Energy Facility Siting Board Environmental Report

V148N 115 kV Transmission Line Reconductoring Project

North Smithfield and Lincoln, Rhode Island

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List of Acronyms/GLOSSARY

115 kV	115 kilovolts or 115,000 volts
AAC	All Aluminum Conductor Wire
ACI	American Concrete Institute
ACSR	Aluminum Conductor Steel Reinforced Wire
ACSS	Aluminum Conductor Steel Supported Wire
The Act	Energy Facility Siting Act, RI Gen. Laws Section 42-98-1 et seq. as amended.
ANSI	American National Standards Institute
Applicant	The Narragansett Electric Company (TNEC)
ASCE	American Society of Civil Engineers
ASF	Areas Subject to Flooding, RI Wetlands
ASSF	Areas Subject to Storm Flowage, RI Wetlands
BMPs	Best Management Practices
Brayton Point	Brayton Point Energy, LLC generation plant in Somerset, Massachusetts.
Bundle (conductor)	Two or more wires joined together to operate as a single phase.
Cable	A fully insulated conductor usually installed underground but in some circumstances can be installed overhead.
CERCLA	Comprehensive Environmental Response Compensation and Liability Act of 1980
Circuit	A system of conductors (3 conductors or 3 bundles of conductors) through which an electric current is intended to flow and which may be supported above ground by transmission structures or placed underground.
Circuit Breaker	A switch that automatically disconnects power to the circuit in the event of a fault condition. Located in substations. Performs the same function as a circuit breaker in a home.
Conductor	A metallic wire busbar, rod, tube or cable that serves as a path for electric current to flow.
Contingency:	An event, usually involving the loss of one or more elements, which affects the power system at least momentarily.
CWPA	Community Wellhead Protection Area
Demand	The total amount of electric power required at any given time by an electric supplier's customers.
DEPO	Dead end pull off structure
Distribution Line or System	The power lines and facilities that transport electrical energy from the transmission system to the customer.
Double-Circuit	Two circuits on one structure.
Ed	Excessively drained soils.
EFI	Environmental Field Issue Guidelines: set of guidelines developed for construction and maintenance projects
EFSB	Rhode Island Energy Facility Siting Board
EG-303NE	EG-303 NE *ROW Access, Maintenance and Construction Best Management Practices*
EHS	Extra High Strength
Electric Transmission	The facilities ($\geq$ 69 kV) that transmit electrical energy from generating plants to substations
EMF	Electric and magnetic fields
Environmental monitor	Inspects environmental conditions within the construction site, reviews the contractors' compliance with environmental permit conditions during the construction phase of a project, and makes recommendations for corrective actions to protect sensitive environmental resources proximate to a construction site.
Fault	A failure or interruption in an electrical circuit (a.k.a. short circuit).
FEMA	Federal Emergency Management Agency

List of Acronyms/GLOSSARY

FERC	Federal Energy Regulatory Commission
GA/GAA	Rhode Island groundwater classifications under RIDEM Groundwater Quality Rules.
Ground Wire	Cable/wire used to connect wires and metallic structure parts to the earth. Sometimes used to describe the lightning shieldwire.
H-frame Structure	A wood or steel transmission line structure constructed of 2 upright poles with a horizontal cross-arm and diagonal bracings.
Hel	Highly erodible land.
IEEE	Institute of Electrical and Electronic Engineers
IRP	Interstate Reliability Project
ISO-NE	ISO – New England, Inc. The independent system operator of New England.
kcm	1,000 circular mils, approximately 0.0008 square inches. A measure of conductor cross-sectional area.
kV	Kilovolt. 1 kV equals 1,000 volts.
kV/m	kilovolts per meter; measurement typically used for an electric field.
Load	Amount of power delivered upon demand at any point or points in the electric system. Load is created by the power demands of customers' equipment (residential, commercial, and industrial).
mG	Milligauss; measurement typically used for a magnetic field.
Monopole	A single pole supporting overhead utility wires
Msl	Mean Sea Level
MW	Megawatt. A unit of power equal to 1 million watts. A measure of the output of a power station.
Mwd	Moderately well drained soils.
N-1, N-1-1	N-1 represents a single event in a contingency analysis; N-1-1 represents the second event in a contingency analysis that occurs close in time to the N-1 event.
National Grid	The Narragansett Electric Company d/b/a/ National Grid
NEPOOL	New England Power Pool
NERC	North American Electric Reliability Corporation
NESC	National Electrical Safety Code
NPCC	Northeast Power Coordinating Council
NOI	Notice of Intent
NRCS	Natural Resources Conservation Service
OPGW	Optical Ground Wire
PAC	ISO-NE Planning Advisory Committee
Pd	Poorly drained (hydric) soils.
PDWS	Public Drinking Water Supply
Phases	Transmission and distribution AC circuits are comprised of 3 conductors that have voltage and angle differences between them. Each of these conductors is referred to as a phase.
Phel	Potentially highly erodible land
Power Transformer	A device used to transform voltage levels to facilitate the efficient transfer of power from the generating plant to the customer. A step-up transformer increases the voltage while a step-down transformer decreases it. Power transformers have a high voltage and a low voltage winding for each phase (see also Auto Transformer).
Reconductor	Replacement of existing conductors (wires) with new conductors.

List of Acronyms/GLOSSARY

Reinforcement	Any of a number of approaches to increase the capacity of the transmission system, including reconductoring, clearance improvements to facilitate increased electrical loading and voltage uprating.
RIDEM	Rhode Island Department of Environmental Management
RIDOT	Rhode Island Department of Transportation
RIGIS	Rhode Island Geographical Information System
RIHPHC	Rhode Island Historic Preservation and Heritage Commission
RINHP	Rhode Island Natural Heritage Program
ROW	Right-of-way. Corridor of land within which a utility company holds legal rights necessary to build operate and maintain power lines.
The Rules	The Rules and Regulations Governing the Administration and Enforcement of the Freshwater Wetlands Act, RIDEM, d pursuant to R.I. Gen. Laws Chapters 2-1-20.1, 42-17.1, and 42-17.6, as amended, and have been promulgated pursuant to the procedures set forth in the R.I. Administrative Procedures Act, R. I. Gen. Laws Chapter 42-35.
SEMA-RI	Southeastern Massachusetts-Rhode Island
Shieldwire	Wire strung at the top of transmission lines intended to prevent lightning from striking transmission circuit conductors. Sometimes referred to as static wire or aerial ground wire. May contain glass fibers for communication use. See also “OPGW”.
SRPW	Special Resource Protection Water
Substation	A fenced-in yard containing switches, power transformers, line terminal structures, and other equipment enclosures and structures. Voltage change, adjustments of voltage, monitoring of circuits and other service functions take place in this installation.
Swed	Somewhat excessively drained soils.
SWPA	Surface Water Protection Area
Terminal Point	The substation or switching station at which a transmission line terminates.
Terminal Structure	Structure typically within a substation or switching station that ends a section of transmission line.
TGP-28	National Grid Transmission Planning Group Procedure 28
TMDL	Total Maximum Daily Load, Maximum allowed pollutant load to a water body without exceeding water quality standards
TNEC	The Narragansett Electric Company
TO	Transmission Owner
Transmission Line	An electric power line operating at 69 kV or above
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
US EPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
V148N Line	The existing V148N 115 kV overhead electrical transmission line
Voltage	A measure of the electrical pressure that transmits electricity. Usually given as the line-to-line root-mean square magnitude for three-phase systems.
Voltage Collapse	A condition where voltage drops to unacceptable levels and cascading interruptions of transmission system elements occur resulting in widespread blackouts.
Vpd	Very poorly drained (hydric) soils.
Watercourse	Rivers, streams, brooks, waterways, lakes, ponds, marshes, swamps, bogs, and all other bodies of water, natural or artificial, public or private.

List of Acronyms/GLOSSARY

Wd	Well drained soils.
Wetland	Land, including submerged land, which consists of any of the soil types designated as poorly drained, very poorly drained, alluvial or flood plain by the U.S. Department of Agriculture, Natural Resources Conservation Service. Wetlands include federally jurisdictional wetlands of the U.S. and navigable waters, freshwater wetlands or coastal resources regulated by a state or local regulatory authority. Jurisdictional wetlands are classified based on a combination of soil type, wetland plants, and hydrologic regime, or state-defined wetland types.
Wire	See Conductor
Working Group	ISO-NE Working Group responsible for the transmission planning study
WSS	Web Soil Survey

1 EXECUTIVE SUMMARY

1.1 INTRODUCTION

This Environmental Report has been prepared in accordance with Rule 1.6(f) of the Rhode Island Energy Facility Siting Board (EFSB) *Rules of Practice and Procedure*, to support a Notice of Intent (NOI) for the reconductoring a portion of the existing V148N 115 kilovolt (kV) overhead electrical transmission line (V148N Line), owned by The Narragansett Electric Company d/b/a National Grid (TNEC or the Applicant) and located in North Smithfield and Lincoln, Rhode Island (the Project).[1] The Project constitutes an alteration under the Energy Facility Siting Act (the Act), RI Gen. Laws Section 42-98-1 et seq. as amended, because it involves the modification of a power line of 69 kV or more.

This Executive Summary presents a general overview of the Project. Section 2 discusses the purpose and need for the Project. Section 3 provides a detailed Project description, including the Project's scope of work, construction practices for each phase of work, and safety and health overview. The Project's estimated cost, schedule and abutter outreach efforts are also discussed in Section 3. Section 4 reviews the alternatives to the Proposed Action. Sections 5 and 6 present the existing natural environment and social conditions, respectively, which may be affected by the Project. Section 7 presents the Project's anticipated impact, and Section 8 provides an overview of mitigation measures to be implemented to avoid or minimize impacts.

1.2 PROPOSED ACTION

The Applicant proposes to reconductor the approximately 4.2-mile V148N Line in an existing right-of-way (ROW) from the Woonsocket Substation in North Smithfield to the Washington Substation in Lincoln (see Figure 1-1: Project Locus[2] and Figure 3-1: Existing Conditions (Sheets 1-3)). The process of reconductoring involves replacing existing wires (conductors) with new larger conductors. In the case of this Project, the new conductors will increase the capacity of the transmission line. In some cases it is necessary to reinforce or replace structures as part of a reconductoring project. For the Project, the existing conductors and shieldwire will be replaced and, where necessary, structures will be reinforced or replaced to support the reconductoring and withstand the additional loads. There are currently 45 existing structures along the portion of the V148N Line to be reconductored. Seven wood structures will be replaced by 6 steel structures. When the Project is completed there will be a total of 44 structures along the ROW.

During construction, the Project will require the use of existing and improved access roads that are both on and off the ROW. Six pull pads will be situated at route angles to anchor heavy equipment which will be needed to pull the new electrical lines (see Figure 3-3: Permitting and Access Plans, Sheets 1-18).

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[1] TNEC, a subsidiary of National Grid USA, is an electricity distribution and transmission company serving approximately 465,000 customers in 38 Rhode Island communities. National Grid USA is a public utility holding company. Other subsidiaries of National Grid USA include operating companies such as New England Power Company, Massachusetts Electric Company, Nantucket Electric Company, and Niagara Mohawk Power Corporation (in New York), as well as National Grid USA Service Company, Inc. (National Grid) which provides services such as engineering, facilities construction and accounting.

[2] Figures are included in a separate bound volume.

Project construction is scheduled to commence in September of 2015, with completion expected by mid-2016. This schedule is designed specifically to ensure that the reconductoring is completed prior to the June 2017 retirement of the Brayton Point Energy, LLC generation plant in Somerset, Massachusetts (Brayton Point), which drives the need for the Project. The estimated cost of the Project is $1.994 million.

1.3 NEED FOR PROJECT

This Project will address transmission system reliability issues resulting from the planned retirement of Brayton Point in June 2017. Closure of Brayton Point, historically one of the largest generators of electricity in New England, has the potential to affect the system's ability to reliably meet power demand. The independent system operator of New England (ISO-NE) assessed reliability issues caused by Brayton Point's retirement, and carefully evaluated the feasibility and effectiveness of the possible solutions for resolving the issues. ISO-NE concluded that the Project is necessary in the short term to mitigate potential thermal overloads on transmission system equipment caused by N-1 single element contingencies.

1.4 SUMMARY OF ENVIRONMENTAL EFFECTS AND MITIGATION

The Project is located within the existing V148N Line ROW, and access will be via existing or improved routes, thereby minimizing adverse environmental impacts. No long-term impacts to soil, bedrock, vegetation, surface water, groundwater, wetland resources, or air quality are anticipated. Any potential sedimentation impacts and other short-term construction impacts to wetlands and surface waters will be mitigated by the use of soil erosion and sediment control best management practices (BMPs) and swamp mats to protect wetland soils, vegetation root stock, streams and stream bank. Swamp mats consist of timbers which are bolted together and placed over wetland areas to distribute equipment loads and minimize disturbance to the wetland and soil substrates. Minor, temporary disturbances of wildlife may result from equipment and construction crews working within the Project corridor. Any wildlife displacement will be negligible and temporary, since no permanent alteration of the existing habitat is proposed. As part of the Project, an environmental monitor will work with the construction team to ensure compliance with regulatory programs and permit conditions, and to oversee the proper installation and maintenance of the soil erosion and sediment control BMPs.

1.5 SUMMARY OF SOCIAL EFFECTS AND MITIGATION

The Project involves improvements to an existing transmission line within an existing ROW and is not anticipated to result in any long-term impacts to residential, commercial or industrial land uses. Any construction noise impacts are expected to be brief and localized. The Project will result in minor changes to structure height or placement, and no significant visual impacts are anticipated. Traffic management plans will be developed in consultation with the Rhode Island Department of Transportation (RIDOT) and employed as necessary at ROW access points off local and state roads. The Project will not adversely impact the social and economic conditions in the Project Area.

1.6 CONCLUSION

The Project is proposed to allow TNEC to continue to provide a reliable supply of electricity to customers in a cost effective manner. With the implementation of appropriate construction mitigation measures, no significant environmental or social impacts are anticipated from the Project.

2 PURPOSE AND NEED

2.1 INTRODUCTION

National Grid strives to provide its customers with high quality, reliable electric service at the lowest possible cost, while minimizing adverse environmental and social impacts. Reliability is measured in terms of the frequency and duration of power outages lasting one minute or more. The quality of electric service refers to voltage levels, variations in voltage frequency, harmonics, and outages lasting less than one minute.

To reduce the chance of a long-term outage affecting large numbers of customers in one geographic area, National Grid, like other U.S. electric utilities, has developed design criteria, policies, and standards used both to assess the adequacy of the existing and future transmission system for reasonably anticipated conditions and also to provide guidance in the design of future modifications or upgrades to the transmission system. These electric transmission design criteria and standards are contained in the latest version of the National Grid Transmission Planning Group Procedure 28 (TGP-28).

National Grid, in cooperation with ISO-NE and other affected transmission owners (TOs), routinely undertakes transmission planning studies to determine whether new or upgraded facilities are needed within a specified timeframe (typically 10 years) to maintain reliable electric power within a specific geographic area. In March 2011, an ISO-NE Working Group (Working Group) launched a transmission planning study for the southeastern Massachusetts and Rhode Island (SEMA-RI) area (including Cape Cod).

In October 2013, Brayton Point Energy LLC notified ISO-NE of its intent to retire its approximately 1,500-megawatt (MW) Brayton Point generating facility in Somerset, Massachusetts, effective June 2017. In response, the Working Group assessed the reliability issues raised by the Brayton Point retirement and identified short-term improvements needed prior to June 2017 to maintain the reliability of the SEMA-RI area electric transmission system. This analysis was presented to the ISO-NE Planning Advisory Committee (PAC) at its July 2014 meeting. Among these needed improvements is the reconductoring of the V148N Line.

The proposed Project will help to maintain the reliability of the electric supply in northern Rhode Island area following the retirement of the Brayton Point generation in June 2017. Specifically, the Project will reinforce the V148N Line so that it will not overload during certain contingency operating conditions.

2.2 REGIONAL TRANSMISSION PLANNING PROCESS

National Grid's transmission system is part of a complex network of generation, transmission and distribution facilities which must reliably deliver electrical power to utility customers within New England. The National Grid transmission system affects and is affected by the generation, load, and transmission configurations of the electric systems operated by neighboring utilities and in neighboring states.

The Federal Energy Regulatory Commission (FERC) has designated all of New England as a single operating area, and has designated ISO-NE as the independent system operator for the New England control area. As such, ISO-NE is responsible for the reliable operation of New England's power generation and transmission system, and for managing a comprehensive transmission planning process consistent with federal and regional standards.

2.2.1 Transmission Planning Studies – Contingency Analysis

ISO-NE and its Working Groups conduct transmission planning studies to determine whether New England transmission facilities meet the reliability criteria and standards established by the North American Electric Reliability Corporation (NERC), the Northeast Power Coordinating Council (NPCC), the New England Power Pool (NEPOOL), and ISO-NE itself. These studies are conducted using a "what-if" approach that tests the loading of each piece of equipment under a range of reasonably stressed system conditions. The capability of the system under these conditions is studied using computer simulations which model the electrical parameters of the system. The transmission system is analyzed under "normal" conditions, and also under contingencies involving the loss of one or more transmission system facilities.

Contingency analysis involves two levels of study. The first level is single contingency analysis (commonly referred to as N-1 analysis). It involves testing all possible single contingencies that could affect the area of interest. A single contingency represents a "single event", such as the outage of a single transmission line, transformer or generator, or the failure of a circuit breaker or double-circuit tower. The contingency is simulated and the effects of the contingency on the power system are studied. The resulting system loadings and voltage levels are assessed to see if they meet criteria following the contingency event.

The second level of study is second contingency analysis (commonly referred to as N-1-1 analysis). Second contingency analysis studies the reliability of the transmission system in response to two separate events that occur close together in time. The first event involves taking out of service an element that is critical to the area of interest, such as a 345 kV line, a 345/115 kV transformer, a 115 kV line, or a generator. System generation and power flows can be adjusted following the first event in preparation for a second event, using generators capable of 10-minute reserve, generation tripping, transformer load tap changers and switching series and shunt capacitors and reactors. The second event is performed by running the single contingency analysis (N-1 analysis).

Once the computer modeling is complete, the results of each N-1 and N-1-1 contingency are analyzed to determine whether any piece of equipment is carrying more electric current than the equipment is rated for, based on the assumed ambient temperatures. Voltage levels are checked to determine that they are within appropriate ranges. System stability, grounding, fault current levels, operability, and ability to maintain the system are also considered. As a result of this analysis, transmission planners can identify elements of the transmission system that need to be reinforced in order to continue to provide reliable electric service within the study area.

2.2.2 Transmission Planning Studies – Solutions

After identifying potential problems within the study area under expected electrical loads and possible contingency situations, plans are developed to mitigate the problems. Typically these plans call for replacing existing equipment or adding facilities to the electric system. The plans are developed and evaluated based on the reliability criteria as described in the Transmission Planning Documents. Other factors used to evaluate proposed plans include equipment standards and specifications, relaying practices, operational and maintenance considerations, safety, environmental impacts, and economics. The evaluation of electrical alternatives leads to a recommended plan that is presented to the ISO-NE PAC.

2.3 SEMA-RI WORKING GROUP ANALYSIS

The Working Group's analysis of the June 2017 Brayton Point retirement is summarized in a July 2014 PAC presentation entitled "Brayton Point Non-Price Retirement: Short Term Reliability Upgrades." The thermal and voltage performance of the SEMA-RI transmission system was modeled using 2017 peak load conditions, and without the Brayton Point generation.[3] Potential thermal overloads were identified on the V148N Line between Washington Substation and Woonsocket Substation under both N-1 and N-1-1 contingencies.[4] The Working Group determined that the best means of resolving these potential overloads is to reconductor the V148N Line with a higher rated conductor, based on its lower estimated cost when compared to other considered alternatives and its anticipated ease and speed of construction. In addition, this solution involves minimal change to the existing area transmission system and therefore is expected to complement the recommendations of the broader SEMA-RI transmission planning study.

2.4 CONCLUSION

Analysis undertaken by the SEMA-RI Working Group demonstrates that existing transmission facilities are inadequate to meet NERC, NPCC and ISO-NE reliability standards and criteria following the June 2017 retirement of 1,500 MW of generation at Brayton Point in Somerset, Massachusetts. Among the identified issues are potential thermal overloads on the V148N Line. This Project addresses these potential thermal overloads by reconductoring the V148N Line to allow it to increase the capacity. Because the need for the Project is driven by the June 2017 retirement of generation at Brayton Point, it must be addressed immediately.

[3] The Working Group modeled cases with and without the Interstate Reliability Project (IRP) in service. The short term reliability upgrades described in July 2014 presentation reflect the IRP-in-service cases. The IRP is currently under construction; its anticipated in-service date is December 2015.

[4] The Working Group also identified potential overloads of a 345/115 kV transformer at the West Farnum substation, a 345/115 kV transformer at the Kent County substation, and of the 1280 and 1870S transmission lines under N-1-1 contingencies. These issues are being addressed in separate projects.

3 PROJECT DESCRIPTION AND PROPOSED ACTION

3.1 INTRODUCTION

This section presents an overview of the existing and proposed facilities along the V148N Line, typical construction practices, estimated Project costs, and the anticipated Project schedule. The Permitting and Access Plans (Figure 3-3, Sheets 1 to 18) provide an overview of Project site conditions and are referred to extensively throughout this section.

