would not be exceeded post site work, and memorialized baseline conditions. These baseline values may be used later to superimpose on modeled values of EMF for the proposed transmission lines and electrical components to assess expected health based exposure limits, and the reliability of any implanted medical devices (IMDs) in members of the public.

PHYSICAL CONDITIONS

An electromagnetic field (EMF) survey was performed at three (3) individual locations along the proposed Woburn-to-Wakefield Junction Underground 345-kV transmission lines running through sections of Stoneham, MA. During the survey, the following environmental conditions were noted: Sunny skies; Temperature 86-87°F (85-88°F "Real Feel™); Humidity 25%-26%; Winds 9-10 SW; Visibility 10 miles; Barometric pressure 1015 mbar.[1]

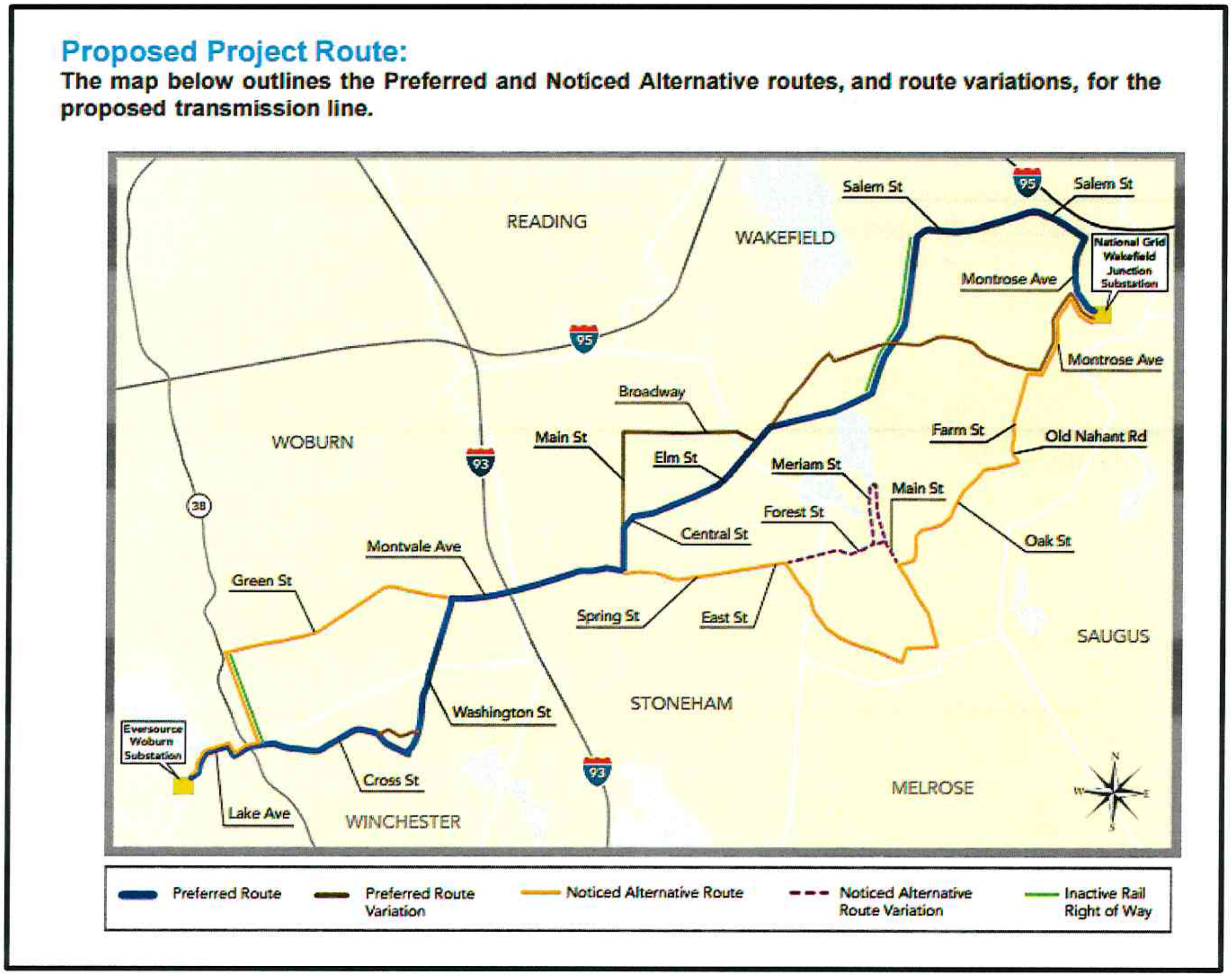

Figure 1: Proposed Routes for Eversource/National Grid

Woburn-To-Wakefield Junction Underground 345-Kv Transmission Line Route

[1] Source: Weather.com

DISCUSSION OF UNITS

The nomenclature for expressing the ***intensity*** of magnetic fields varies with frequency. Below listed are customary units and symbols used to express magnetic field intensities:

Magnetic Field Strength: H => A/m or A^2/m^2
Magnetic Flux Density: B => Gauss (G) or Tesla (T) (10,000 G = 1 T)

To covert to units of field strength (A/m), divide by the permeability of free space (4π X 10^{-7} henry/meter); or simply multiply by 0.08 (80 A/m = 1000 mG).

EXPOSURE LIMITS AND GUIDELINES

Neither the Federal Government nor the Commonwealth of Massachusetts regulates the electric/magnetic field intensities associated with the transmission or distribution of electric power. However, electromagnetic field exposure limit values, often referred to as "Maximum Permissible Exposure" limits (MPEs), have been published by standard-setting agencies. Established electromagnetic field exposure limits that relate to the potential fields from common electricity, i.e. 60$\pm$ Hz, are listed below:

- International Commission on Non-Ionizing Radiation Protection (ICNIRP) *Guidelines For Limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields (Up to 300 GHz).* [i, ii]
- ANSI/IEEE C95.6-2002; *Standard for Safety Levels With Respect to Human Exposure to Electromagnetic Fields, 0 to 3 kHz.* [iii]
- American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLV); Subfrequency (30 kHz and below) Magnetic Fields, Subfrequency (30 kHz and below) and Static Electric Fields, and Static Magnetic Fields. [iv]

SUMMARY: The Maximum Permissible Exposure (MPE) limit published by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines (1998; Tables 6 and 7) for 60-Hz magnetic fields for the instantaneous exposure of the general public is 0.833 G (83.3 µT), and the MPE for controlled environments where only employees work is 4.2 G (420 µT). For comparison, the magnetic field ranges from 500 to 700 mG (0.5 to 0.7 G; 50 to 70 µT) which are non-time-varying (or DC) at the surface of the earth. Average estimated alternating current (AC) magnetic field levels within homes are approximately 1 mG (0.001 G) (0.1 µT), and measured AC values range from 9 to 20 mG (0.009 to 0.020 G) (0.9 to 2 µT) near appliances. The intensity of the electric and/or magnetic field ("EMF") rapidly decreases with distance away from the source; therefore it makes sense then to find higher than background levels close to potential sources such as motors (hence the equipment and/or appliances that house them), wiring and breakers, and transformers. Sources [v] suggest typical interference levels for common types of sensitive equipment occur above 2 mG.