3.2 DESCRIPTION OF THE EXISTING V148N LINE

The existing V148N Line, originally constructed in 1966, begins at the Woonsocket Substation in North Smithfield and terminates at the Washington Substation in Lincoln (see Figure 1-1: Site Locus). The existing and proposed ROW cross-sections showing typical arrangements of lines are presented in Figure 3-2, Sheets 1 to 3.

From the Woonsocket Substation to Structure 179, a distance of approximately 0.7 miles, the ROW is approximately 232.5 feet wide and contains the V148N Line, the 115 kV H17 Line, and the 105K1 distribution feeder, all on different structures. Along the 1.2-mile section between Structures 180 and 190 the ROW is approximately 270 feet wide and contains the V148N Line and the 105K1 distribution feeder. Finally, along the 2.3-mile section from Structure 191 to Washington Substation the ROW is approximately 125 feet wide and contains only the V148N Line.

The existing V148N Line is primarily supported by double circuit steel lattice towers interspersed with a few wood structures. The conductors are predominantly 795 kcm All Aluminum Conductor Wire (AAC) “Arbutus”, and the shieldwire is 1-3/8” Extra High Strength (EHS) shieldwire.

3.3 SCOPE OF THE PROJECT

The process of reconductoring a transmission line involves replacing existing conductors with new conductors. In the case of the Project, the new conductors will increase the capacity of the line. The Project scope includes reconductoring approximately 4.2 miles of the 115 kV V148N Line with 795 kcm 26/7 Aluminum Conductor Steel Supported (ACSS) “Drake” conductors. The scope also includes replacing the existing shieldwire with Optical Ground Wire (OPGW). To support the additional structure loads from the new wires, the following structure work will commence:

- Replace 6 structures and associated hardware: 3 are installed on concrete foundations and 3 are installed using direct embed methods;
- Remove 1 structure and associated hardware; and
- Reinforce 31 towers and associated hardware.

The proposed modifications will not significantly change the appearance of the existing ROW or the V148N Line. When the project is complete, the total number of structures will be reduced from 45 to 44. Work at both substations is expected to be minimal. Vegetation mowing and minor tree trimming will be performed along the existing ROW in conjunction with the Project. A detailed overview of the Project is presented in the Permitting and Access Plans (Figure 3-3). The typical cross-sections in Figure 3-2 also depict the proposed typical arrangement of lines.

3.4 CONSTRUCTION PRACTICES

Construction will be carried out using conventional overhead electric power line methodologies, and is expected to proceed through the phases listed below and described in the following sections.

- ROW Vegetation Maintenance
- Erosion and Sediment Controls/BMP Measures
- Access Road Improvements and Maintenance
- Installation of Foundations and Structures
- Removal and Disposal of Existing Line Components
- New Conductor and OPGW Installation
- Restoration of the ROW

An environmental monitor will work with the contractor and construction supervisor on a day-to-day basis and will be on-site throughout construction. The environmental monitor's primary responsibilities include the following:

- Inspect and monitor construction including the installation and condition of soil erosion and sediment controls and construction BMPs; propose modifications, as appropriate;
- Monitor compliance with Project commitments and environmental permit conditions and approvals;
- Provide oversight when work is located in or near sensitive environmental resources;
- Ensure strict adherence to National Grid environmental policies and procedures; and
- Maintain good communications with the Applicant's Construction Supervisor, the Contractor and work crews.

All applicable policies, procedures, and BMPs, will be implemented in accordance with National Grid's EG-303 NE *ROW Access, Maintenance and Construction Best Management Practices* (EG 303NE).

An Environmental Field Issue (EFI) will be developed for the Project to provide a single, comprehensive document that outlines permit conditions and requirements to be followed before, during and after Project construction. Copies of the EFI will be kept on file at the site trailer and/or the site supervisor's vehicle. The EFI details the scope of the Project, approved access routes, permit deliverables, sensitive areas to be avoided, detailed soil erosion and sedimentation controls, notifications and expiration dates, a list of Project contacts, training requirements/documentation, a copy of the EG-303NE, appropriate plan sets, and copies of permits and approvals obtained for the Project. All contractors and environmental leads will be required to participate in EFI training before beginning to work on the site. Regular team meetings will provide the opportunity to reinforce the contractor's awareness of environmental and regulatory matters.

3.4.1 Project ROW Vegetation Maintenance

Vegetation mowing and selective tree trimming along the V148N Line ROW will provide access to Project structure locations, facilitate safe equipment passage, and provide safe work sites for personnel within the ROW. Vegetation maintenance conducted for the Project will also maintain safe clearances between vegetation and transmission line conductors for the reliable operation of the transmission facilities.

Typical equipment used for vegetation management includes track-mounted mowers and shears. Herbicides will not be used for this Project.

3.4.2 Erosion and Sediment Controls/BMP Measures

Following the vegetation maintenance activities, proper soil erosion and sediment control devices, such as straw bales, straw wattles, compost mulch tubes and/or siltation fencing will be installed in accordance with the Rhode Island Soil Erosion and Sediment Control Handbook and the approved plans and permit requirements (as developed based on site-specific conditions). The soil erosion and sediment control program for the Project will follow the procedures identified in EG-303NE.

Sediment control devices will be periodically inspected and monitored by the environmental monitor and construction supervisor, and the results will be reported regularly to the construction supervisor. The soil erosion and sediment controls will be installed between the work area and environmentally sensitive areas such as wetlands, streams, drainage courses, roads and adjacent property when work activities will disturb soils and result in a potential for causing soil erosion and sedimentation. The devices will function to mitigate construction-related soil erosion and sedimentation, and will also serve as a physical boundary to delineate resource areas and to contain construction activities within approved areas.

Where upland access is not available, wetland and stream crossings may be accomplished by the temporary placement of temporary swamp mats or swamp mat bridges. Crane or log trucks will be used to place swamp mats in locations where temporary access across wetland areas is proposed. Swamp mats and swamp mat bridges will be removed following completion of construction and, if necessary, areas will be restored to re-establish pre-existing topography and hydrology. The use of swamp mats and swamp mat bridges for the Project will follow the procedures identified in EG-303NE.

3.4.3 Access Road Improvements and Maintenance

Access roads are required within the ROW to provide the ability to construct, inspect, and maintain the existing and proposed transmission line facilities. Proposed access routes are shown in the Permitting and Access Plans (Figure 3-3). Existing access roads will require maintenance or upgrades to support construction activities in some areas. For example, placement of clean gravel or trap rock may be necessary to stabilize and level the roads for construction vehicles.

Access across wetlands and streams, where upland access is not available, will be accomplished by the temporary placement of swamp mat bridges, as described in the previous section. Such temporary swamp mat access roads will be removed following completion of construction and if necessary, areas will be restored to re-establish pre-existing topography and hydrology.

Any access road improvements and/or maintenance will be carried out in compliance with the conditions and approvals of the appropriate federal, state, and local regulatory agencies. Exposed soils on access roads will be wetted and stabilized as necessary to suppress dust generation. Crushed stone aprons will be used at access road entrances to public roadways to clean the tires of construction vehicles and minimize the migration of soils off-site. Public roadways will be swept to remove soil accumulations from the Project, as appropriate.

Off-ROW access via existing or improved access routes will be necessary for Project construction activities at Structures 198 and 199. Selective tree trimming may be required in order to allow the safe passage of vehicles and equipment. The above-described BMPs will also be implemented for any off-ROW access road improvements.

Equipment used to maintain access roads typically consists of dump trucks used to transport fill materials to work sites, and bulldozers, excavators, backhoes and graders to place fill materials or to make cuts to achieve the proper access road profile. Crane or log trucks will be used to place swamp mats in locations where temporary access across wetland areas is proposed. Throughout the Project, pick-up trucks will be used to transport crews and equipment to work sites. Low-bed trailers will be used to transport tracked equipment which cannot be operated on public roadways.

3.4.4 Installation of Foundations and Structures

As noted previously, 6 steel replacement structures will be installed. Three of the steel replacement structures will be H-frame suspension structures installed using direct embed methods. The remaining 3 will have concrete caisson foundations, and consist of an H-frame deadend structure, an H-frame switch structure and a 3-pole dead end pull off (DEPO) structure. Please refer to Figure 3-2, Sheets 4 to 6. Installation procedures followed for direct embed and concrete caisson foundations are described below.

Excavation for direct embedment structures typically will be performed using a soil auger or rock coring equipment. Excavations will be up to 12 feet in depth and 3 feet in diameter. A steel casing will be placed vertically into each excavation and backfilled. The structures will be field assembled and placed by cranes into the steel-cased excavations. The annular space between the structure and casing will then be backfilled with crushed stone or similar select backfill.

Reinforced caisson foundations are expected to be between 20 to 50 feet deep and 6 to 10 feet in diameter. The caisson construction involves drilling a vertical shaft, installing the steel reinforcing cage, placing steel anchor bolts, pouring concrete, and backfilling as needed. The structure would be attached to the anchor bolts. Structures will be lifted by a crane and attached to the anchor bolts.

For both types of installation, excavated material will be temporarily stockpiled next to the excavation. This material will not be placed directly into resource areas. If the stockpile is in close proximity to wetlands, it will be enclosed by staked straw bales or other sediment controls. Additional controls, such as watertight mud boxes may be used for saturated stockpile management in work areas in wetlands (i.e., swamp mat platforms) where sediment-laden runoff would pose an issue for the surrounding wetland. Following the backfilling operations, excess soil will be spread over unregulated upland areas or removed from the site.

Rock encountered during foundation excavation will generally be removed by means of drilling or other mechanical means. Blasting is not anticipated for this Project. If dewatering is necessary during foundation activity, it will be performed in compliance with EG-303NE procedures and applicable regulatory approvals.

Upland work pads will be created at structure locations by grading or adding gravel to provide a level work surface for construction equipment and crews. Once construction is complete, the work pad locations will be stabilized with topsoil and mulched to allow vegetation to re-establish. In wetlands, these work pads will be created with timber swamp mats. Temporary swamp mat access roads will be removed following completion of construction and if necessary, areas will be restored to re-establish pre-existing topography and hydrology.

Equipment typically used during the installation of foundations and pole structures includes excavating equipment such as backhoes and clam shell diggers, drill rigs, rock drills and concrete trucks. Cranes will be used to erect structures. Hand-held equipment, including shovels and vibratory tampers, will be used during the backfilling of foundations and pole structures. Dump trucks will be used to remove excavated materials from the work site if necessary. Tracked equipment which cannot be operated on public roadways will be transported to work sites by means of a low-bed trailer.

3.4.5 Removal and Disposal of Existing Line Components

The existing conductors and steel material will be removed from the structures and recycled, where possible. Seven wood structures also will be removed. These are all direct embed structures which will be extracted by cranes and removed from the ROW for proper recycling or disposal. Once the wood structures are removed, soil excavated for new structures will be used for fill, and any disturbed surface area will be restored, as necessary.

Equipment typically used during the removal and disposal of existing line components includes cranes and bucket trucks. Dump trucks will be used to remove materials from the work site for recycling or disposal at approved facilities.

3.4.6 New Conductor and OPGW Installation

Insulators will be installed on the structures to separate the energized power conductors from the structure. Conductors and OPGW will then be installed using stringing blocks and wire stringing equipment. The wire stringing equipment is used to pull the conductors from a wire reel on the ground through stringing blocks attached to the structure to achieve the desired sag and tension condition. During the stringing operation, temporary guard structures may be placed at road and highway crossings and at crossings of existing utility lines. Guard structures are used to ensure public safety and uninterrupted operation of other utility equipment by keeping the new conductor off the traveled way and away from other utility wires at these critical locations. To avoid impacts in environmentally sensitive areas, the booms of small cranes and bucket trucks may be used as guard structures during the stringing operation. The OPGW is used for communication as well as lightning protection and will be installed on top of the structure in a similar manner.

As noted previously, existing or re-established access roads will be used to the extent practicable to support wire stringing equipment. However, some grading may be required to provide a level work space for equipment and personnel or to establish remote wire stringing set-up sites at angle points in the transmission line.

Equipment typically used during the installation of conductors includes puller-tensioners, conductor reel stands, bucket trucks, and small platform cranes. Pickup trucks will be used to transport work crews and small materials to work sites.

3.4.7 Restoration of the ROW

Restoration efforts, including removal of construction debris, final grading, stabilization of disturbed soil, and installation of permanent sediment control devices, will be completed following the construction operations. All disturbed areas around structures and other graded locations will be seeded with an appropriate conservation seed mixture and/or mulched to stabilize the soils in accordance with applicable regulations. Temporary sediment control devices will be removed following the stabilization of disturbed areas. Pre-existing drainage patterns, ditches, roads, walls, and fences will generally be restored to their former condition, where feasible. To the extent feasible, regulated environmental resource areas temporarily disturbed by construction will be restored to pre-construction conditions in accordance with applicable permit conditions.

3.4.8 Environmental Compliance and Monitoring

The services of an environmental monitor will be retained throughout the construction phase to facilitate compliance with federal, state and local permit requirements and National Grid policies. In addition, the construction contractor will be required to designate an individual to be responsible for the daily inspection and upkeep of environmental controls. This person will also be responsible for providing direction to the other members of the construction crew regarding matters such as wetland access and appropriate work methods. Installation and repair of BMPs and other compliance issues are tracked on an inspection form or action log that is updated and distributed weekly to appropriate personnel. Additionally, construction personnel will be briefed on Project environmental concerns and obligations prior to the start of construction. Regular construction progress meetings will reinforce the contractors' awareness of these issues.

3.4.9 Construction Traffic

Access to the ROW for construction equipment will typically be gained from local or state-controlled roadways in various locations in the vicinity of the route, but in some cases access may be via private property in accordance with access agreements. Traffic will be intermittent at entry roadways because construction tasks will take place at different times and locations over the course of construction. Vehicle types will range from pick-up trucks to heavy construction equipment.

The safety and well-being of work crews, drivers, and the public is of paramount importance. National Grid policies and state or local permit conditions will be followed to ensure safe transport of crews and roadway users.

3.5 ONGOING ROW MAINTENANCE

Ongoing ROW vegetation maintenance includes mowing and selective tree trimming. Maintenance activities typically occur once every 3 to 5 years. Regular maintenance supports the safe, reliable delivery of power to consumers by allowing access to structure locations for necessary inspections, repair, and maintenance, enables safe equipment passage, provides safe work sites for personnel within the ROW, and maintains safe and reliable clearances between vegetation and transmission line conductors.

ROW maintenance activities are conducted in accordance with Rhode Island Department of Environmental Management (RIDEM) Division of Agriculture requirements, the ongoing ROW maintenance program, and state and federal regulations that mandate the management of utility ROWs. National Grid's Policies and procedures incorporate extensive BMPs, which provide oversight and consistency while minimizing impacts to resource areas.

Vegetation management on the ROW is performed using integrated procedures, combining hand cutting, targeted herbicide use, mowing, selective trimming and side trimming. Three methods of targeted herbicide treatments are utilized: basal application, cut stump treatment, and foliar application. Herbicide will not be used for this Project.

The appropriate method of vegetation management is chosen by a forester or arborist in accordance with the overall ROW maintenance program. The long-term vegetation maintenance of the ROW will continue to be accomplished by hand and mechanical cutting, and possibly the selective application of herbicides, where necessary. Long-term ROW vegetation maintenance practices encourage the growth of low-growing shrubs and other vegetation that provide a degree of natural vegetation control. Herbicides are never applied in areas of standing water or within designated protective buffer areas associated with wells, surface waters, and agricultural areas.

3.6 SAFETY AND PUBLIC HEALTH CONSIDERATIONS

The reconductored V148N Line will be designed, built and maintained such that the health and safety of the public are protected. Work will comply with applicable regulations, industry standards, and guidelines established for the protection of the public. Specifically, the Project will be designed, built, and maintained in accordance with the National Electrical Safety Code (NESC).

The facilities will be designed in accordance with sound engineering practices using established design codes and guides published by, among others, the Institute of Electrical and Electronic Engineers (IEEE), the American Society of Civil Engineers (ASCE), the American Concrete Institute (ACI), and the American National Standards Institute (ANSI). Practices which will be used to protect the public during construction will include, but not be limited to, establishing traffic control plans to maintain safe driving conditions, restricting public access to potentially hazardous work areas, and use of temporary guard structures at road and electric line crossings to prevent accidental contact with the conductor during installation. Following construction, transmission structures and switching station facilities will be clearly marked with warning signs to alert the public of potential hazards if climbed or entered.

A discussion of the current status of the health research relevant to exposure to electric and magnetic fields (EMF) is attached as Appendix A. This report was prepared by Exponent, Inc.

3.7 PROJECT COSTS

National Grid prepared a planning grade estimate of the costs associated with the Project. Planning estimates are prepared prior to detailed engineering in accordance with their estimating guidelines. Planning grade estimates are prepared using historical cost data, data from similar projects, and other stated assumptions of the Project engineer. The accuracy of planning grade estimates is expected to be ± 25%. Estimated costs include costs of materials, labor and equipment, and escalation. The estimated capital cost associated with the Project is approximately $11.994 million.

3.8 PROJECT SCHEDULE

Project construction is anticipated to begin in September of 2015 and be completed by mid-2016. This schedule is designed specifically to ensure that the reconductoring is completed prior to the June 2017 retirement of Brayton Point.

3.9 PROJECT OUTREACH

Prior to construction, abutters within 200 feet of the ROW will be sent fact sheets describing the Project need, location and anticipated construction schedule. The fact sheet will also include the direct contact number for the Stakeholder Specialist assigned to the Project. Additional meetings will be arranged with abutters at their request. A member of the Project team met with local officials in December 2014 and January 2015 to brief them on the Project.

4 ALTERNATIVES TO THE PROPOSED ACTION

4.1 INTRODUCTION

This Project is one of several short term measures to be undertaken by TNEC at the direction of ISO-NE to address transmission system reliability issues created by the impending retirement of approximately 1,500 MW of generation at Brayton Point in 2017. This Project will address projected thermal overloads of the V148N Line under contingency conditions by increasing the capacity of the line.

4.2 "DO NOTHING" ALTERNATIVE

The Do Nothing alternative would avoid environmental impacts but would not address contingency thermal overloads on the V148N Line following the retirement of generation at Brayton Point, and thus would leave at risk the transmission system serving Rhode Island and southeast Massachusetts. Because this alternative does not address projected transmission system reliability issues, TNEC did not pursue it further.

4.3 NEW 115 KV TRANSMISSION LINE -- OVERHEAD

As an alternative to reconductoring the existing V148N Line, TNEC considered construction of a parallel 115 kV overhead transmission line, either on the existing ROW or in a new ROW. Construction of a parallel 115 kV transmission line could reduce the post-contingency loading on the existing V148N Line sufficiently to eliminate potential thermal overloads. However, construction of a new line would require TNEC to purchase all new structures and conductor and to acquire any necessary land rights. This would inherently be more costly than simply replacing the existing conductor and repairing or replacing a more limited number of structures. It also likely would result in increased land use and visual impacts, without substantially reducing other natural or human environmental impacts. In light of the higher cost of these alternatives, and in the absence of any countervailing benefits, TNEC concluded that a new overhead transmission line would not be a superior alternative to the Project.

4.4 NEW 115 KV TRANSMISSION LINE -- UNDERGROUND

TNEC also considered the construction of a parallel 115 kV underground transmission line, either on the existing ROW or in an alignment within public roads. Construction of a parallel 115 kV underground transmission line could reduce the post-contingency loading on the existing V148N Line sufficiently to eliminate potential thermal overloads. However, it would introduce a short stretch of underground line into a primarily overhead transmission system, which could create operational issues. In addition, the construction of a new underground line would be substantially more expensive than reconductoring the existing V148N Line. It also would require TNEC to acquire either the rights to build an underground transmission line in the existing ROW, or to acquire rights to place an underground cable within public roadways; either process would be likely to significantly delay the project and would jeopardize TNEC's ability to address projected thermal overloads before the Brayton Point generation is retired. Finally, constructing a new underground line likely would result in increased land use and other natural and human environmental impacts, without notably reducing visual impacts (since the existing V148N Line would remain in place). In light of the substantially higher cost of these alternatives, and in the absence of any countervailing benefits, TNEC concluded that a new underground transmission line would not be a superior alternative to the Project.

5 DESCRIPTION OF THE AFFECTED NATURAL ENVIRONMENT

5.1 INTRODUCTION

As required by Section 1.6(c) of the EFSB Rules, a description of the existing conditions of the natural and social environments within and surrounding the Project ROW has been prepared. This section of the report describes the existing conditions of the natural environment, and Section 6 presents the existing social conditions. Potential impacts and associated mitigation measures are discussed in Sections 7 and 8, respectively. The specific natural features which have been assessed for the evaluation of impacts and mitigation measures include topography, soils, surface water and groundwater resources, wetlands, and wildlife. Consistent with EFSB Rule 1.6(f), this report does not address several environmental parameters (e.g., geology, air quality climate and weather) because Project activities will not impact these features.

Information pertaining to existing site conditions was obtained through available published resource information, the Rhode Island Geographic Information System (RIGIS) database, various state and local agencies, and field investigations within the ROW.

5.2 PROJECT STUDY AREA

A Project Study Area was established to accurately assess the existing environment within and immediately adjacent to the ROW. The Study Area consists of a 2,500-foot wide corridor centered on the existing ROW (see Figure 5-1: Project Study Area).

The approximately 4.2-mile Project corridor extends from the Woonsocket Substation in a southeasterly direction. Based on information obtained from RIGIS, the route is characterized by gently rolling to moderately sloped hills, with elevations ranging from a low of 210 feet above mean sea level (msl) to a high of 360 feet. The lowest elevation point is proximate to Crookfall Brook, which runs in a north/south direction across the central portion of the Study Area near Structure 192. The path of Crookfall Brook is also the North Smithfield/Lincoln town boundary. Crookfall Brook flows through a valley, with hills on both sides rising to the Study Area's highest elevations of approximately 360 feet along the southern side. Another low elevation area (approximately 230 feet) is located at the Woonsocket Substation. The ROW crosses 3 state highways as it extends to the southeast from the Woonsocket Substation – Route 146 (also called the Old Louisquisset Pike), Route 99, and I-295.

Land uses within the Study Area were identified using RIGIS, supplemented by field observation and Google Earth, and are discussed further in Section 6 of this Environmental Report. In general, the perimeter Study Area is predominately comprised of forest and brushland. Other land uses are fragmented within the Study Area, and include residential, power lines/utility, commercial/industrial, highway, and recreation. There are also very small amounts of cropland/pasture and water/wetlands.

5.3 SOILS

This section presents detailed information concerning the physical properties, classification, agricultural suitability, and erodibility of soils in the vicinity of the ROW. Information was obtained from the Natural Resources Conservation Services (NRCS) Web Soil Survey (WSS) and RIGIS.[5,6]

The Soil Survey identifies soil types by classification, and describes their characteristics in terms of slope, the presence of stones (e.g. rocky, outcrop, or ledge) and soil texture (e.g., fine, sandy and/or loam). Also identified are the areas of urban land, where the underlying soil has been altered, cut away or covered by fill material, and/or covered with impervious surfaces. Table 5-1 lists the characteristics of soils found within the Study Area and notes the drainage class and percent slope of each. This information is depicted in Figure 5-2: Soil Drainage Classes. The percentage of the Study Area comprised by each type of soil type is noted in the last column. As shown, *Canton and Charlton fine sandy loams, very rocky* is the predominant soil type, followed by *Ridgebury, Whitman, and Leicester extremely stony fine sandy loams*.

Table 5-1: Soil Characteristics within the Study Area

V148N 115 kV Overhead Transmission Line				
Soil Map Unit Symbol	**Soil Name**	**Drainage Class (See Notes)**	**Percent Slope (%)**	**Percentage of Study Area (%)**
AfB	Agawam fine sandy loam	wd	3 to 8	0.1%
CaC*	Canton-Charlton-Rock outcrop complex	wd	3 to 15	1.3%
CaD*	Canton-Charlton-Rock outcrop complex	wd	15 to 35	3.9%
CB	Canton-Urban land complex	wd	0 to 15	1.0%
CC	Canton-Urban land complex, very rocky	wd	0 to 15	0.3%
CdA	Canton And Charlton fine sandy loams	wd	0 to 3	0.2%
CdB	Canton And Charlton fine sandy loams	wd	3 to 8	6.3%
CeC*	Canton and Charlton fine sandy loams, very rocky	wd	3 to 15	38.1%
ChB*	Canton and Charlton very stony fine sandy loams	wd	3 to 8	3.8%
ChC*	Canton and Charlton very stony fine sandy loams	wd	8 to 15	0.8%
FeA	Freetown, mucky peat	vpd	0 to 2	0.4%
HkC	Hinckley gravelly sandy loam, rolling	ed	3 to 15	2.3%
HkD	Hinckley gravelly sandy loam, hilly	ed	15 to 35	0.6%
MmB*	Merrimac sandy loam	swed	3 to 8	0.4%
MU*	Merrimac-Urban land complex	wd	0 to 8	3.6%
Nt	Ninigret fine sandy loam	mwd	0 to 15	0.6%
PD	Paxton-Urban land complex	wd	0 to 15	0.4%
Rf*	Ridgebury, Whitman, and Leicester extremely stony fine sandy loams	pd and vpd	0 to 3	19.2%
Ru*	Rippowam fine sandy loam	pd	0 to 3	0.4%
Sb*	Scarboro mucky sandy loam	vpd	0 to 3	1.4%
StA*	Sutton fine sandy loam	mwd	0 to 3	0.6%

[5] http://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

[6] Rhode Island Geographic Information System Data Distribution System, http://www.edc.uri.edu/rigis, Environmental Data Center, University of Rhode Island, Kingston, Rhode Island

V148N 115 kV Overhead Transmission Line				
Soil Map Unit Symbol	Soil Name	Drainage Class (See Notes)	Percent Slope (%)	Percentage of Study Area (%)
StB*	Sutton fine sandy loam	mwd	3 to 8	2.1%
SuB	Sutton very stony fine sandy loam	mwd	0 to 8	0.5%
SwA	Swansea mucky peat	vpd	0 to 2	0.3%
UD*	Udorthents-Urban land complex	mwd/ed	variable	7.5%
UR	Urban Land	variable	0 to 5	0.9%
W	Water	subaquatic	n/a	0.3%
Wa	Walpole sandy loam	pd	0 to 8	0.3%
WhB	Woodbridge fine sandy loam	mwd	3 to 8	0.4%
WoB	Woodbridge very stony fine sandy loam	mwd	0 to 8	1.9%

Notes: * This soil type is also within the ROW
ed = excessively drained, swed = somewhat excessively drained, wd = well drained, mwd = moderately well drained, pd = poorly drained (hydric), vpd = very poorly drained (hydric), 8 to 15% slope = highly erodible
Sources: NRCS WSS & RIGIS

5.3.1 Prime Farmland Soils

Prime farmland, as defined by the United States Department of Agriculture (USDA), is the land that is best suited to producing food, feed, forage, fiber, and oilseed crops. It has the soil quality, growing season, and moisture supply needed to economically produce a sustained high yield of crops when it is treated and managed using acceptable farming methods. Rhode Island currently recognizes 33 prime farmland soils.[7] The Study Area includes 8 prime farmland soil units, as listed in Table 5-2.

Table 5-2: USDA Prime Farmland Soils

V148N 115 kV Overhead Transmission Line			
Soil Map Unit Symbol	Soil Name	Percent Slope (%)	Percentage of Study Area (%)
AfB	Agawam fine sandy loam	3 to 8	0.1%
CdA	Canton And Charlton fine sandy loams	0 to 3	0.2%
CdB	Canton And Charlton fine sandy loams	3 to 8	6.3%
MmB*	Merrimac sandy loam	3 to 8	1.3%
Nt	Ninigret fine sandy loam	0 to 15	0.6%
StA*	Sutton fine sandy loam	0 to 3	0.3%
StB*	Sutton fine sandy loam	3 to 8	0.6%
WhB	Woodbridge fine sandy loam	3 to 8	0.4%

Notes: * This soil type is also within the ROW

[7] USDA Natural Resources Conservation Service, Rhode Island Soil Survey, http://www.nrcs.usda.gov/wps/portal/nrcs/detail/ri/home/?cid=nrcs144p2_016615

Prime farmland soils could be utilized as cropland, pastureland, rangeland, forestland or other land. Urbanized land and water are exempt from consideration as prime farmland. Overall, prime farmland soils comprise approximately 9.8% of the Study Area, on land occupied by residential and commercial land uses, conservation land/forest, cleared ROW, and roads. Prime farmland comprises approximately 2.2% of the ROW, primarily on undeveloped land (between Structures 199 and 200) and residentially developed land (intermittently between Structures 203 and 206).

5.3.2 Farmland of Statewide Importance

Farmland of statewide importance is land that is designated by the Rhode Island Department of Administration Division of Planning to be of statewide importance for the production of food, feed, fiber, forage and oilseed crops. Generally, farmland of statewide importance include those lands that do not meet the requirements to be considered prime farmland but that economically produce high crop yields when treated and managed with modern farming methods. In Rhode Island, all USDA-designated prime farmland soils are also categorized as farmland of statewide importance. Therefore, this category includes the 33 soil types identified in Section 5.3.1 as prime farmland, plus 19 additional soil types identified as farmland of statewide importance.[8]

As shown in Table 5-3, soils categorized as farmland of statewide importance comprise just over approximately 13.3% of the Study Area. These soils are located on land occupied by residential and commercial land uses, conservation land/forest, cleared ROW, and roads. Within the ROW, farmland of statewide importance covers approximately 3.3% of land.

Table 5-3: Farmland of Statewide Importance within the Study Area

Soil Map Unit Symbol	Soil Name	Percent Slope (%)	Percent within the Study Area (%)
AfB	Agawam fine sandy loam	3 to 8	0.1%
CdA	Canton And Charlton fine sandy loams	0 to 3	0.2%
CdB	Canton And Charlton fine sandy loams	3 to 8	6.3%
HkC	Hinckley gravelly sandy loam, rolling	3 to 15	2.3%
MmB*	Merrimac sandy loam	3 to 8	1.3%
Nt	Ninigret fine sandy loam	0 to 15	0.6%
RU*	Rumney fine sandy loam	0 to 3	1.2%
StA*	Sutton fine sandy loam	0 to 3	0.3%
StB*	Sutton fine sandy loam	3 to 8	0.6%
Wa	Walpole sandy loam	0 to 8	0.3%
WhB	Woodbridge fine sandy loam	3 to 8	0.4%

*This soil type is also within the ROW

[8] http://www.nrcs.usda.gov/wps/portal/nrcs/detail/ri/home/?cid=nrcs144p2_016615

5.3.3 Potentially Erosive Soils within the ROW

The erodibility of a soil is dependent on a number of factors, including the soil type and texture and the slope of the land. NRCS has characterized soil map units as "highly erodible", "potentially highly erodible", or "not highly erodible" based on factors such as the effects of rainfall, soil characteristics, and the length and steepness of slope. Table 5-4 lists the soil map units with strongly sloping or rolling hills (potential slopes of 8% or greater) and soil map units that are considered to be erodible.

Table 5-4: Soil Mapping Units with Steep Slopes and Potential Erodibility within the ROW

V148N 115 kV Overhead Transmission Line				
Soil Map Unit Symbol	**Soil Name**	**Percent Slope (%)**	**Erodibility Hazard[1]**	**Percent within the ROW (%)[2]**
CaC	Canton-Charlton-Rock outcrop complex	3 to 15	phel	4.3%
CaD	Canton-Charlton-Rock outcrop complex	15 to 35	hel	11.3%
CeC	Canton and Charlton fine sandy loams, very rocky	3 to 15	phel	40.9%
ChC	Canton and Charlton very stony fine sandy loams	8 to 15	hel	0.7%
MmB*	Merrimac sandy loam	3 to 8	phel	1.3%
StB	Sutton fine sandy loam	3 to 8	phel	0.6%

Notes: [1] hel = highly erodible land, phel = potentially highly erodible land
[2] The total does not add to 100% due to the presence lower erodibility soil types along the ROW.
Source: http://www.nrcs.usda.gov/wps/portal/nrcs/detail/ri/soils/?cid=nrcs144p2_016637

5.4 SURFACE WATER

The Project lies within the southernmost section of the Blackstone River drainage basin of Rhode Island, which comprises 258 square miles and has a length of 24 river miles. The major Rhode Island tributaries of the Blackstone River are the Clear and Branch Rivers and Abbott Run. Ten Rhode Island municipalities are located either entirely or partially within the Blackstone River Watershed.[9] Figure 5-3: Surface and Groundwater Resources provides an overview of water resources, and Figure 5-4: Wetlands and Surface Waters shows the Surface Water Protection and Community Wellhead Protection Areas within the Study Area. Much of the central portion of the Project lies within the Crookfall Brook watershed. Crookfall Brook flows along the town line between North Smithfield and Lincoln and cuts across the ROW between Structures 191 and 192 before continuing north to meet the Blackstone River.

Spring Brook, a tributary to Crookfall Brook, flows parallel to and north of the V148N Line between Structures 181 and 187. Unnamed tributaries to Spring Brook are located near Structures 182 and 185. In Lincoln, Meaders and Rochambeau Ponds are hydrologically connected to the Blackstone River. The ponds are situated northeast of the transmission line near Structures 195 to 203. Meaders Pond drains northwest to Rochambeau Pond via an unnamed tributary. Unnamed tributaries to Rochambeau Pond are near structures 198 and 199, and an unnamed tributary to Meaders Pond is near Structures 203 and 204.

Rhode Island waters are assigned a Use Class, per the Rhode Island Water Quality Regulations, which is defined by the most sensitive, and therefore governing, uses which it is intended to protect. Waters are classified based on considerations of public health, safety and welfare, recreation, propagation and

[9] http://www.ririvers.org/wsp/Watersheds/BlackstoneRiverWatershed.htm

protection of fish and wildlife, and economic and social benefit. Table 5-5 presents the water quality classification and use of the surface waters that fall within the Study Area, where available.

Table 5-5: Surface Water Resources within the Study Area

V148N 115 kV Overhead Transmission Line				
Water Body Name/ ID#[1]	**Town**	**Approximate Location**	**Use Classification[2]**	**Fishery Designation[2]**
Crookfall Brook ID# RI0001004R-01	North Smithfield and Lincoln	Between Structures 191 and 192 of the V148N Line	AA	Cold
Spring Brook ID# RI0001004R-02	North Smithfield	Parallel to Structures 181 to 187	AA	Warm
Meaders Pond	Lincoln	Near Structure 202	-	-
Upper Rochambeau Pond/Handy Pond ID# RI0001003L-04	Lincoln	North of Structure 199	B	-
Rochambeau Pond/Handy Pond Tributary	Lincoln	Between Meaders Pond and Handy Pond	-	-

Notes: [1] ID #'s are presented if identifiable based on available information.
[2] - indicates information not available.
Source: RIDEM Office of Water Resources, Water Quality Regulations, Amended December 2010, http://www.dem.ri.gov/pubs/regs/regs/water/h2oq10.pdf.

Additional information pertaining to the use classification and fishery designation for each water body is provided below. Table 5-6 presents the impairment status for the surface waters listed above.

Table 5-6: Impairment Status of Surface Water Resources within the Study Area

	Designated Use				
Surface Waters	**Fish, other Aquatic Life and Wildlife**	**Primary and/or Secondary Recreation**	**Public Drinking Water Supply**	**Fish Consumption**	**Cause of Impairment/ Category[1,2]**
Crookfall Brook	Good	Impaired	Good	Not Assessed	Enterococcus Bacteria/ TMDL Completed
Spring Brook	Not Assessed	Not Assessed	Not Assessed	Not Assessed	-
Upper Rochambeau Pond/Handy Pond	Good	Good	-	Not Assessed	-
Handy Pond Tributary	Not Assessed	Not Assessed	-	Not Assessed	-
Meaders Pond	-	-	-	-	-

Notes:
[1]TMDL = Total Maximum Daily Load; the maximum allowed pollutant load to a water body without exceeding water quality standards.
[2] - indicates information not available.
Source: Rhode Island Department of Environmental Management, 2012 303(d) List of Impaired Waters, Final, August 2012 http://www.dem.ri.gov/pubs/303d/303d12.pdf

5.4.1 Crookfall Brook Watershed

Crookfall Brook is a 6.1-mile long stream located in the Towns of Lincoln, North Smithfield, and Smithfield. The brook originates in a forested area in Smithfield south of I-295, and flows northward into Lincoln and through a series of wetland areas. Within the Project ROW, Crookfall Brook forms the boundary between North Smithfield and Lincoln.

The Woonsocket Reservoirs and Crookfall Brook and its tributaries are components of a public drinking water supply. Specifically, Crookfall Brook is within the watershed for Woonsocket Reservoir #1, and protection of this reservoir and its watershed are critical as Crookfall Brook conveys water directly from Reservoir #3 to Reservoir #1, with an emergency pipeline between Reservoirs in the event of contaminant problems in the brook. A large segment of the ROW is within the Crookfall Brook Surface Water Protection Area (SWPA) (see the Permitting and Access Plans (Figure 3-3), sheets 3 through 11 and Figure 5-4).

The use classification of "AA" indicates that these waters are designated as a source of public drinking water supply (PDWS) or as tributary waters within a public drinking water supply watershed. In addition, AA waters have primary and secondary contact recreational activities and for fish and wildlife habitat. These waters are intended to have excellent aesthetic value. However, as it is not a terminal reservoir, the brook's applicable designated uses are primary and secondary contact recreation. Crookfall Brook's designation as a cold water fish habitat indicates a dissolved oxygen content of not less than 75% saturation, based on a daily average, and an instantaneous minimum dissolved oxygen concentration of at least 5 mg/l, except as naturally occurs.

Crookfall Brook is designated as a "Special Resource Protection Water" (SRPW), which means it has significant recreational or ecological uses, and it is provided special protections under RIDEM's Antidegradation Provisions. According to the Rhode Island Water Quality Regulations, as amended December 2010, where high quality waters constitute a SRPW, there shall be no measurable degradation of the existing water quality necessary to protect the characteristic(s) which cause the waterbody to be designated as an SRPW.

The probable sources contributing to the Crookfall Brook impairment for reporting year 2012 include septic systems and similar decentralized systems, urban runoff/storm sewers, wastes from pets, and wildlife other than waterfowl.[10]

5.4.2 Spring Brook

Spring Brook is an approximately 2-mile stream in North Smithfield with a water use classification of AA, as described above. Spring Brook is not listed as a SRPW, and it has not been assessed for impairment. Its designation as a warm water fish habitat indicates dissolved oxygen content of not less than 60% of saturation, based on a daily average, and an instantaneous minimum dissolved oxygen concentration of at least 5.0 mg/l, except as naturally occurs.

[10] USEPA 2012 Waterbody Report for Crookfall Brooks and Tribs, http://ofmpub.epa.gov/waters10/attains_waterbody.control?p_au_id=RI0001004R-01&p_cycle=2012#attainments

5.4.3 Upper Rochambeau Pond/Handy Pond, Meaders Pond and the Tributary to Rochambeau/Handy Pond

An unnamed tributary flows north between Meaders Pond and Rochambeau Pond/Handy Pond. Only a small portion of Rochambeau Pond is within the Study Area, but it should be noted that this is a man-made pond, divided into upper and lower portions by a dam and impounded at the northern end of the upper portion of the pond by a second dam. Rochambeau Pond and most of the tributary are within the Handy Pond Conservation Area. Meaders Pond is situated to the east and is outside of the conservation area. RIDEM stocks Upper Rochambeau Pond with trout in the spring and allows fly fishing only.[11]

Rochambeau Pond's use classification of "B" indicates that these waters are designated for fish and wildlife habitat, and primary and secondary contact recreational activities. Class B waters are considered suitable for compatible industrial processes and cooling, hydropower, aquaculture uses, navigation, and irrigation and other agricultural uses. These waters are intended to have good aesthetic value. The pond is not designated as a cold or warm water fishery or a SRPW.

5.4.4 Floodplain

The 100-year floodplain represents the extent of flooding that would result during a storm event having a 1% chance of occurring per year. Based on available Federal Emergency Management Agency (FEMA) mapping, the Study Area crosses several areas of designated 100-year (Zone A) frequency floodplain. Specifically, floodplains are located in the vicinity of the Woonsocket Substation, near Structure 181-1, north of Structures 184 to 187, and in the vicinity of Structures 191 to 193. These areas include the floodplain of Crookfall Brook and Spring Brook. The Permitting and Access Plans (Figure 3-3) provide floodplain detail within the ROW.

5.5 GROUNDWATER

There is a community wellhead protection area (CWPA) associated with Well #2942518-01 that extends from east of Structure 187 to Route 99, just east of Structure 193. The Groundwater Classification of this area is Class GAA, which is the highest classification and identifies an area with the highest potential yield and quality.[12] Class GAA groundwater is presumed suitable for public drinking water use without prior treatment. Outside of the GAA, the Study Area is classified as Class GA. Groundwater classified GA is also presumed suitable for public or private drinking water use without prior treatment. However, the potential yield of this resource is less than that of Class GAA due to the nature of the surrounding geologic deposits (glacial till and bedrock). Both Class GAA and GA are subject to the same groundwater quality standards and preventative action limits for organic and inorganic chemicals, microbiological substances, and radionuclides. Groundwater resources within the Study Area are depicted in Figure 5-4 and designated as Community Wellhead Protection Area in the Permitting and Access Plans (Figure 3-3), Sheet 7 through 10.

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[11] RIDEM Designated Trout Waters, http://www.dem.ri.gov/programs/bnatres/fishwild/troutwaters.htm

[12] Rhode Island DEM, Groundwater Classification, Wellhead Protection Areas and Drinking Water Reservoir Watersheds for Rhode Island, http://www.dem.ri.gov/maps/mapfile/gw/pdf/statemap.pdf.

There is also a groundwater recharge area associated with the Blackstone River, also designated Class GAA, which overlaps a small portion of the Study Area northeast of structures 201 through 207-1. This recharge area does not extend into the ROW.[13]

5.6 VEGETATION

The Study Area contains a variety of vegetative cover types typical of southern New England. Within the ROW, vegetation is typically representative of an old field successional community. The Study Area includes Oak-Hickory Forest with areas of Oak-Heath Forest.[14] This section of the report focuses on upland communities with wetland communities discussed in Section 5.7 of this report.

5.6.1 Old Field Successional Community

Vegetation within the cleared portions of the ROW is typically representative of an old field successional community. Old field communities are established through the process of natural succession from cleared land to mature forest. Within the cleared ROW, periodic vegetation management has favored the establishment and persistence of grasses and herbs, as well as some shrubs. Grasses and herbs observed in the ROW include sheep laurel (*Kalmia angustifolium*), sweet fern (*Comptonia peregrina*), dewberry (*Rubus sp.*), goldenrod (*Solidago sp.*), little bluestem (*Schizachyrium scoparium*), princess pine (*Dendrolycopodium obscurum*), Queen Annes lace (*Daucus carota*), ground pine (*Lycopodium sp*.), common timothy (*Phleum pratense*), rambler rose (*Rosa multiflora*), bracken fern (*Pteridium aquilinum*), false lily-of-the-valley (*Maianthemum canadense*), haircap moss (*Polytrichum commune*), and one-cone groundpine (*Lycopodium lagopus*). Shrubs and saplings include highbush blueberry (*Vaccinium corymbosum*), eastern white pine sapling (*Pinus strobus*), fox grape (*Vitis labrusca*), green briar (*Smilax sp.*), American witch hazel (*Hamamelis virginiana*), maleberry (*Lyonia ligustrina*), and crabapple (*Malus sp.*). Trees are less common, but present along the ROW perimeter, including eastern white pine (*Pinus strobus*), red maple (*Acer rubrum*) and sweet birch (*Betula lenta*).

5.6.2 Oak-Hickory Forest

The forested habitats located within the Study Area include Oak-Hickory Forest. Although these woodlands appear similar throughout, the tree and shrub communities vary based on precipitation and aspect. Precipitation and aspect are important factors in determining what vegetation a particular site will support. Hilltops and south facing slopes are often deficient in the amount of soil moisture available to the plant community. In summer, when the moisture requirements of plants are highest, hilltops become substantially drier than sites farther down slope. The trees growing on hilltops, therefore, are more tolerant of dry conditions, smaller, more widely spaced and are a different species composition than those on more favorable sites.

The Oak-Hickory forest community is typically deciduous with well-drained soils of ridgetops and slopes. Soils are usually loams/sandy loams and slightly more mesic and nutrient rich than in Oak - Heath Forests. Red oak (*Quercus rubra*) is typically dominant or co-dominant with lower densities of white oak (*Quercus alba*) and hickories (pignut hickory, *Carya glabra*; shagbark hickory, *C. ovata*; and, mockernut hickory, *C.*

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[13] Ibid.

[14] Brown, Virginia. Ecological and Land Management Survey for Handy Pond Conservation Area, Lincoln, Rhode Island, 2004.

tomentosa). Occasionally black oak is dominant. Other associated trees include white ash (*Fraxinus americana*), red maple (*Acer rubrum*), tulip tree (*Liriodendron tulipifera*), and white pine (*Pinus strobus*). A tall shrub subcanopy is typically present with saplings of the canopy trees along with witch hazel (*Hamamelis virginiana*) and flowering dogwood (*Cornus florida*), which are fairly good indicators of this community. Maple-leaved viburnum (*Viburnum acerifolium*) is a characteristic shrub and other low shrubs include lowbush blueberries (*Vaccinium pallidum* and *V. angustifolium*), and sheep laurel (*Kalmia angustifolia*). Typical plants in the herb layer are wild sarsaparilla (*Aralia nudicaulis*), wood ferns (*Dryopteris spp*.), and early sedge (*Carex pensylvanica*). The herb layer is usually more diverse than in the Oak – Heath Forest. The American chestnut (*Castanea dentata*) was formerly a co-dominant canopy tree species in this community prior to the infestation of chestnut blight; today chestnut sprouts remain common in the understory.[15]

5.6.3 Oak-Heath Forest

An Oak-Heath Forest is a deciduous forest typically comprised of well-drained, acidic soils. Black oak and/or scarlet oak (*Quercus velutina, Q. coccinea*) are generally dominant, but in less common instances chestnut oak (*Q. prinus*) or white oak (*Q. alba*) are the dominant trees. Common associates include white oak (*Quercus alba*), black birch (*Betula lenta*), black gum (*Nyssa sylvatica*), red maple (*Acer rubrum*) and sassafras (*Sassafras albidum*). Pitch pine (*Pinus rigida*) and white pine (*Pinus strobus*) may be present in small amounts. American chestnut (*Castanea dentata*) was a common associate prior to the chestnut blight; saplings are still found in the understory. Total percent canopy cover can range from 60 to 100% (woodland to forest). The shrub layer is ericaceous with characteristic species including black huckleberry (*Gaylussacia baccata*), mountain laurel (*Kalmia latifolia*), and lowbush blueberries (*Vaccinium pallidum* and *V. angustifolium*). Plants in the ground layer include early sedge (*Carex pensylvanica*), wild sarsaparilla (*Aralia nudicaulis*), and wintergreen (*Gaultheria procumbens*).[16]

5.6.4 Managed Lawn

Portions of the cleared ROW are managed as residential lawn. Typically these areas consist of continuous grass cover, which may include Kentucky bluegrass, red fescue, clover, and plaintains. Ornamental shrubs and landscaping are also present within these areas. In the ROW, residential lawns are located intermittently between structures 203 through 207-1. This area contains public and private access roads with single family homes near Albion Street (Structures 203 and 204) and multi-family apartments and condominium buildings (e.g., Kirkbrae Apartments and Kirkbrae Glen), and the Highridge Swim and Tennis Club (Structures 205 to 207-1).

5.6.5 Agricultural Areas

Based on the RIGIS land use information, less than 1% of land within the Study Area is allocated to cropland or pasture, none of which is within the Project ROW.

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[15] Enser, Richard W., and Julie A. Lundgren. Natural Communities of Rhode Island, December 2006.
[16] Ibid.

5.7 WETLANDS

Wetlands are resources which potentially provide ecological functions and societal values. Wetlands are characterized by three criteria, including the (i) presence of undrained hydric soils, (ii) a prevalence (>50%) of hydrophytic vegetation, and (iii) wetland hydrology, soils that are saturated near the surface or flooded by shallow water during at least a portion of the growing season.

5.7.1 Study Area Wetlands

State-regulated freshwater wetlands and streams have been identified in the Study Area (see Figure 5-4), and delineated within the ROW (see Figure 3-3). Study area wetlands are based on 2013 US Fish and Wildlife Service (USFWS) wetlands data. RIGIS data was not used for this assessment because the datalayer dates back to 1993 and is based on 1988 aerials.

Within the ROW, 21 wetlands were delineated, and are consecutively numbered W1 through W21 in Figure 3-3: Permitting and Access Plans. Field methodology for the delineation of regulated resource areas within the ROW was based on vegetative composition, presence of hydric soils and evidence of wetland hydrology. Based on the provisions of the Rhode Island Fresh Water Wetlands Act and Rules and Regulations Governing the Administration and Enforcement of the Freshwater Wetlands Act (RIDEM 2014) (the Rules), state-regulated fresh water wetlands include swamps, marshes, bogs, forested or shrub wetlands, emergent plant communities and other areas dominated by wetland vegetation and showing wetland hydrology.

In addition to these vegetated wetland communities, Rhode Island also regulates activities in and around streams and open waterbodies which include Rivers, Streams, Ponds, Areas Subject to Storm Flowage (ASSF), Areas Subject to Flooding (ASF) and Flood Plain.

Upland areas within 50 feet of the edge of swamps, marshes, bogs and ponds are regulated as the 50-foot Perimeter Wetland under the Rules (see Figure 3-3). Emergent plant communities, forested wetlands and shrub wetlands do not merit a 50-foot Perimeter Wetland.

Wetlands and waterbodies relevant to the Project are discussed below. As noted above, ROW Wetlands are consecutively numbered W1 through W21. Streams are identified based on the wetland they are associated with, e.g., S1 is associated with W1, or by name when they are associated with multiple wetland systems.

5.7.1.1 Ponds

A pond is a water body that is at least ¼-acre in size, with open standing or slowly moving water present for at least 6 months a year. The boundary of a pond is determined by the extent of water which is delineated and surveyed.

The USFWS data indicate that the Study Area contains all or a portion of 7 ponds that meet the ¼-acre size criteria. As shown in Figure 5-4, none of the ponds are within the Project ROW. There are also 5 waterbodies that are smaller than ¼-acre in size, 3 of which appear to be drainage areas adjacent to large impervious areas in the southern end of the Study Area.

5.7.1.2 Swamp

Swamps are defined as areas at least 3 acres in size, dominated by woody vegetation, where groundwater is at or near the ground surface for a significant part of the growing season.

Because the ROW is maintained, wetlands within the ROW contain limited woody vegetation. Therefore, no ROW wetlands are characterized as swamp. It should be noted, however, that where a ROW wetland is part of a larger system, the portion that is outside of the ROW may meet the criteria for a swamp.

5.7.1.3 Marsh

Marshes are wetlands at least 1 acre in size where water is generally above the surface of the substrate and where the vegetation is dominated by emergent herbaceous species. A number of wetlands within the Study Area meet the one-acre threshold, and some of these are partially within the Project ROW. Vegetation observed in Marsh includes American hornbeam (*Carpinus caroliniana*), glossy buckthorn (*Rhamnus frangula*), yellow birch (*Betula alleghaniensis*), and southern arrow-wood (*Viburnum dentatum*). The herb stratum included skunk cabbage (*Symplocarpus foetidus*), rambler rose (*Rosa multiflora*), uptight sedge (*Carex stricta*), cattail (*Typha sp*.), sensitive fern (*Onoclea sensibilis*), white meadowsweet (*Spirea alba*).

5.7.1.4 River

A River is a body of water designated as a perennial stream by the US Geologic Survey (USGS) as a blue line stream on a USGS topographic map. If the river is less than 10 feet wide, the area within 100 feet of each bank is regulated as 100-foot Riverbank Wetland. If the river is greater than 10 feet wide, the area within 200 feet of each bank is regulated as 200-foot Riverbank Wetland.

The USGS identifies the following rivers within the Project Area: Spring Brook, Crookfall Brook, unnamed tributaries to Rochambeau/Handy Pond that flow from the south and west (S18, S19-1 and S19-2), and the unnamed tributary located both south and north of Meander Pond (S20-1 and S20-2, respectively). Based field delineations and observations, none of the waterbodies exceed the 10-foot threshold, and 100-foot Riverbank Wetlands associated with the Rivers are shown in the Permitting and Access Plans.

5.7.1.5 Stream/Intermittent Stream

A stream is any flowing body of water or watercourse other than a river which flows during sufficient periods of the year to develop and maintain defined channels. Such watercourses carry groundwater discharge and/or surface runoff. Such watercourses may not have flowing water during extended dry periods but may contain isolated pools or standing water. Perennial streams identified on the USGS map are noted above as rivers; intermittent streams include unnamed tributaries associated with these waterways, some of which cross the ROW.

Streams within the ROW are identified on the Permitting and Access plans as S1, S3, S4-A/S4-B, S6, S7, S11, S12, 14-1/14-2, S17, and S21.

5.7.1.6 Emergent Plant Communities

Emergent plant communities are areas similar to marshes in vegetation composition; however, there is no size criterion.

Wetlands categorized as Emergent plant communities within the ROW wetlands include (but are not limited to) W7 and W20. Emergent wetlands are characterized by American hornbeam (*Carpinus caroliniana*), skunk cabbage (*Symplocarpus foetidus*), red osier dogwood (*Cornus alba*), sensitive fern (*onoclea sensibilis*), black elder (*Sambucus nigra*), speckled alder (*Alnus incana*). Invasive species such as rambler rose (*Rosa multiflora*), autumn olive (*Elaeagnus umbellata*), Japanese knotweed (*Polygonum japonica*), and common reed (*Phragmites australis*) were observed.

5.7.1.7 Forested and Shrub Wetland

Forested and Shrub wetlands are similar to swamps, but do not meet the 3-acre size criteria.

A number of wetlands within the ROW are categorized as Palustrine Scrub Shrub, including (but not limited to) W1, W6 and W18. Vegetation observed within scrub shrub wetlands in the transmission line ROW include red maple (*Acer rubrum*), highbush blueberry (*Vaccinium corymbosum),* maleberry (*Lyonia ligustrina*), red osier dogwood (*Cornus alba*), skunk cabbage (*Symplocarpus foetidus*), white meadowsweet (*Spiraea alba),* quaking aspen (*Populus tremuloides*), sweet pepperbush (*Clethra alnifolia*), dewberry (Rubus sp.), white meadowsweet (*Spiraea alba*) and tussock sedge (Carex sp.). Additional vegetation included cottongrass bulrush (*Scirpus cyperinus*), rambler rose (*Rosa multiflora*), and lamp rush (*Juncus effusus*).

As noted previously, the ROW is maintained, and Forested wetlands are not generally present. However, they may be located at the edge of the maintained ROW. Vegetation would likely include red maple (*Acer rubrum*) and quaking aspen (*Populus tremuloides*) with an understory generally consisting of vegetation mentioned previously for the shrub wetland.

5.7.1.8 Floodplains

A floodplain is the land area adjacent to a river or stream or other body of flowing water which is, on the average, likely to be covered with flood waters resulting from a 100-year frequency storm event as mapped by FEMA. The floodplain areas within the ROW were described in Section 5.4.4., and are shown on Sheets 1, 6 and 9 of the Permitting and Access Plans (Figure 3-3).

5.7.1.9 Areas Subject to Storm Flowage

An ASSF is defined as a body of flowing water as identified by a scoured channel or change in vegetative composition or density that conveys storm runoff into or out of a wetland. ASSFs are channel areas and water courses which carry storm, surface, groundwater discharge or drainage waters out of, into, and/or connect freshwater wetlands or coastal wetlands. ASSFs are recognized by evidence of scouring and/or a marked change in vegetative density and/or composition. No ASSFs were identified in the Project area.

5.7.1.10 Special Aquatic Site

A Special Aquatic Site (vernal pool) is a contained basin that lacks a permanent above ground outlet. It fills with water with the rising water table of fall and winter or with the meltwater and runoff of winter and spring snow and rain. Special Aquatic Sites contain water for a few months in the spring and early summer.

There are no known documented or observed Special Aquatic Sites within the ROW.

5.8 WILDLIFE

As previously described, the ROW passes through a variety of aquatic and terrestrial habitats, and the wildlife assemblages present within the Study Area vary according to habitat characteristics. An overall list of wildlife species expected to be found within the transmission line ROW is presented in Table 5-7: Expected and Observed Wildlife Species. This list encompasses the major habitats encountered within the ROW and includes amphibian, reptiles, birds and mammals expected to be found within a given habitat. This information is based on geographical distribution and habitat preferences as described in New England Wildlife: Habitat, Natural History and Distribution (DeGraaf and Yamasaki, 2001) and supplemented by field observations. It should be noted that individual species may not be present in one particular area as opposed to another, but may be found in the general area of the transmission line.

5.8.1 Rare and Endangered Species

In order to assess the potential for federally-listed, endangered, threatened, and/or candidate species to occur along the Project, the USFWS Endangered Species Consultation Procedure was followed. As a result of the Consultation Procedure, it was determined that the Project is not located where known federally listed species are present. In accordance with Step 1.D. of this procedure, no further coordination with the USFWS is necessary.

There is an area between Structures 194 and 202 that is mapped as RI Natural Heritage Program (RINHP) area habitat, according to the RIDEM 2014 Natural Heritage Area Datalayer. This habitat is located within the Handy Pond Conservation Area and indicates the potential presence of rare or endangered species of plant or animal life. The "Ecological and Land Management Survey for Handy Pond Conservation Area" report, available on the Town of Lincoln's website, documents the results of a 2004 survey completed which identified the following three state-listed plant species within Handy Pond Conservation Area: bloodroot (*Sanguinaria canadensis*), wood lily (*Lilium philadelphicum*), and slippery elm (*Ulmus rubra*).[17] Bloodroot and wood lily are both designated as state species of concern. However, in 2007 slippery elm was delisted and is no longer a state species of concern. Populations of bloodroot and wood lily were identified along the edge of the V148N Line ROW in 2004.

[17] http://www.lincolnri.com/documents/landtrust/handypondreport.pdf

Table 5-7: Expected and Observed Wildlife Species

	V148N 115 kV Overhead Transmission Line							
	Terrestrial Habitat		Aquatic Habitats					Observed
Species	**Oak-Hickory Forest**	**Old Field**	**Shallow Marsh**	**Shrub Swamp**	**Forested Wetland**	**River**	**Stream**	
AMPHIBIANS & REPTILES								
Spotted Salamander	X			X	X			
Eastern Newt	X			X				
Redback Salamander	X				X			
Eastern American Toad	X		X	X	X			
Northern Spring Peeper			X	X	X			
Bullfrog			X	X	X			
Gray Tree Frog	X			X	X			
Green Frog			X	X	X	X	X	O*
Pickerel Frog	X				X		X	O*
Wood Frog	X		X	X	X		X	O*
Common Snapping Turtle	X	X	X		X	X	X	
Eastern Garter Snake	X	X		X	X			O*
BIRDS								
Red-tailed Hawk	X	X			X			
Ruffed Grouse	X	X			X			
Mourning Dove	X	X						O
Downy Woodpecker	X				X			O
Northern Flicker	X				X			O
Eastern Wood-Pewee	X				X			
Eastern Phoebe	X				X			
Eastern Kingbird		X			X			
Tree Swallow		X	X					
Blue Jay	X	X			X			
American Crow	X	X						O
Black-capped Chickadee	X	X						O
Tufted Titmouse	X				X			O
White-breasted Nuthatch	X				X			O
Carolina Wren	X	X						O
House Wren	X	X			X			
Wood Thrush	X				X			
American Robin	X	X		X	X			O
Gray Catbird		X		X				O
Northern Mockingbird		X						O
Brown Thresher	X	X						
Cedar Waxwing	X	X		X				
European Starling		X						O
Yellow Warbler	X	X		X				
Chestnut-sided Warbler		X		X				
Yellow-rumped Warbler	X	X		X	X			
Pine Warbler	X							O

	V148N 115 kV Overhead Transmission Line							
	Terrestrial Habitat		Aquatic Habitats					Observed
Species	**Oak-Hickory Forest**	**Old Field**	**Shallow Marsh**	**Shrub Swamp**	**Forested Wetland**	**River**	**Stream**	
Prairie Warbler		X						
Black & White Warbler	X				X			
American Redstart	X				X			
Ovenbird	X				X			
Common Yellowthroat	X	X	X	X	X			
Northern Cardinal		X		X		X	X	O
Rufous-sided Towhee	X	X						O
Chipping Sparrow	X							O
Song Sparrow	X	X		X				O
Tree Sparrow		X		X				
Red-winged Blackbird				X	X			
Common Grackle	X			X	X			O
Brown-headed Cowbird	X				X			
Northern Oriole	X				X			
House Finch	X							
American Goldfinch			X	X	X			O
House Sparrow		X						O
MAMMALS								
Virginia Opossum	X	X	X	X	X			
Big Brown Bat	X	X	X	X	X	X	X	
Eastern Cottontail		X	X					
Eastern Chipmunk	X	X			X			O
Woodchuck	X	X						
Gray Squirrel	X	X			X			O
Red Fox	X	X		X	X			
Gray Fox	X	X		X	X			
Raccoon	X	X	X	X	X			
Striped Skunk	X	X		X	X			
White-tailed Deer	X	X		X	X			O

Legend:

X = expected to be present
O = observed in the field, spring 2014
O*= observed only during the Ecological Land Management Survey for Handy Pond Conservation Area, 2004

6 DESCRIPTION OF THE AFFECTED SOCIAL ENVIRONMENT

6.1 INTRODUCTION

This section provides information on the land uses within and proximate to the ROW, cultural resources, noise, EMF, visual resources in vicinity of the Project, and the public roadway systems in the area. Based on the nature of the Project (reconductoring of existing facilities) and the limited scope of the work, information is not being provided on regional population trends, or employment conditions as permitted by EFSB Rule 1.6(f).

6.2 LAND USE

This section describes existing and future land use within the Study Area. The scope of this discussion will address those features which might be affected by the Project.

Land use within the Study Area includes a mix of forest, residential, utility, commercial/industrial and transportation, shown in Figure 6-1 and summarized Table 6-1.

Table 6-1: Study Area Land Uses

Land Use Type	Percentage of Study Area (Approximate) (%)
Forest/Brushland	58.8%
Residential	16.2%
Utilities	8.2%
Commercial/Industrial/Waste Disposal	7.7%
Transportation (Divided Highways)	5.2%
Developed Recreation	2.3%
Water/Wetland	0.6%
Other (Urban Open, Vacant, etc.)	0.2%

6.2.1 Land Use along the Transmission Line Corridor

The Project ROW is currently used for electric utility operations, including structures and access roads to facilitate structure and vegetation maintenance. The northern terminus of the Project is located off Greenville Road in North Smithfield, and the southern terminus is the Washington Substation in Lincoln. Land uses along the 4.2-mile transmission corridor include single and multi-family residential, industrial, commercial, recreational and conservation areas.

Within the Study Area, the Masjid Al-Islam mosque is located at 40 Sayles Hill Road, south of Structures 189 and 190. There is a private childcare center in the Amica Insurance Company office building at 25 Blackstone Valley Place. This is situated approximately 450 feet southwest of the transmission line just before the line enters the Washington Substation. A cell tower is situated south of the Washington Substation.

6.2.2 Open Space and Recreation

There are a number of conservation areas in the Project Study Area. The Crookfall Brook Conservation Area is partially located in North Smithfield and partially in Lincoln, but the land is owned by the City of Woonsocket as part of an initiative to protect the city's public water supply that is associated with Reservoir #3 and Reservoir #2. The Handy Pond and Eagle Nest Conservation Areas are both owned by the Town of Lincoln and contain trails for passive recreation. The Handy Pond Conservation Area is approximately 129 acres, and the Eagle Nest Conservation area is approximately 18 acres.

6.2.3 Future Land Use

In order to assess future land use, an analysis of current zoning was undertaken. The comprehensive plans for North Smithfield and Lincoln were also reviewed to identify references to the electric transmission lines or public utilities in the ROW.

Typically, towns and cities manage future growth through zoning regulations which provide a degree of oversight and control. Most of the Study Area in both North Smithfield and Lincoln is zoned agricultural, residential or industrial/manufacturing in varying densities. The portion of the ROW in the vicinity of structures 203 to 207-1 is zoned for higher density residential development; between Structures 208-1 and 209A the area is zoned limited manufacturing.

The towns of North Smithfield and Lincoln have Comprehensive Plans which describe the local direction regarding future development and growth in each community. Both Comprehensive Plans were evaluated with regard to expressed town-wide goals. The Project was then evaluated for consistency with the local planning initiatives in each community.

North Smithfield embraces its industrial heritage while seeking to expand its influence, particularly at the regional level, and plans to encourage both redevelopment and controlled new development. Lincoln's comprehensive planning process focused on developing a good balance between growth and conservation with flexibility to respond to changing market conditions.

Limited references to electrical transmission or public utilities were found in the North Smithfield Comprehensive Plan Five Year Update (2006) and the Town of Lincoln Comprehensive Plan (2003). For example, North Smithfield's Economic Development section noted the importance of locating development "in close proximity to transportation and utility infrastructure" to reduce the rate of suburban development sprawl.[18] Both plans emphasize the importance of the Woonsocket Reservoir system watershed and Crookfall Brook in terms of drinking water protection, and focus primarily on improving stormwater management capabilities of paved areas to protect water quality in streams and rivers.[19] The North Smithfield Plan notes that the Woonsocket Substation is listed in the Comprehensive Environmental Response Compensation and Liability Act of 1980 (CERCLA) inventory as a potential hazardous waste site, indicating that there may have been a release, disposal or storage of hazardous materials on the site presently or in the past.[20]

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[18] http://www.nsmithfieldri.org/_resources/common/userfiles/file/Planning/F_Economic_Development.pdf

[19] http://www.nsmithfieldri.org/_resources/common/userfiles/file/Planning/A_Overview.pdf

[20] http://www.nsmithfieldri.org/_resources/common/userfiles/file/Planning/G_Natural_and_Cultural_Resources.pdf

6.2.4 Subsurface Pipeline

There is an Exxon Mobil pipeline within the ROW in the vicinity of Structures 180 and 182, and parallel to but outside of the ROW north of Structures 183 to 185, and 188 to 190.

6.3 VISUAL RESOURCES

The Rhode Island Department of Administration has not designated any areas within or immediately adjacent to the Study Area as a "scenic area of statewide importance." The transmission line and associated structures are visible at roadway crossings, in the vicinity of some residential areas (particularly at the southern end), and in the Blackstone Valley Place business park.

6.4 HISTORIC AND CULTURAL RESOURCES

6.4.1 Approach

Cultural resources specialists from Gray & Pape, Inc. conducted a Phase IA archaeological reconnaissance survey in the V148N Line ROW in June 2014. Their results were summarized in a Memorandum dated December 4, 2014. The reconnaissance survey focused on identifying previously recorded sites and architectural resources, and identifying where work will be located within areas categorized as having high to moderate sensitivity for potential cultural resources. The archaeologists evaluated the ROW and a Study Area of 300 meters (approximately 985 feet) on either side of the center line. This is only slightly smaller than the 1,250 feet on either side of the center line that was otherwise applied as the Study Area.

Archaeologists conducted research at the Rhode Island Historical Preservation & Heritage Commission (RIHPHC), and consulted the State and National Registers of Historic Places. Following the collection of previously recorded site data, a sensitivity model of the ROW corridor and surrounding Study Area was developed, and areas were ranked into zones of high, moderate and low potential to contain pre-historic archaeological sites. Ranking considerations included the soil matrix, landform, degree of disturbance, and distance to water or other subsistence and raw material resources.

The reconnaissance survey also involved a site visit to assess the location of each structure to be replaced and each pull pad location. This field visit allowed archaeologists to field verify the model's sensitivity analysis results and determine recommendations for future testing. Considerations included topographic conditions, vegetation, and evidence of disturbance, soil drainage, proximity to water and roads, and any evidence of historic or Native American use. The intensity of the proposed use (i.e., need for soil disturbance) was considered in developing recommendations for additional investigations.

6.4.2 Results and Recommendations

Based on the research, 5 previously recorded archaeological assets were identified in the Study Area, only 1 of which is located within the Project ROW. Specifically, the former route of an electric streetcar line runs roughly parallel to Crookfall Brook and crosses the ROW just northwest of Sayles Hill Road. The streetcar operated from 1904 to 1930 and the rail bed is still visible.

The archaeologists recommend subsurface testing at 6 locations, 1 associated with a structure replacement, and 5 at pull pad sites. The structure replacement is located in a sandy, well-drained hilltop in North Smithfield with potential for pre-contact Native American activity. Subsurface testing for the site examinations is currently underway by National Grid and Gray & Pape. All work will continue to comply with the Antiquities Act of Rhode Island, G.L. 42-45 and the Rhode Island Procedures for Registration and Protection of Historic Properties.

6.5 TRANSPORTATION

The transportation needs of the Project are served by a network of state highways and local roads, as listed in Table 6-2. The ROW also crosses private roads that are part of a condominium/apartment development (see Figure 3-1: Existing Conditions).

Table 6-2: ROW Road Crossings

V148N 115 kV Overhead Transmission Line			
Town	**Road Name**	**Roadway Type**	**Plan Sheet Reference**
North Smithfield	Hanton Road	Local	2
	Route 146/146A Interchange/ramps	State Highway	4, 5
	Sayles Hill Road	Local	8
	Old Smithfield Road	Local	9
Lincoln	Route 99	State Highway	10
	Albion Road at Parkview Road	Local	14
	Old River Road/ Kirkbrae Glen complex (two roads)	Private	15
	I-295	Interstate	15
	Blackstone Valley Place	Local	17

Source: http://www.dot.ri.gov/documents/maps/StateRoads/PC03.PDF

The state highways are under RIDOT jurisdiction. The local roads are maintained by the town in which they are located.

There are no designated RIDOT scenic roadways or bikeways within the Project area. The nearest scenic roadway is located along Great Road and Breakneck Hill Road in Lincoln, which is well north of the Project.[21] The nearest RIDOT bikeway is the Blackstone River Bikeway, which is east of the Project.

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[21] Source: http://ridot.maps.arcgis.com/apps/MapTour/index.html?appid=9a547195413e4f9d9af7f242453c355c&webmap=1a7feb3420474107b50c41287cceec85

6.6 ELECTRIC AND MAGNETIC FIELDS

Electric and magnetic fields are produced whenever a conductor is connected to a source of electrical voltage. The voltage causes an electric field which is usually measured in kilovolts per meter (kV/m). The current causes a magnetic field which is usually measured in milligauss (mG). Electric and magnetic fields were modeled and calculated to determine the edge of ROW field strengths with the existing conductors, field strengths after the new conductors are installed, and then five years after the Project is completed.

For the purpose of EMF modeling, the Project route was divided into three segments where the transmission lines change configuration, as described below.

- Section 1: From Woonsocket Substation to Structure 179 (0.7 miles).
  - The ROW is 232.5 feet wide and contains the V148N Line, the 115 kV H17 Line and the 105K1 24.9 kV distribution feeder.
- Section 2: From Structure 180 to Structure 190 (1.2 miles).
  - The ROW is 270 feet wide and contains the V148N Line and the 105K1 distribution feeder.
- Section 3: From Structure 191 to the Washington Substation (2.3 miles).
  - The ROW is 125 feet wide and houses only the V148N Line.

Tables 6-3 and 6-4 present the existing electric field and magnetic field conditions, respectively. Please refer to Section 7.14 for a review of the post-construction modeling results.

Table 6-3: Existing Conditions - Electric Field

Electric Field at the Edge of the ROW, kV/m		
Section	Before the Project	
	Northern Edge of ROW	Southern Edge of ROW
1	0.27	0.18
2	0.26	0.02
3	0.26	0.17

Table 6-4: Existing Conditions - Magnetic Field

Magnetic Field at the Edge of the ROW/mG		
Section	Before the Project	
	Northern Edge of ROW	Southern Edge of ROW
Average Load		
1	33.6	26.0
2	27.7	2.4
3	27.9	24.4
Maximum Normal Load		
1	36.8	25.6
2	27.9	2.4
3	28.2	24.6

7 IMPACT ANALYSIS

7.1 INTRODUCTION

The potential impacts to environmental resources and social environments associated with implementation of the Project have been carefully evaluated. Short-term impacts associated with construction are the primary focus, although long-term issues were also considered. No impacts to bedrock, flood plain, groundwater, farmland soils, or air quality are expected.

7.2 SOILS

Construction activities which disturb soil have the potential to increase the rates of erosion and sedimentation. Minor soil disturbance is anticipated, primarily where 7 existing structures will be removed and 6 new structures installed. In addition, vehicle travel within the ROW may result in some soil compaction and slightly decreased infiltration rates in areas affected by construction.

Soil impacts associated with the Project are expected to be minor and temporary. Standard construction techniques and BMPs, in accordance with the Rhode Island Soil Erosion and Sediment Control Handbook, will be installed and routinely maintained throughout the construction period. BMPs including the installation of erosion control barriers and swamp mats; the re-establishment of vegetation; and dust control measures will be employed to minimize any short- or long-term effects due to construction activity. These controls will be inspected by the environmental monitor frequently during construction and supplemented, repaired or replaced when needed. The EFI will detail the BMPs and inspection protocols to guide the construction contractor and their personnel.

Excess soil from excavation at pole structures in uplands will be spread around the poles and stabilized to prevent migration to wetland areas, or the materials will be removed from the ROW. Topsoil will be spread over any excess excavated subsoil material which will then be seeded and mulched to promote rapid revegetation. None of the poles to be replaced are located within wetlands; therefore, it is not necessary to implement special procedures for stockpiling wetland soils for subsequent reuse.

Dewatering is not expected, however, it may be necessary during excavations for structures adjacent to wetland areas. If dewatering is needed, water will be pumped into appropriate dewatering basins. Dewatering will be performed in compliance with National Grid policies and procedures. The basin and all accumulated sediment will be removed following dewatering operations and the area will be seeded and mulched.

As shown in Table 5-5, potentially highly erodible land is present over a large portion of the Project area, and highly erodible land is also present to a much smaller degree. The environmental monitor will consider site-specific slope conditions when developing the erosion and sediment control plan for the Project. Also, the contractor will be required to inspect and maintain these controls to ensure that storm events do not compromise functionality. Any soils disturbed by construction activity within erodible areas will be stabilized with straw mulch or an erosion control blanket to minimize the off-site migration of sediments.

Mapped areas of farmland soils (Prime Farmland Soils and Farmland of Statewide Importance) comprise approximately 3.3% of the ROW total area. These areas do not appear to be actively farmed, and new farming within existing utility ROW is generally not encouraged. The Project will not displace any prime farmland soils.

7.3 SURFACE WATERS

Construction activities temporarily increase risks for erosion and sedimentation that may temporarily degrade existing water quality. Potential impacts to surface waters if sediment transport is not controlled include increased sedimentation (locally and downstream) and subsequent alterations of benthic substrates, decreases in primary production and dissolved oxygen concentrations, releases of toxic substances and/or nutrients from sediments, and destruction of benthic invertebrates.

Overall, any impact of the Project upon surface watercourses will be minor and temporary. Emphasis has been placed on utilizing existing gravel roadways within the ROW and seeking access points that avoid crossing wetlands and surface waters. Where access routes or swamp mats must unavoidably cross streams within the Project area, National Grid environmental policies will be followed, and appropriate BMPs implemented. For example, impacts will be minimized by using swamp mats as bridge spans, which allow equipment to access structure construction locations without impacting the banks or channels. The swamp mats will be installed so as to not impede water flow. The implementation and maintenance of stringent erosion and sedimentation control BMPs during construction will further limit the levels of Project-related sedimentation and will minimize adverse impacts to surface waters. Controls will remain in place until proper stabilization has been achieved.

Work within the SWPA is expected to include all aspects of reconductoring activities. While appropriate BMPs will be implemented in accordance with EG303-NE to avoid or minimize impacts, there is a potential for impacts associated with construction activities and the presence of construction equipment. Coordination with the Woonsocket Water Department will be undertaken, as appropriate. Appropriate measures to protect drinking water supplies will be implemented, such as:

- no refueling, vehicle maintenance or storage of equipment within 100 feet of a wellhead protection area; and
- no depositing of excess snow or soil stockpiling within a wellhead protection area.

If implementation of these measures is not feasible, the environmental monitor will review permits and determine the appropriate protection measures.

7.4 GROUNDWATER

Potential impacts to groundwater resources within the transmission line ROW as a result of construction activity will be negligible. Equipment used for the construction of the transmission line will be properly maintained and operated to reduce the chances of spills of petroleum products and antifreeze. Refueling of equipment will be conducted in upland areas, where feasible. Within primary groundwater recharge areas, special safeguards will be implemented to assure the protection of groundwater resources. Refueling equipment will be required to carry spill containment and prevention devices (i.e., absorbent pads, clean up rags, 5-gallon containers, absorbent material etc.). In addition, maintenance equipment and replacement parts for construction equipment will be on hand to repair failures and stop a spill in the event of equipment malfunction. In some scenarios, refueling in place will be allowed for equipment that cannot be moved from a fixed location. Appropriate precautions will be utilized and the environmental monitor will be consulted prior to initiating the refueling. Following construction, the normal operation and maintenance of the transmission line facility will not impact groundwater resources.

7.5 VEGETATION

Minor temporary impacts to vegetation will occur during Project construction, with no long-term impacts are anticipated. The Project will be located within existing ROW that has been managed to maintain vegetation at a height that does not interfere with the existing power lines. The Project will require mowing of vegetation in and along the ROW access roads and near structures that are to be replaced or accessed. Selective tree trimming may take place in conjunction with the Project. Management of the ROW vegetation will continue after the Project is completed to ensure continued access to the transmission line structures. ROW vegetation management will be completed in accordance with National Grid ROW maintenance procedures and the Rules and Regulations Governing the Administration and Enforcement of the Freshwater Wetlands Act (the Rules). Herbicides will not be used for this Project.

7.6 WETLANDS

None of the replacement structures are located within wetlands, so no long-term wetland impacts (e.g., permanent fill from pole installation) are anticipated from the Project. However, temporary wetland impacts during construction are anticipated due to work pads needed to provide equipment access for reconductoring, as well as along some access routes.

Where work within wetlands is unavoidable, swamp mats will be placed to establish safe and stable construction work areas/pads or provide access for equipment and vehicles. Where access road locations unavoidably cross wetlands, the crossings are situated at previously impacted locations or at narrow points of the wetland, as practicable. Swamp mats are placed over existing vegetation (i.e., there is little or no ground disturbance). After work is completed, swamp mats will be removed and the site restored, if necessary.

As shown in the Permitting and Access Plans, swamp mats will be placed in wetlands W6, W7, W8, W11, W13, W14, W16, W17, W18, W20, and W21. This list includes structures located within wetlands that will require equipment access for reconductoring and tower reinforcements (i.e., Structures 180 in W7, 185 in W11, 191 in W16, and 204 and 205 in W21). Swamp mats are also necessary in some areas to accommodate an access road crossing or where a portion of a work pad overlaps a wetland.

7.7 WILDLIFE

Wildlife may experience minor temporary disturbance from equipment travel and construction crews working in the Project corridor. During construction, wildlife may be displaced due to disturbance associated with ROW mowing and the operation of construction equipment. Wildlife currently utilizing the forested edge of the cleared ROW may be affected by the construction of the Project. Larger, more mobile species, such as eastern white tailed deer or red fox, will leave the construction area. Individuals of some bird species will also be temporarily displaced. Depending on the time of year of these operations, this displacement could impact breeding and nesting activities.

Smaller and less mobile animals such as small mammals, reptiles, and amphibians may be affected during vegetation mowing and construction. The species impacted during the reconductoring of the transmission line are expected to be limited in number. Effects will be localized to the immediate area of construction around structure locations and along existing access roads. However, this is anticipated to be a temporary effect as it is expected that existing wildlife utilization patterns will resume and population sizes will recover once work activities are completed. Any wildlife displacement will be negligible and temporary, since no permanent alteration of the existing habitat is proposed. No long-term impacts to wildlife are expected to result from the Project.

7.7.1 Rare and Endangered Species

When work is undertaken within area designated as potentially containing rare or endangered species, activities will take place in accordance with the National Grid EG-305RI Rare and Endangered Species guidance document. Impacts will be avoided in these sensitive habitat areas to the extent practicable. Use of existing access routes will minimize the potential for impacts in the Natural Heritage Area habitat.

7.8 LAND USE AND RECREATION

Since the Project involves the reconductoring of existing facilities within an existing cleared ROW, there will be no permanent, long-term impacts to the existing residential, commercial, institutional, or recreational land uses in the ROW as outlined in the following sections.

7.8.1 Residential

Because the Project is within an area dedicated to use for electrical facilities, the Project will not displace any existing residential uses, nor will it affect any future development proposals. For most of the route, residential development in proximity to the ROW is sparse and scattered and in most locations the existing vegetation will continue to provide visual screening of the facilities from residences. The ROW is adjacent to a residential area at Albion Road and Parkview Road near Structures 203 and 204, then passes through a multi-family development near Structures 205, 206, and 207-1. In these areas, land use conditions will essentially remain unchanged.

7.8.2 Commercial

Normal operations of area commercial businesses will not be adversely affected by the Project. The Project route crosses a business/industrial park area on the south side of I-295 by Blackstone Valley Place. These businesses include office and manufacturing facilities. No displacement of businesses will result from the Project.

7.8.3 Recreation

Impacts to existing parks and recreational areas from the Project will be minimal and short-term. Since the Project is located within an existing electric transmission line ROW, potential long-term impacts will be avoided. There are 2 passive recreation trails in the Handy Pond Conservation Area. During construction, public trail access will be temporarily restricted. The Town of Lincoln will be contacted to coordinate appropriate notification of reconductoring activities.

7.8.4 Subsurface Pipeline

The work pad for Structure 182 may overlap a small section of subsurface Exxon Mobil pipeline. Exxon Mobil will be contacted to initiate consultations regarding pipeline safety measures that are appropriate to prevent impacts to the pipeline and ensure safety of field crews during construction.

7.8.5 Consistency with Local Planning

The Project will use an existing ROW and will not alter existing land use patterns or adversely impact future planned development. The Project will provide an adequate supply of electricity for the growth and development envisioned by the Comprehensive Plans of North Smithfield and Lincoln.

7.9 VISUAL RESOURCES

No significant impacts to visual resources are anticipated as a result of the Project. Seven structures will be removed and 6 replacement structures will be installed. All will be located within existing ROW in roughly the same locations. Structure 4 will be shifted slightly to the north, which eliminates the need to replace Structure 5. The height of the 6 new structures will increase slightly from existing conditions, with increases ranging from 0.5 to 11 feet.

7.10 CONSTRUCTION NOISE

Noise generated by construction activities may cause short-term impacts to homes or businesses in the immediate vicinity of active work sites. Typical construction work hours for the Project will be 7:00 a.m. to 7:00 p.m. Monday through Friday when daylight permits, and 7:00 a.m. to 5:00 p.m. on Saturdays. However, there are exceptions to these standard hours. For example, some work tasks, such as concrete pours and transmission line stringing, once started, must be continued through to completion and may go beyond normal work hours. In addition, the nature of transmission line construction requires line outages for certain procedures such as transmission line connections, equipment cutovers, or stringing under or over other transmission lines. These outages are dictated by the system operator, ISO-NE, and can be very limited based on regional system load and weather conditions. Work requiring scheduled outages and crossings of certain transportation and utility corridors may need to be performed on a limited basis outside of normal work hours, including Sundays and holidays.

7.11 TRANSPORTATION

Overall, traffic impacts are expected to be temporary and negligible with the implementation of appropriate mitigation measures. Any construction-related increase in traffic will be small relative to total traffic volume on public roads in the area. In addition, traffic will be intermittent and temporary. Construction equipment will use existing access roads onto the ROW, where feasible. No increase in traffic congestion, or change in operating conditions along area roadways, is anticipated. In addition, there are no state-designated scenic roads or bicycle trails in the Project area.

RIDOT will be consulted to develop acceptable traffic management plans for any necessary work within the ROW of state highways (i.e., I-295, Route 146 and Route 99). Work on town roads will be coordinated with local authorities. At locations where construction equipment must be staged within a public way, the contractor will follow a pre-approved work zone traffic control plan to ensure roadway safety for drivers, bicyclists, pedestrians and construction workers.

7.12 HISTORIC AND CULTURAL RESOURCES

Subsurface investigations recently commenced, and ongoing consultation with the RIHPHC will identify the need for any additional subsurface testing to identify archaeological materials or potential historic properties prior to the commencement of construction. The Project will continue to comply with applicable state and federal regulations, including (but not limited to) Section 106 of the National Historic Preservation

Act of 1966, the National Environmental Policy Act of 1969 (PL 91-990, 42 USC 4321), Executive Order 11593, 1971 (16 USC 470), Procedures for the Protection of Historic and Cultural Properties (36 CFR 800), and the Archaeological and Historic Preservation Act of 1974 (PL 93-291). It is expected that the RIHPHC will review the Project under Section 106, in consultation with the US Army Corps of Engineers (USACE). State legislation dealing with the protection of historic and archaeological resources is covered under Rhode Island General Laws 42-45.

If archaeological materials or potential historic properties are discovered during any pre-construction field investigations of recommended test areas, and these areas cannot be avoided during construction, then an appropriate mitigation strategy will be developed during consultations with state and federal agencies.

7.13 SAFETY AND PUBLIC HEALTH

Because the proposed electrical facilities will be designed, built and maintained in accordance with the standards and codes as discussed in Section 3.6, public health and safety will be protected.

7.14 ELECTRIC AND MAGNETIC FIELDS

EMF modelling projected the electric and magnetic fields before, immediately after, and 5 years after the Project. As summarized in Section 6.6, the analysis assessed the route in three segments. The calculated electric field values and magnetic field values are summarized in Tables 7-1 and 7-2, respectively.

Table 7-1: Electric Field

Electric Field at the Edge of the ROW, kV/m						
Section	Before		After		5 Years After	
	Northern Edge of ROW	Southern Edge of ROW	Northern Edge of ROW	Southern Edge of ROW	Northern Edge of ROW	Southern Edge of ROW
1	0.27	0.18	0.28	0.06	0.28	0.06
2	0.26	0.02	0.26	0.02	0.26	0.02
3	0.26	0.17	0.26	0.18	0.26	0.18

Table 7-2: Magnetic Field

Magnetic Field at the Edge of the ROW/mG						
Section	Before		After		5 Years After	
	Northern Edge of ROW	Southern Edge of ROW	Northern Edge of ROW	Southern Edge of ROW	Northern Edge of ROW	Southern Edge of ROW
Average Load						
1	33.6	26.0	29.5	20.8	29.5	20.8
2	27.7	2.4	26.3	3.3	26.3	3.3
3	27.9	24.4	26.4	27.2	26.4	27.2
Maximum Normal Load						
1	36.8	25.6	32.6	20.1	34.6	21.8
2	27.9	2.4	26.4	3.3	28.7	3.6
3	28.2	24.6	27.0	27.8	29	29.9

A comparison of the results for the lines before and after the reconductoring indicate the following conclusions:

- Electric field:
  - There is no change in Section 2 (Structures 180 to 190) after the reconductoring.
  - There is a minimal increase after reconductoring in Sections 1 (the Woonsocket Substation to Structure 179) and 3 (Structure 191 to the Washington Substation), which is attributable to the increase in conductor diameter.
- Magnetic field:
  - The magnetic field level shows a minimal decrease after the construction of the Project in Section 1 as a result of a change in phasing for the reconductoring;
  - The magnetic field level shows a minimal increase after the construction of the Project in Sections 2 and 3 as a result of a change in load flow attributable to the reconductoring.
  - No cost-effective measures to reduce field levels could be identified since the majority of the structures will remain in place and the scope of the Project is limited. Calculated field increases are minimal and modifications to the transmission line facilities to reduce levels further would be outside the scope of work as stated in National Grid's Transmission Line Guideline GL.06.01.101 dated 8/15/14.

8 MITIGATION MEASURES

8.1 INTRODUCTION

Mitigation is integrated into the overall approach to Project design and management. During design, constraints mapping and field constructability reviews allow engineers to refine Project layout in a manner that avoids or minimizes impacts to sensitive environmental resources. Where impacts to such resources are unavoidable, the contractor will implement construction BMPs supplemented by site-specific mitigation measures to minimize these impacts. These measures will be described in the EFI, and included in contractor training. Implementation will be overseen in the field by the environmental monitor, Project scientist and designated members of the construction team.

8.2 CONSTRUCTION PHASE

Construction activities for the Project are described in Section 3.4. This work will take place within managed ROW and require only minor disturbances to the surrounding natural environment. The use of existing access roads (where feasible) and the implementation of appropriate erosion and sediment controls will mitigate possible disturbances to soils, wetlands, and other water resources.

Several measures will be implemented during construction to minimize impacts to the environment. These include the use of existing access roads and structure pads, where feasible, installation of erosion and sediment controls, supervision and inspection of construction activities within resource areas by an environmental monitor, and minimization of disturbed areas. Soil stabilization measures will be implemented in disturbed areas, as appropriate and in accordance with regulatory requirements.

8.2.1 Mitigation of Natural Resource Impacts

When the existing transmission lines were constructed, access roads were established within most portions of the ROW. Use of these access routes during construction of the Project, where practical, will minimize disturbance to natural resources.

Swamp mats will be installed to minimize soil disturbance and rutting when crossing or working within wetlands. Construction access will be limited to the existing structure locations and proposed access routes, and access routes will be lined with erosion and sedimentation control BMPs where needed. The swamp mats will be removed when construction is finished.

Vegetation management operations will be confined to the ROW. Where possible, existing vegetation will be retained at all road crossings and areas subject to public view to maintain a visual buffer to the ROW.

At stream crossings, swamp mats will be used to bridge or span streams to avoid impacts to the waterbody and its banks. Work will comply with standards and specifications outlined in the Rhode Island Soil and Erosion Handbook.

8.2.1.1 Erosion and Sedimentation Control

Erosion and sediment control devices will be installed along the perimeter of identified wetland resource areas prior to the onset of soil disturbance activities to ensure that soil stockpiles and other disturbed soil areas are confined and do not result in downslope sedimentation of sensitive areas. Low growing tree species, shrubs and grasses will only be mowed along access roads and at pole locations. Daily inspections will be conducted, and erosion controls will be maintained or replaced as necessary.

If necessary, soil erosion and sedimentation controls will be used where vegetation mowing takes place adjacent to wetland areas to prevent stormwater runoff into the resource area. Excavated soils will be stockpiled and spread in approved soil areas outside of wetlands such that general drainage patterns will not be affected.

Dewatering may be necessary during excavations for pole structures adjacent to wetland areas. Water will be pumped into hay bale or silt fence settling basins or dewatering filter bags which will be located in approved areas outside wetland resource areas. Throughout dewatering, the pump intake hose will not be allowed to set on the bottom of the excavation. The basins or bags and any accumulated sediment will be removed following dewatering operations and the areas will be seeded and mulched. All activities will comply with the BMPs outlined in EG303-NE.

8.2.1.2 Supervision and Monitoring

Throughout the entire construction process, an environmental monitor will be responsible for overseeing construction activities to ensure compliance with permit requirements as well as National Grid policies and procedures. The environmental monitor will be a trained environmental scientist familiar with carrying out construction activities relative to environmental issues. The monitor will also be experienced in the erosion control techniques described in this report and will have an understanding of the wetland resources to be protected.

During periods of prolonged precipitation, the monitor will inspect all locations to confirm that the environmental controls are functioning properly. In addition, the contractor will designate an individual to be responsible for the daily inspection and upkeep of environmental controls. This person will also be responsible for providing direction to other members of the construction crew regarding matters of wetland access and appropriate work methods. Additionally, construction personnel will be briefed on Project environmental compliance issues and obligations prior to the start of construction. Regular construction progress meetings will provide the opportunity to reinforce the contractor's awareness of these issues.

8.2.2 Mitigation of Social Resource Impacts

The Project's design incorporates the effective mitigation measure of using an established ROW rather than creating a new ROW. This approach minimized disruption due to construction activities, and limited what construction activities there will be to an area already dedicated to transmission line uses.

Noise generated during construction will be minimized by the use of mufflers on construction equipment, and to the extent possible, by limiting construction activities to the hours specified in the local ordinances.

Dust will be controlled by wetting and stabilizing access road surfaces, as necessary, and by maintaining crushed stone aprons at the intersections of access roads with paved roads. To minimize the potential for disturbance to area residents, abutters will be notified of planned construction activities before and during construction of the Project, as needed.

Some short-term impacts are unavoidable, even though they have been minimized. By carrying out the reconductoring of the line in a timely fashion, impacts will be kept to a minimum.

A traffic management plan will be developed and implemented to minimize impacts associated with increased construction traffic on local and state roadways.

8.3 POST-CONSTRUCTION PHASE

Following the completion of construction, standard mitigation measures are used on transmission line construction projects to minimize impacts to the natural and social environment. These measures include revegetation and stabilization of disturbed soils, ROW vegetation management practices and vegetation screening maintenance at road crossings and in sensitive areas. Appropriate site-specific measures will also be implemented, as appropriate. Restoration efforts, including final grading and installation of permanent erosion control devices, and seeding of disturbed areas, will be completed following construction. There are no additional impacts that will require mitigation.

9 CONCLUSIONS

This document presents a comprehensive overview of the V148N 115 kV Transmission Line Reconductoring Project in North Smithfield and Lincoln, Rhode Island, including Project need, existing conditions for environmental and social environment parameters, potential impacts to these parameters, and the measures that will be implemented to avoid, minimize or mitigate these impacts. The Project is proposed to allow TNEC to continue to provide a reliable supply of electricity to customers in a cost effective manner.

Based on the analysis presented herein, there are no significant long-term impacts associated with the Project. The implementation of appropriate BMPs and mitigation measures during construction will avoid or minimize the construction-phase impacts to environmental resources and the social environment. Thus the short-term impacts will be temporary and negligible.

APPENDIX A:

CURRENT STATUS OF RESEARCH ON EXTREMELY LOW FREQUENCY ELECTRIC AND MAGNETIC FIELDS AND HEALTH: RHODE ISLAND TRANSMISSION PROJECTS – THE NARRAGANSETT ELECTRIC COMPANY D/B/A/ NATIONAL GRID MARCH 9, 2015

Health Sciences Practice

Exponent®

Current Status of Research on Extremely Low Frequency Electric and Magnetic Fields and Health:

Rhode Island Transmission Projects – The Narragansett Electric Company d/b/a/ National Grid

Current Status of Research on Extremely Low Frequency Electric and Magnetic Fields and Health:

Rhode Island Transmission Projects – The Narragansett Electric Company d/b/a National Grid

Prepared for:

Rhode Island
Energy Facility Siting Board
and
The Narragansett Electric Company d/b/a
National Grid

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March 9, 2015

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Acronyms and Abbreviations

AC	Alternating current
ALL	Acute lymphoblastic leukemia
ALS	Amyotrophic lateral sclerosis
AMI	Acute myocardial infarction
CI	Confidence interval
DMBA	7,12-dimethylbenz[a]anthracene
ELF	Extremely low frequency
EMF	Electric and magnetic fields (or electromagnetic fields)
G	Gauss
HCN	Health Council of the Netherlands
Hz	Hertz
IARC	International Agency for Research on Cancer
ICES	International Commission on Electromagnetic Safety
ICNIRP	International Committee on Non-Ionizing Radiation Protection
JEM	Job exposure matrix
kV	Kilovolt
kV/m	Kilovolts per meter
mG	Milligauss
OR	Odds ratio
RR	Relative risk
SCENIHR	Scientific Committee on Emerging and Newly Identified Health Risks
TWA	Time weighted average
V/m	Volts per meter
WHO	World Health Organization

Limitations

At the request of Narragansett Electric Company d/b/a National Grid, Exponent prepared this summary report on the status of research related to extremely low-frequency electric- and magnetic-field exposure and health. The findings presented herein are made to a reasonable degree of scientific certainty. Exponent reserves the right to supplement this report and to expand or modify opinions based on review of additional material as it becomes available, through any additional work, or review of additional work performed by others.
The scope of services performed during this investigation may not adequately address the needs of other users of this report, and any re-use of this report or its findings, conclusions, or recommendations presented herein are at the sole risk of the user. The opinions and comments formulated during this assessment are based on observations and information available at the time of the investigation. No guarantee or warranty as to future life or performance of any reviewed condition is expressed or implied.

1 Executive Summary

This report was prepared to address the topic of health and extremely low frequency (ELF) electric and magnetic fields (EMF) for the Rhode Island Energy Facility Siting Board at the request of The Narragansett Electric Company d/b/a National Grid as part of its Applications for the 2015 Rhode Island Transmission Projects.

ELF EMF are invisible fields surrounding all objects that generate, use, or transmit electricity. There are also natural sources of ELF EMF, including the electric fields associated with the normal functioning of our circulatory and nervous systems. People living in developed countries are constantly exposed to ELF EMF in their environments, since electricity is fundamental part of technologically-advanced societies. Sources of man-made ELF EMF include appliances, wiring, and motors, as well as distribution and transmission lines. Section 3 of this report provides information on the nature and sources of ELF EMF, as well as typical exposure levels.

Research on ELF EMF and health began with the goal of finding therapeutic application and understanding biological electricity, i.e., the role of electrical potentials across cell membranes and current flows between cells in our bodies. Over the past 35 years, researchers have examined whether ELF EMF from man-made sources can cause short- or long-term health effects in humans using a variety of study designs and techniques. Research on ELF EMF and long-term human health effects was prompted by an epidemiology study conducted in 1979 of children in Denver, Colorado, which studied the relationship of their cancers with the potential for ELF EMF exposure from nearby distribution and transmission lines. The results of that study prompted further research on childhood leukemia and other cancers. Childhood leukemia has remained the focus of EMF and health research, although many other diseases have been studied, including other cancers in children and adults, neurodegenerative diseases, reproductive effects, and cardiovascular disease, among others.

Guidance on the possible health risks of all types of exposures comes from health risk assessments, or systematic weight-of-evidence evaluations of the cumulative literature, on a particular topic conducted by expert panels organized by scientific organizations. The public and policy makers should look to the conclusions of these reviews, since the reviews are conducted using set scientific standards by scientists representing the various disciplines required to understand the topic at hand. In a health risk assessment of any exposure, it is essential to consider the type and strength of research studies available for evaluation. Human health studies vary in methodological rigor and, therefore, in their capacity to extrapolate findings to the population at large. Furthermore, relevant studies in three areas of research (epidemiologic, *in vivo,* and *in vitro* research) must be evaluated to understand possible health risks. Section 4 of this report provides a summary of the methods used to conduct a health risk assessment.

The World Health Organization (WHO) published a health risk assessment of ELF EMF in 2007 that critically reviewed the cumulative epidemiologic and laboratory research to date, taking into account the strength and quality of the individual research studies. Section 5 provides a summary of the WHO's conclusions with regard to the major outcomes they evaluate. The WHO report provided the following overall conclusions:

> New human, animal, and in vitro studies published since the 2002 IARC Monograph, 2002 [*sic*] do not change the overall classification of ELF as a possible human carcinogen (WHO, 2007, p. 347).
>
> Acute biological effects [i.e., short-term, transient health effects such as a small shock] have been established for exposure to ELF electric and magnetic fields in the frequency range up to 100 kHz that may have adverse consequences on health. Therefore, exposure limits are needed. International guidelines exist that have addressed this issue. Compliance with these guidelines provides adequate protection. Consistent epidemiological evidence suggests that chronic low-intensity ELF magnetic field exposure is associated with an increased risk of childhood leukaemia. However, the evidence for a causal relationship is limited, therefore exposure limits based upon epidemiological evidence are not recommended, but some precautionary measures are warranted (WHO, 2007, p. 355).

This report provides a systematic literature review and a critical evaluation of relevant epidemiology and *in vivo* studies published from July 2013 to November 2014, and it updates the report submitted as part of the Application for the G-185S 115-kilovolt Transmission Line Project.[1] These recent studies did not provide sufficient evidence to alter the basic conclusion of the WHO: the research does not suggest that electric fields or magnetic fields are a cause of cancer or any other disease at the levels we encounter in our everyday environment.

There are no national recommendations, guidelines, or standards in the United States to regulate ELF EMF or to reduce public exposures, although the WHO recommends adherence to the International Commission on Non-Ionizing Radiation Protection's or the International Committee for Electromagnetic Safety's exposure limits for the prevention of acute health effects at high exposure levels and low-cost measures to minimize exposures. In light of the epidemiologic data on childhood leukemia, scientific organizations are still in agreement that only low-cost interventions to reduce ELF EMF exposure are appropriate. This approach is mirrored by the Rhode Island Energy Facility Siting Board that has approved transmission projects that have proposed effective no-cost and low-cost technologies to reduce magnetic-field exposure to the public. While the large body of existing research does not indicate any harm associated with ELF EMF, research on this topic will continue to reduce remaining uncertainty.

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[1] Exponent, Inc. *Current Status of Research on Extremely Low Frequency Electric and Magnetic Fields and Health: G-185S 115-kV Transmission Line*. Prepared for the Rhode Island Energy Facility Siting Board. October 31, 2013.

Note that this Executive Summary provides only an outline of the material discussed in this report. Exponent's technical evaluations, analyses, conclusions, and recommendations are included in the main body of this report, which at all times the controlling document.

2 Introduction

Questions about electric and magnetic fields (EMF) and health are commonly raised during the permitting of transmission lines. Numerous national and international scientific and health agencies have reviewed the research and evaluated potential health risks of exposure to extremely low frequency (ELF) EMF. The most comprehensive of these reviews of ELF EMF research was published by the World Health Organization (WHO) in 2007. The WHO's Task Group critically reviewed the cumulative epidemiologic and laboratory research through 2005, taking into account the strength and quality of the individual research studies.

The Narragansett Electric Company d/b/a National Grid requested that Exponent provide an easily-referenced document that supplements a report previously prepared for the Rhode Island Energy Facility Siting Board to bring the WHO report's conclusions up to date.[2] The G-185S 115-kilovolt (kV) Transmission Line Project report systematically evaluated peer-reviewed research and reviews by scientific panels published up to July 2013. This current report systematically evaluates peer-reviewed research and reviews by scientific panels published between July 2013 and November 2014 and also describes if and how these recent results affect conclusions reached by the WHO in 2007.

[2] Exponent, Inc. *Current Status of Research on Extremely Low Frequency Electric and Magnetic Fields and Health: G-185S 115-kV Transmission Line*. Prepared for the Rhode Island Energy Facility Siting Board. October 31, 2013.

3 Extremely Low Frequency Electric and Magnetic Fields: Nature, Sources, Exposure, and Known Effects

Nature of ELF EMF

Electricity is transmitted as current from generating sources to high-voltage transmission lines, substations, distribution lines, and then finally to our homes and workplaces for consumption. The vast majority of electricity in North America is transmitted as alternating current (AC), which changes direction 60 times per second (i.e., a frequency of 60 Hertz [Hz]).

Everything that is connected to our electrical system (i.e., power lines, wiring, appliances, and electronics) produces ELF EMF (Figure 1). Both electric fields and magnetic fields are properties of the space near these electrical sources. Forces are experienced by objects capable of interacting with these fields; electric charges are subject to a force in an electric field, and moving charges experience a force in a magnetic field.

- **Electric fields** are the result of voltages applied to electrical conductors and equipment. The electric field is expressed in measurement units of volts per meter (V/m) or kilovolts per meter (kV/m); one kV/m is equal to 1,000 V/m. Conducting objects including fences, buildings, and our own skin and muscle easily block electric fields. Therefore, certain appliances within homes and workplaces are the major source of electric fields indoors, while transmission and distribution lines are the major source of electric fields outdoors.

- **Magnetic fields** are produced by the flow of electric currents; however, unlike electric fields, most materials do not readily block magnetic fields. The strength of a magnetic field is expressed as magnetic flux density in units called gauss (G), or in milligauss (mG), where 1 G = 1,000 mG.[3] The strength of the magnetic field at any point depends on characteristics of the source; in the case of power lines, strength is dependent on the arrangement of conductors, the amount of current flow, and distance from the conductors.

[3] Scientists also refer to magnetic flux density at these levels in units of microtesla. Magnetic flux density in units of mG can be converted to microtesla by dividing by 10, i.e., 1 mG = 0.1 microtesla.

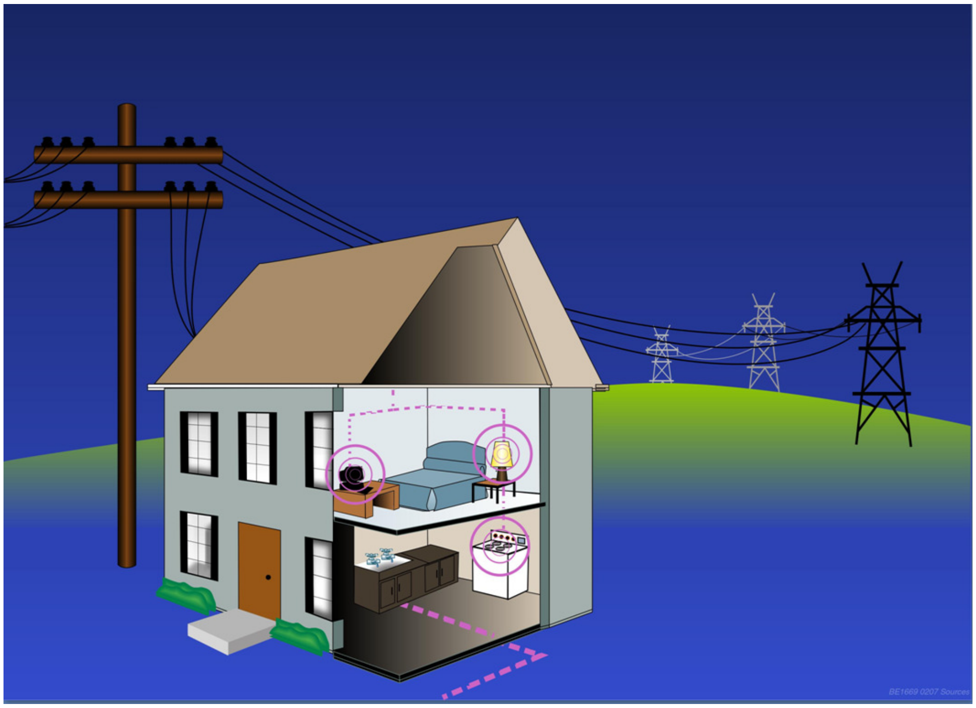

Figure 1. Numerous sources of ELF EMF in our homes (appliances, wiring, currents running on water pipes, and nearby distribution and transmission lines).

Sources and exposure

The intensity of both electric fields and magnetic fields diminishes with increasing distance from the source. Electric and magnetic fields from transmission lines generally decrease with distance from the conductors in proportion to the square of the distance, described as creating a bell-shaped curve of field strength around the lines.

Since electricity is such an integral part of our infrastructure (e.g., transportation systems, homes, and businesses), people living in modern communities literally are surrounded by these fields. Figure 2 describes typical EMF levels measured in residential and occupational environments, compared to levels measured on or at the edge of transmission-line rights-of-way. While EMF levels decrease with distance from the source, any home, school, or office tends to have a "background" EMF level as a result of the combined effect of the numerous EMF sources. In general, the background magnetic-field level in a house away from appliances is typically less than 20 mG, while levels can be hundreds of mG in close proximity to appliances. Background levels of electric fields range from 10-20 V/m, while appliances produce levels up to several tens of V/m (WHO, 2007).

Experiments have yet to show which aspect of ELF EMF exposure, if any, may be relevant to biological systems. The current standard of EMF exposure for health research is long-term, average personal exposure, which is the average of all exposures to the varied electrical sources encountered in the many places we live, work, eat, and shop. As expected, this exposure is difficult to approximate, and exposure assessment is a major source of uncertainty in studies of ELF EMF and health (WHO, 2007).

Little research has been done to characterize the general public's exposure to magnetic fields, although some basic conclusions are available from the literature:

- *Personal magnetic-field exposure:*
    - The vast majority of persons in the United States have a *time-weighted average* (TWA) exposure to magnetic fields less than 2 mG (Zaffanella and Kalton, 1998).[4]
    - In general, personal magnetic-field exposure is greatest at work and during travel (Zaffanella and Kalton, 1998).
- *Residential magnetic-field exposure:*
    - The highest magnetic-field levels are typically found directly next to appliances (Zaffanella, 1993). For example, Gauger (1985) reported the maximum AC magnetic field at 3 centimeters from a sampling of appliances as 3,000 mG (can opener), 2,000 mG (hair dryer), 5 mG (oven), and 0.7 mG (refrigerator).
    - The following parameters affect the distribution of personal magnetic-field exposures at home: residence type, residence size, type of water line, and proximity to overhead power lines. Persons living in small homes, apartments, homes with metallic piping, and homes close to three-phase electric power distribution and transmission lines tended to have higher at-home magnetic-field levels (Zaffanella and Kalton, 1998).
    - Residential magnetic-field levels are caused by currents from nearby transmission and distribution systems, pipes or other conductive paths, and electrical appliances (Zaffanella, 1993).
- *Workplace magnetic-field exposure*
    - Some occupations (e.g., electric utility workers, sewing machine operators, telecommunication workers) have higher exposures due to work near equipment with high magnetic-field levels.[5]

[4] TWA is the average exposure over a given specified time period (i.e., an 8-hour workday or a 24-hour day) of a person's exposure to a chemical or physical agent. The average is determined by sampling the exposure of interest throughout the time period.

[5] http://www.niehs.nih.gov/health/assets/docs_p_z/emf-02.pdf

- *Power line magnetic-field exposure*
    - The magnetic-field levels associated with transmission and distribution lines vary substantially depending on their configuration, amount of current flow (load), and distance from conductors, among other parameters. At distances of approximately 300 feet from overhead transmission lines and during average electricity demand, the magnetic-field levels from many transmission lines are often similar to the background levels found in most homes (Figure 2).

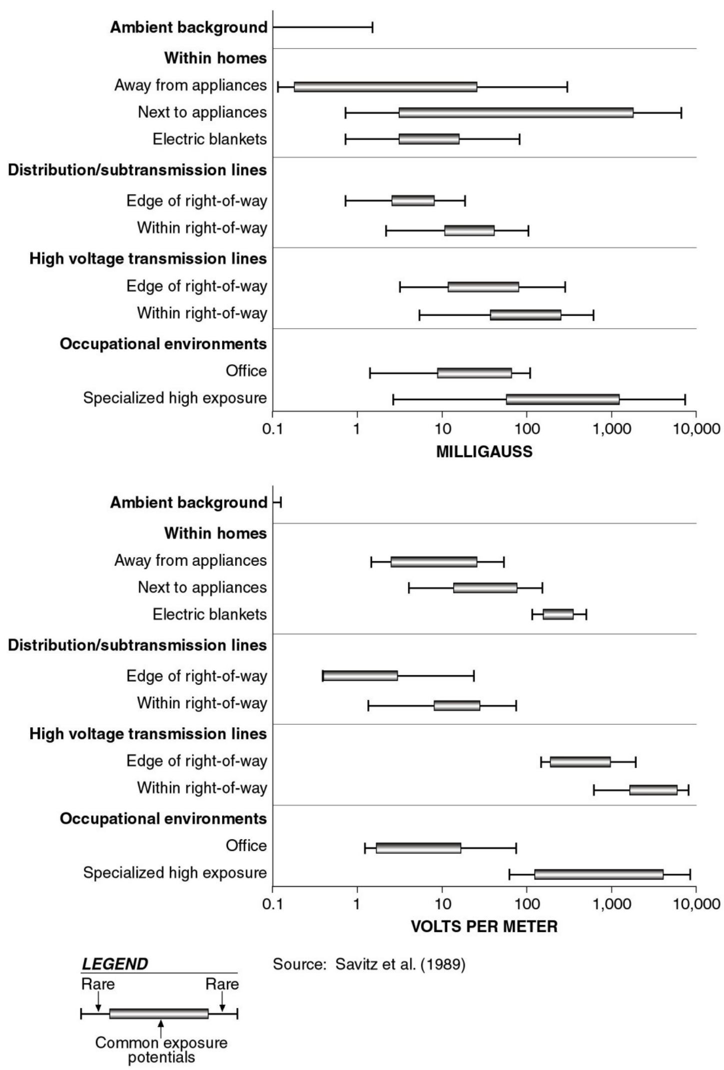

Figure 2. Electric- and magnetic-field strengths in the environment.

Known effects

Similar to virtually any exposure, adverse effects can be expected from exposure to very high levels of ELF EMF. If the current density or electric field induced by an extremely strong magnetic field exceeds a certain threshold, excitation of muscles and nerves is possible. Also, strong electric fields can induce charges on the surface of the body that can lead to small shocks, i.e., micro shocks. These are acute and shock-like effects that cause no long-term damage or health consequences. Limits for the general public and workplace have been set to prevent these effects, but real-life situations where these levels would be exceeded are rare. Standards and guidelines are discussed in more detail in Section 8.

4 Methods for Evaluating Scientific Research

Science is more than a collection of facts. It is a method of obtaining information and of reasoning to ensure that the information and conclusions are accurate and correctly describe physical and biological phenomena. Many misconceptions in human reasoning occur when people casually interpret their observations and experience. Therefore, scientists use systematic methods to conduct and evaluate scientific research and assess the potential impact of a specific agent on human health. This process is designed to ensure that more weight is given to those studies of better quality and studies with a given result are not selected out from all of the studies available to advocate or suppress a preconceived idea of an adverse effect. Scientists and scientific agencies and organizations use these standard methods to draw conclusions about the many exposures in our environment.

Weight-of-evidence reviews

The scientific process entails looking at *all* the evidence on a particular issue in a systematic and thorough manner to evaluate if the overall data presents a logically coherent and consistent picture. This is often referred to as a weight-of-evidence review, in which all studies are considered together, giving more weight to studies of higher quality and using an established analytic framework to arrive at a conclusion about a possible causal relationship. Weight-of-evidence reviews are typically conducted within the larger framework of health risk assessments or evaluations of particular exposures or exposure circumstances that qualitatively and quantitatively define health risks. Weight-of-evidence and health risk assessment methods have been described by several agencies, including the International Agency for Research on Cancer (IARC), which routinely evaluates substances such as drugs, chemicals, and physical agents for their ability to cause cancer; the WHO International Programme for Chemical Safety; and the US Environmental Protection Agency, which set guidance for public exposures (WHO, 1994; USEPA, 1993; USEPA, 1996). Two steps precede a weight-of-evidence evaluation: a systematic review to identify the relevant literature and an evaluation of each relevant study to determine its strengths and weaknesses.

The following sections discuss important considerations in the evaluation of human health studies of EMF in a weight-of-evidence review, including exposure considerations, study design, methods for estimating risk, bias, and the process of causal inference. The purpose of discussing these considerations here is to provide context for the later weight-of-evidence evaluations.

Exposure considerations

Exposure methods range widely in studies of ELF EMF, including: the classification of residences based on the relative capacity of nearby power lines to produce magnetic fields (i.e., wire code categories); occupational titles; calculated magnetic-field levels based on job histories (i.e., a job-exposure matrix [JEM]); residential distance from nearby power lines; spot measurements of magnetic-field levels inside or outside residences; 24-hour and 48-hour measurements of magnetic fields in a particular location in the house (e.g., a child's bedroom); calculated magnetic-field levels based on the characteristics of nearby power installations; and, finally, personal 24-hour and 48-hour magnetic-field measurements.

Each of these methods has strengths and limitations (Kheifets and Oksuzyan, 2008). Since magnetic-field exposures are ubiquitous and vary over a lifetime as the places we frequent and the sources of ELF EMF in those places change, making valid estimates of personal magnetic-field exposure challenging. Furthermore, without a biological basis to define a relevant exposure metric (average exposure or peak exposure) and a defined critical period for exposure (e.g., *in utero*, shortly before diagnosis), relevant and valid assessments of exposure are problematic. Exposure misclassification is one of the most significant concerns in studies of ELF EMF.

In general, long-term personal measurements are the metrics selected by epidemiologists. Other methods are generally weaker because they may not be strong predictors of long-term exposure and do not take into account all magnetic-field sources. ELF EMF can be estimated indirectly by assigning an estimated amount of exposure to an individual based on calculations considering nearby power installations or a person's job title. For instance, a relative estimate of exposure could be assigned to all machine operators based on historical information on the magnitude of the magnetic field produced by the machine. Indirect measurements are not as accurate as direct measurements because they do not contain information specific to that person or the exposure situation. In the example of machine operators, the indirect measurement may not account for how much time any one individual spends working at that machine or any potential variability in magnetic fields produced by the machines over time. In addition, such occupational measurements do not take into account the worker's residential magnetic-field exposures.

While JEMs are an advancement over earlier methods, they still have some important limitations, as highlighted in a review by Kheifets et al. (2009) summarizing an expert panel's findings.[6] A person's occupation provides some relative indication of the overall magnitude of their occupational magnetic-field exposure, but it does not take into account the possible variation in exposure due to different job tasks within occupational titles, the frequency and intensity of contact to relevant exposure sources, or variation by calendar time. This was highlighted by a recent study of 48-hour magnetic-field measurements of 543 workers in Italy in a variety of occupational settings, including: ceramics, mechanical engineering, textiles, graphics, retail, food, wood, and biomedical industries (Gobba et al., 2011). In this study, there was significant variation in measured TWA magnetic-field levels for workers in many of the International Standard Classification of Occupations' job categories, which the authors attributed to variations within these task-defined categories in some of the industries.

Types of health research studies

Research studies can be broadly classified into two groups: 1) epidemiologic observations of people and 2) experimental studies on animals, humans, cells, and tissues conducted in laboratory settings. Epidemiology studies investigate how disease is distributed in populations

[6] Kheifets et al. (2009) reports on the conclusions of an independent panel organized by the Energy Networks Association in the United Kingdom in 2006 to review the current status of the science on occupational EMF exposure and identify the highest priority research needs.

and what factors influence or determine this disease distribution (Gordis, 2000). Epidemiology studies attempt to identify potential causes for human disease while observing people as they go about their normal, daily lives. Such studies are designed to quantify and evaluate the associations between disease and reported exposures to environmental factors.

The most common types of epidemiology studies in the ELF EMF literature are case-control and cohort studies. In case-control studies, people with and without the disease of interest are identified and the exposures of interest are evaluated. Often, people are interviewed or their personal records (e.g., medical records or employment records) are reviewed in order to establish the exposure history for each individual. The exposure histories are then compared between the diseased and non-diseased populations to determine whether any statistically significant differences in exposure histories exist. In cohort studies, on the other hand, individuals within a defined cohort of people (e.g., all persons working at a utility company) are classified as exposed or non-exposed and followed over time for the incidence of disease. Researchers then compare disease incidence in the exposed and non-exposed groups.

Experimental studies are designed to test specific hypotheses under controlled conditions and are vital to assessing cause-and-effect relationships. An example of a human experimental study relevant to this area of research would be studies that measure the impact of magnetic-field exposure on acute biological responses in humans, such as hormone levels. These studies are conducted in laboratories under controlled conditions. *In vivo* and *in vitro* experimental studies are also conducted under controlled conditions in laboratories. *In vivo* studies expose laboratory animals to very high levels of a chemical or physical agent to determine whether exposed animals develop cancer or other effects at higher rates than unexposed animals, while attempting to control other factors that could possibly affect disease rates (e.g., diet, genetics). *In vitro* studies of isolated cells and tissues are important because they can help scientists understand biological mechanisms as they relate to the same exposure in intact humans and animals. In the case of *in vitro* studies, the responses of cells and tissues outside the body may not reflect the response of those same cells if maintained in a living system, so their relevance cannot be assumed. Therefore, it is both necessary and desirable that agents that could present a potential health threat be explored by both epidemiology and experimental studies.

Both of these approaches—epidemiology and experimental laboratory studies—have been used to evaluate whether exposure to ELF EMF has any adverse effects on human health. Epidemiology studies are valuable because they are conducted in human populations, but they are limited by their non-experimental design and typical retrospective nature. In epidemiology studies of magnetic fields, for example, researchers cannot control the amount of individual exposure, how exposure occurs over time, the contribution of different field sources, or individual behaviors other than exposure that may affect disease risk, such as diet. In valid risk assessments of ELF EMF, epidemiology studies are considered alongside experimental studies of laboratory animals, while studies of isolated tissues and cells are generally considered supplementary.

Estimating risk

Epidemiologists measure the statistical association between exposures and disease in order to estimate risk. This brief summary of risk is included to provide a foundation for understanding and interpreting statistical associations in epidemiology studies as risk estimates.

Two common types of risk estimates are absolute risk and relative risk (RR). Absolute risk, also known as incidence, is the amount of new disease that occurs in a given period of time. For example, the absolute risk of invasive childhood cancer in children ages 0 to 19 years for 2004 was 14.8 per 100,000 children (Reis et al., 2007). RRs are calculated to evaluate whether a particular exposure or inherent quality (e.g., EMF, diet, genetics, race) is associated with a disease outcome. This is calculated by looking at the absolute risk in one group relative to a comparison group. For example, white children in the 0 to 19 year age range had an estimated absolute risk of childhood cancer of 15.4 per 100,000 in 2004, and African American children had an estimated absolute risk of 13.3 per 100,000 in the same year. By dividing the absolute risk of white children by the absolute risk of African American children, we obtain a RR of 1.16. This RR estimate can be interpreted to mean that white children have a risk of childhood cancer that is 16% greater than the risk of African American children. Additional statistical analysis is needed to evaluate whether this association is statistically significant, as defined in the following sub-section.

It is important to understand that risk is estimated differently in cohort and case-control studies because of the way the studies are designed. Traditional cohort studies provide a direct estimate of RR, while case-control studies only provide indirect estimates of RR, called odds ratios (OR). For this reason, among others, cohort studies usually provide more reliable estimates of the risk associated with a particular exposure. Case-control studies are more common than cohort studies, however, because they are less costly and more time efficient.

Thus, the association between a particular disease and exposure is measured quantitatively in an epidemiology study as either the RR (cohort studies) or OR (case-control studies) estimate. The general interpretation of a risk estimate equal to 1.0 is that the exposure is not associated with an increased incidence of the disease. If the risk estimate is greater than 1.0, the inference is that the exposure is associated with an increased incidence of the disease. On the other hand, if the risk estimate is less than 1.0, the inference is that the exposure is associated with a reduced incidence of the disease. The magnitude of the risk estimate is often referred to as its strength (i.e., strong vs. weak). Stronger associations are given more weight because they are less susceptible to the effects of bias.

Statistical significance

Statistical significance testing provides an idea of whether or not a statistical association is a chance occurrence or whether the association is likely to be observed upon repeated testing. The terms “statistically significant” or “statistically significant association” are used in epidemiology studies to describe the tendency of the level of exposure and the occurrence of disease to be linked, with chance as an unlikely explanation. Statistically significant associations, however, are not necessarily an indication of cause-and-effect, because the interpretation of statistically significant associations depends on many other factors associated with the design and conduct of the study, including how the data were collected and the number of study participants.

Confidence intervals (CI) reported along with RR and OR values, indicate a range of values for an estimate of effect that has a specified probability (e.g., 95%) that the sample of data examined includes the "true" estimate of effect; CIs evaluate statistical significance, but do not address the role of bias, as described further below. A 95% CI indicates that, if the study were conducted a very large number of times, 95% of the measured estimates would be within the upper and lower confidence limits based on sampling of a normal statistical distribution.

The range of the CI is also important for interpreting estimated associations, including the precision and statistical significance of the association. A very wide CI indicates great uncertainty in the value of the "true" risk estimate. This is usually due to a small number of observations. A narrow CI provides more certainty about where the "true" RR estimate lies. If the 95% CI does not include 1.0, the probability of an association being due to chance alone is 5% or lower and the result is considered statistically significant, as discussed above.

While a 95% CI is commonly applied, it provides marginal protection against falsely rejecting a hypothesis of no effect, so acceptance of a 99% CI level is recommended (e.g., Goodman, 1999).

Meta-analysis and pooled analysis

In scientific research, the results of smaller studies may be difficult to distinguish from normal, random variation. This is also the case for sub-group analyses where few cases are estimated to have high exposure levels, e.g., in case-control studies of childhood leukemia and TWA magnetic-field exposure greater than 3-4 mG. Meta-analysis is an analytic technique that combines the published results from a group of studies into one summary result. A pooled analysis, on the other hand, combines the raw, individual-level data from the original studies and analyzes the data from the studies altogether. These methods are valuable because they increase the number of individuals in the analysis, which allows for a more robust and stable estimate of association. Meta- and pooled analyses are an important tool for qualitatively synthesizing the results of a large group of studies.

The disadvantage of meta- and pooled analyses is that they can convey a false sense of consistency across studies if *only* the combined estimate of effect is considered (Rothman and Greenland, 1998). These analyses typically combine data from studies with different study populations, methods for measuring and defining exposure, and disease definitions. This is particularly true for analyses that combine data from case-control studies, which often use very different methods for the selection of cases and controls and exposure assessment. Therefore, in addition to the synthesis or combining of data, meta- and pooled analyses should be used to understand what factors cause the results of the studies to vary (i.e., publication date, study design, possibility of selection bias), and how these factors affect the associations calculated from the data of all the studies combined (Rothman and Greenland, 1998).

Meta- and pooled analyses are a valuable technique in epidemiology; however, in addition to calculating a summary RR, they should follow standard techniques (Stroup et al., 2001) and analyze the factors that contribute to any heterogeneity between the studies.

Bias in epidemiology studies

One key reason that the results of epidemiology studies cannot directly provide evidence for cause-and-effect is the presence of bias. Bias is defined as "any systematic error in the design, conduct or analysis of a study that results in a mistaken estimate of an exposure's effect on the risk of disease" (Gordis, 2000, p. 204). In other words, sources of bias are factors or research situations that can mask a true association or cause an association that does not truly exist. As a result, the extent of bias, as well as its types and sources, is one of the most important considerations in the interpretation of epidemiology studies. Since it is not possible to fully control human populations, perfectly measure their exposures, or control for the effects of all other risk factors, bias will exist in some form in all epidemiology studies of human health. Laboratory studies, on the other hand, more effectively manage bias because of the tight control the researchers have over most study variables.

One important source of bias occurs in epidemiology studies when a third variable confuses the relationship between the exposure and disease of interest because of its relationship to both. Consider an example of a researcher whose study finds that people who exercise have a lower risk of diabetes compared to people who do not exercise. It is known that people who exercise more tend to also consume healthier diets and healthier diets may lower the risk of diabetes. If the researcher does not control for the impact of diet, it is not possible to say with certainty that the lower risk of diabetes is due to exercise and not to a healthier diet. In this example, diet is the confounding variable.

Cause vs. association and evaluating evidence regarding causal associations

Epidemiology studies can help suggest factors that may contribute to the risk of disease, but they are not used as the sole basis for drawing inferences about cause-and-effect relationships. Since epidemiologists do not have control over the many other factors to which people in are exposed in their studies, and diseases can be caused by a complex interaction of many factors, the results of epidemiology studies must be interpreted with caution. A single epidemiology study is rarely unequivocally supportive or non-supportive of causation; rather, a weight is assigned to the study based on the validity of its methods and all relevant studies (epidemiology, *in vivo*, and *in vitro*) must be considered together in a weight-of-evidence review to arrive at a conclusion about possible causality between an exposure and disease.

In 1964, the Surgeon General of the United States published a landmark report on smoking-related diseases (HEW, 1964). As part of this report, nine criteria for evaluating epidemiology studies (along with experimental data) for causality were outlined. In a more recent version of this report, these criteria have been reorganized into seven criteria. In the earlier version, which was based on the commonly referenced Hill criteria (Hill, 1965), coherence, plausibility, and analogy were considered as distinct items, but are now summarized together because they have been treated in practice as essentially reflecting one concept (HHS, 2004). Table 1 provides a listing and brief description of each criterion.

Table 1. Criteria for evaluating whether an association is causal

Criteria	Description
Consistency	Repeated observation of an association between exposure and disease in multiple studies of adequate statistical power, in different populations, and at different times.
Strength of the association	The larger (stronger) the magnitude and statistical strength of an association is between exposure and disease, the less likely such an effect is the result of chance or unmeasured confounding.
Specificity	The exposure is the single (or one of a few) cause of disease.
Temporality	The exposure occurs prior to the onset of disease.
Coherence, plausibility, and analogy	The association cannot violate known scientific principles and the association must be consistent with experimentally demonstrated biologic mechanisms.
Biologic gradient	This is also known as a dose-response relationship, i.e., the observation that the stronger or greater the exposure is, the stronger or greater the effect.
Experiment	Observations that result from situations in which natural conditions imitate experimental conditions. Also stated as a change in disease outcome in response to a non-experimental change in exposure patterns in population.

Source: Department of Health and Human Services, 2004

The criteria were meant to be applied to statistically significant associations that have been observed in the cumulative epidemiologic literature (i.e., if no statistically significant association has been observed for an exposure then the criteria are not relevant). It is important to note that these criteria were not intended to serve as a checklist but as guide to evaluate associations for causal inference. Theoretically, it is possible for an exposure to meet all seven criteria, but still not be deemed a causal factor. Also, no one criterion can provide indisputable evidence for causation, nor can any single criterion, aside from temporality, rule out causation.

In summary, the judicious consideration of these criteria is useful in evaluating epidemiology studies, but they cannot be used as the sole basis for drawing inferences about cause-and-effect relationships. In line with the criteria of "coherence, plausibility, and analogy," epidemiology studies are considered along with *in vivo* and *in vitro* studies in a comprehensive weight-of-evidence review. Epidemiologic support for causality is usually based on high-quality studies reporting consistent results across many different populations and study designs that are supported by the experimental data collected from *in vivo* and *in vitro* studies.

Biological response vs. disease in human health

When interpreting research studies, it is important to distinguish between a reported biological response and an indicator of disease. This is relevant because exposure to ELF EMF may elicit a biological response that is simply a normal response to environmental conditions. This response, however, may not be a disease, cause a disease, or be otherwise harmful. There are many exposures or factors encountered in day-to-day life that elicit a biological response, but the response is neither harmful nor a cause of disease. For example, when an individual walks from a dark room indoors to a sunny day outdoors, the pupils of the eye naturally constrict to limit the amount of light passing into the eye. This constriction of the pupil is considered a biological response to the change in light conditions. Pupil constriction, however, is neither a disease itself, nor is it known to cause disease.

5 The WHO 2007 Report: Methods and Conclusions

The WHO is a scientific organization within the United Nations system whose mandate includes providing leadership on global health matters, shaping health research agendas, and setting norms and standards. The WHO established the International EMF Project in 1996, in response to public concern about exposure to ELF EMF and possible adverse health outcomes. The project's membership includes 8 international organizations, 8 collaborating institutions, and over 54 national authorities. The overall purpose of the Project is to assess health and environmental effects of exposure to static and time varying fields in the frequency range of 0 Hz to 300 gigahertz. A key objective of the Project is to evaluate the scientific literature and make periodic status reports on health effects to be used as the basis for a coherent international response, including the identification of important research gaps and the development of internationally acceptable standards for ELF EMF exposure.

In 2007, the WHO published their Environmental Health Criteria (EHC) 238 on EMF summarizing health research in the ELF range. The EHC used standard scientific procedures, as outlined in its Preamble and described above in Section 4, to conduct the review. The Task Group responsible for the report's overall conclusions consisted of 21 scientists from around the world with expertise in a wide range of scientific disciplines. They relied on the conclusions of previous weight-of-evidence reviews,[7] where possible, and mainly focused on evaluating studies published after an IARC review of ELF EMF and cancer in 2002.

The WHO Task Group and IARC use specific terms to describe the strength of the evidence in support of causality between specific agents and cancer. These categories are described here because, while they are meaningful to scientists who are familiar with the IARC process, they can create an undue level of concern with the general public. *Sufficient evidence of carcinogenicity* is assigned to a body of epidemiologic research if a positive association has been observed in studies in which chance, bias, and confounding can be ruled out with reasonable confidence. *Limited evidence of carcinogenicity* describes a body of epidemiologic research where the findings are inconsistent or there are outstanding questions about study design or other methodological issues that preclude making a conclusion. *Inadequate evidence of carcinogenicity* describes a body of epidemiologic research where it is unclear whether the data is supportive or unsupportive of causation because there is a lack of data or there are major quantitative or qualitative issues. A similar classification system is used for evaluating *in vivo* studies and mechanistic data for carcinogenicity.

Summary categories are assigned by considering the conclusions of each body of evidence (epidemiologic, *in vivo,* and *in vitro*) together (see Figure 3). *In vitro* research is not described in Figure 3 because it provides ancillary information and, therefore, is used to a lesser degree in evaluating carcinogenicity and is classified simply as strong, moderate, or weak. Categories

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[7] The term "weight-of-evidence review" is used in this report to denote a systematic review process by a multidisciplinary, scientific panel involving experimental and epidemiologic research to arrive at conclusions about possible health risks. The WHO EHC on EMF does not specifically describe their report as a weight-of-evidence review. Rather, they describe conducting a health risk assessment. A health risk assessment differs from a weight-of-evidence review in that it also incorporates an exposure and exposure-response assessment.

include (from highest to lowest risk): carcinogenic to humans, probably carcinogenic to humans, possibly carcinogenic to humans, unclassifiable, and probably not carcinogenic to humans. These categories are intentionally meant to err on the side of caution, giving more weight to the possibility that the exposure is truly carcinogenic and less weight to the possibility that the exposure is not carcinogenic. The category "possibly carcinogenic to humans" denotes exposures for which there is limited evidence of carcinogenicity in epidemiology studies and less than sufficient evidence of carcinogenicity in studies of experimental animals.

	Epidemiology Studies				Animal Studies			
	Sufficient evidence	Limited evidence	Inadequate evidence	Evidence suggesting lack of carcinogenicity	Sufficient evidence	Limited evidence	Inadequate evidence	Evidence suggesting lack of carcinogenicity
Known Carcinogen	✓							
Probable Carcinogen		✓			✓			
Possible Carcinogen		✓				✓	✓	
Not Classifiable			✓			✓	✓	
Probably not a Carcinogen				✓				✓

Sufficient evidence in epidemiology studies—A positive association is observed between the exposure and cancer in studies, in which chance, bias and confounding were ruled out with "reasonable confidence."

Limited evidence in epidemiology studies—A positive association has been observed between the exposure and cancer for which a causal interpretation is considered to be credible, but chance, bias or confounding could not be ruled out with "reasonable confidence."

Inadequate evidence in epidemiology studies—The available studies are of insufficient quality, consistency or statistical power to permit a conclusion regarding the presence or absence of a causal association between exposure and cancer, or no data on cancer in humans are available.

Evidence suggesting a lack of carcinogenicity in epidemiology studies—There are several adequate studies covering the full range of levels of exposure that humans are known to encounter, which are mutually consistent in not showing a positive association between exposure to the agent and any studied cancer at any observed level of exposure. The results from these studies alone or combined should have narrow confidence intervals with an upper limit close to the null value (e.g. a relative risk of 1.0). Bias and confounding should be ruled out with reasonable confidence, and the studies should have an adequate length of follow-up.

Sufficient evidence in animal studies—An increased incidence of malignant neoplasms is observed in (a) two or more species of animals or (b) two or more independent studies in one species carried out at different times or indifferent laboratories or under different protocols. An increased incidence of tumors in both sexes of a single species in a well-conducted study, ideally conducted under Good Laboratory Practices, can also provide sufficient evidence.

Limited evidence in animal studies—The data suggest a carcinogenic effect but are limited for making a definitive evaluation, e.g. (a) the evidence of carcinogenicity is restricted to a single experiment; (b) there are unresolved questions regarding the adequacy of the design, conduct or interpretation of the studies; etc.

Inadequate evidence in animal studies—The studies cannot be interpreted as showing either the presence or absence of a carcinogenic effect because of major qualitative or quantitative limitations, or no data on cancer in experimental animals are available

Evidence suggesting a lack of carcinogenicity in animal studies—Adequate studies involving at least two species are available which show that, within the limits of the tests used, the agent is not carcinogenic.

Figure 3. Basic IARC method for classifying exposures based on potential carcinogenicity.

The IARC has reviewed close to 1,000 substances and exposure circumstances to evaluate their potential carcinogenicity. Over 80% of exposures fall in the categories possible carcinogen

(29%) or non-classifiable (52%). This occurs because, as described above, it is nearly impossible to prove that something is completely safe, and few exposures show a clear-cut or probable risk, so most agents will end up in either of these two categories. Throughout the history of the IARC, only one agent has been classified as probably not a carcinogen, which illustrates the conservatism of the evaluations and the difficulty in proving the absence of an effect beyond all doubt.

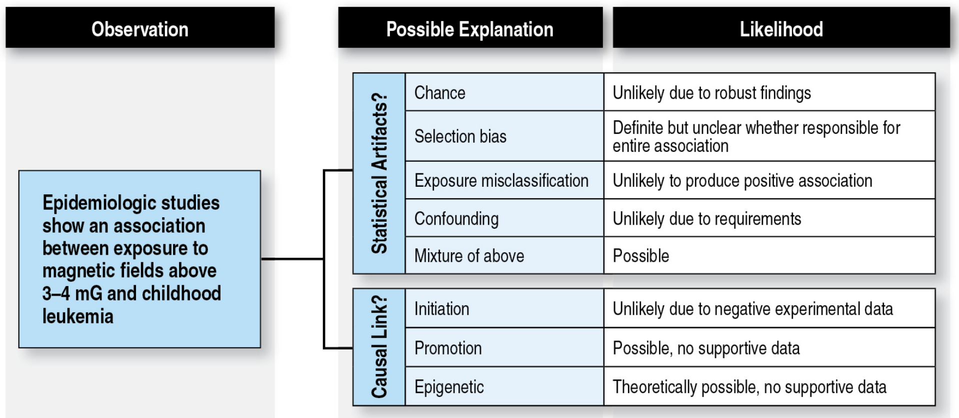
The WHO report provided the following overall conclusions with regard to ELF EMF:

> New human, animal, and in vitro studies published since the 2002 IARC Monograph, 2002 [*sic*] do not change the overall classification of ELF as a possible human carcinogen (p. 347).
>
> Acute biological effects [i.e., short-term, transient health effects such as a small shock] have been established for exposure to ELF electric and magnetic fields in the frequency range up to 100 kHz that may have adverse consequences on health. Therefore, exposure limits are needed. International guidelines exist that have addressed this issue. Compliance with these guidelines provides adequate protection. Consistent epidemiological evidence suggests that chronic low-intensity ELF magnetic field exposure is associated with an increased risk of childhood leukaemia. However, the evidence for a causal relationship is limited, therefore exposure limits based upon epidemiological evidence are not recommended, but some precautionary measures are warranted (p. 355, WHO, 2007).

With regard to specific diseases, the WHO concluded the following:

Childhood cancers. The WHO report paid particular attention to childhood leukemia because the most consistent epidemiologic association in the area of ELF EMF and health research has been reported between this disease and TWA exposure to high, magnetic-field levels. Two pooled analyses reported an association between childhood leukemia and TWA magnetic-field exposure >3-4 mG (Ahlbom et al., 2000; Greenland et al., 2000); it is these data, categorized as limited epidemiologic evidence, that resulted in the classification of magnetic fields as possibly carcinogenic by the IARC in 2002.

The WHO report systematically evaluated several factors that might be partially, or fully, responsible for the consistent association, including: chance, misclassification of magnetic-field exposure, confounding from hypothesized or unknown risk factors, and selection bias. The authors concluded that chance is an unlikely explanation since the pooled analyses had a larger sample size and decreased variability; control selection bias probably occurs to some extent in these studies and would result in an overestimate of the true association, but would not explain the entire observed association; it is less likely that confounding occurs, although the possibility that some yet-to-be identified confounder is responsible for the association cannot be fully excluded; and, finally, exposure misclassification would likely result in an underestimate of the true association, although it is not entirely clear (see Figure 4 below). The WHO concluded that reconciling the epidemiologic data on childhood leukemia and the negative (i.e., no hazard or risk observed) experimental findings through innovative research is currently the highest priority in the field of ELF EMF research. Given that few children are expected to have long-term *average* magnetic-field exposures greater than 3-4 mG, however, the WHO stated that the public health impact of magnetic fields on childhood leukemia would likely be minimal, if the association was determined to be causal.



Source: Adapted from Schüz and Ahlbom (2008)

Figure 4. Possible explanations for the observed association between magnetic fields and childhood leukemia.

Fewer studies have been published on magnetic fields and childhood brain cancer compared to studies of childhood leukemia. The WHO Task Group described the results of these studies as inconsistent and limited by small sample sizes and recommended a meta-analysis to clarify the research findings.

Breast cancer. The WHO concluded that the more recent studies they reviewed on breast cancer and ELF EMF exposure were higher in quality compared with earlier studies, and for that reason, they provide strong support to previous consensus statements that magnetic-field exposure does not influence the risk of breast cancer. In summary, the WHO stated "[w]ith these [more recent] studies, the evidence for an association between ELF magnetic-field exposure and the risk of female breast cancer is weakened considerably and does not support an association of this kind" (WHO, 2007, p. 9). The WHO recommended no further research with respect to breast cancer and magnetic-field exposure.

Adult leukemia and brain cancer. The WHO concluded, "In the case of adult brain cancer and leukaemia, the new studies published after the IARC monograph do not change the conclusion that the overall evidence for an association between ELF [EMF] and the risk of these disease remains inadequate" (WHO, 2007, p. 307). The WHO panel recommended updating the existing European cohorts of occupationally-exposed individuals and pooling the epidemiologic data on brain cancer and adult leukemia to confirm the absence of an association.

In vivo research on carcinogenesis. The WHO concluded the following with respect to *in vivo* research, "[t]here is no evidence that ELF [EMF] exposure alone causes tumours. The evidence that ELF field exposure can enhance tumour development in combination with carcinogens is inadequate" (WHO, 2007, p. 10). Recommendations for future research included the development of a rodent model for childhood acute lymphoblastic leukemia (ALL) and the continued investigation of whether magnetic fields can act as a co-carcinogen.

Reproductive and developmental effects. The WHO concluded that, overall, the body of research does not suggest that maternal or paternal exposures to ELF EMF cause adverse reproductive or developmental outcomes. The evidence from epidemiology studies on miscarriage was described as inadequate and further research on this possible association was recommended, although low priority was given to this recommendation.

Neurodegenerative diseases. The WHO reported that the majority of epidemiology studies have reported associations between occupational magnetic-field exposure and mortality from Alzheimer's disease and amyotrophic lateral sclerosis (ALS), although the design and methods of these studies were relatively weak (e.g., disease status was based on death certificate data, exposure was based on incomplete occupational information from census data, and there was no control for confounding factors). The WHO concluded that there is inadequate data in support of an association between magnetic-field exposure and Alzheimer's disease or ALS. The panel highly recommended that further studies be conducted in this area, particularly studies where the association between magnetic fields and ALS is estimated while controlling for the possible confounding effect of electric shocks.

Cardiovascular disease. It has been hypothesized that magnetic-field exposure reduces heart rate variability, which in turn increases the risk for acute myocardial infarction (AMI). With one exception (Savitz et al., 1999), however, none of the studies of cardiovascular disease morbidity and mortality that were reviewed show an association with exposure. Whether a specific association exists between exposure and altered autonomic control of the heart remains speculative and overall the evidence does not support an association. Experimental studies of both short- and long-term exposure indicate that, while electric shock is an obvious health hazard, other hazardous cardiovascular effects associated with ELF EMF are unlikely to occur at exposure levels commonly encountered environmentally or occupationally.

6 Current Scientific Consensus

The following sections identify and describe epidemiology and *in vivo* studies related to ELF EMF and health published between July 2013 and November 2014. The purpose of this section is to evaluate whether the findings of these recent studies alter the conclusions published by the WHO in their 2007 report, as described in Section 5. The previous Exponent report that summarized the literature up to July 2013[8] concluded that recent results did not provide sufficient evidence to alter the basic conclusion of the WHO EHC published in 2007.

A structured literature search was conducted using PubMed, a search engine provided by the National Library of Medicine and the National Institutes of Health that includes over 15 million up-to-date citations from MEDLINE and other life science journals for biomedical articles (http://www.pubmed.gov). A well-defined search strategy was used to identify literature indexed between July 2013 and November 2014.[9] All fields (e.g., title, abstract, keywords) were searched with various search strings that referenced the exposure and disease of interest.[10] A researcher with experience in this area reviewed the titles and abstracts of these publications for inclusion in this evaluation. Only peer-reviewed, epidemiology studies, meta-analyses, and human experimental studies of 50/60-Hz AC ELF EMF and recognized disease entities, along with whole animal *in vivo* studies of carcinogenesis, were included. The following specific inclusion criteria were applied:

1. **Outcome**. Included studies evaluated one of the following diseases: cancer; reproductive effects; neurodegenerative diseases; or cardiovascular disease. Research on other outcomes was not included (e.g., psychological effects, behavioral effects, hypersensitivity). Few studies are available in these research areas and, as such, research evolves more slowly.

2. **Exposure**. The study must have evaluated 50/60-Hz AC ELF EMF.

3. **Exposure assessment methods**. Exposure must have been evaluated beyond self-report of an activity or occupation. Included studies estimated exposure through various methods including calculated EMF levels using distance from power lines; time-weighted average EMF exposures; and average exposure estimated from JEMs.

4. **Study design**. Epidemiology studies, meta-analyses, human experimental studies, and *in*

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8 Exponent, Inc. *Current Status of Research on Extremely Low Frequency Electric and Magnetic Fields and Health: G-185S 115-kV Transmission Line*. Prepared for the Rhode Island Energy Facility Siting Board. October 31, 2013.

9 Since there is sometimes a delay between the publication date of a study and the date it is indexed in PubMed, it is possible that some studies not yet indexed, but published prior to November 2014, are not included in this update.

10 EMF OR magnetic fields OR electric fields OR electromagnetic OR power frequency OR transmission line AND cancer (cancer OR leukemia OR lymphoma OR carcinogenesis) OR neurodegenerative disease (neurodegenerative disease OR Alzheimer's disease OR amyotrophic lateral sclerosis OR Lou Gehrig's disease) OR cardiovascular effects (cardiovascular OR heart rate) OR reproductive outcomes (miscarriage OR reproduction OR developmental effects).

vivo studies were included. Only *in vivo* studies of carcinogenicity were evaluated in this review; the review relies on the conclusions of the WHO with regard to *in vivo* studies in the areas of reproduction, development, neurology, and cardiology. Further, this report relies on the conclusions of the WHO report (as described in Section 5) with regard to mechanistic data from *in vitro* studies since this field of study is less informative to the risk assessment process (IARC, 2002).

5. **Peer-review**. The study must have been peer-reviewed and published. Therefore, no conference proceedings, abstracts, or on-line material were included.

Epidemiology studies are evaluated below first by outcome (childhood cancer; adult cancer; reproductive or developmental effects; neurodegenerative disease; and cardiovascular effects), followed by an evaluation of *in vivo* research on carcinogenesis. Tables 3 through 9 list the relevant studies that were published between July 2013 and November 2014 in these areas.

Childhood health outcomes

Childhood leukemia

In 2002, the IARC assembled and reviewed research related to ELF EMF to evaluate the strength of the evidence in support of carcinogenicity. The IARC expert panel noted that, when studies with the relevant information were combined in a pooled analysis, a statistically significant two-fold association was observed between childhood leukemia and estimated exposure to high, average levels of magnetic fields (i.e., greater than 3-4 mG of average 24- and 48-hour exposure). This evidence was classified as "limited evidence" in support of carcinogenicity, falling short of "sufficient evidence" because chance, bias, and confounding could not be ruled out with "reasonable confidence." Largely as a result of the findings related to childhood leukemia, the IARC classified magnetic fields as "possibly carcinogenic," a category that describes exposures with limited epidemiologic evidence and inadequate evidence from *in vivo* studies. The classification of "possibly carcinogenic" was confirmed by the WHO in June 2007.

Recent studies (July 2013 to November 2014)

Childhood leukemia remains one of the most studied health outcomes in ELF EMF epidemiologic research. Three large case-control studies from France, Denmark, and the United Kingdom have assessed the risk of childhood leukemia in relation to residential proximity to high-voltage power lines (Sermage-Faure et al., 2013; Bunch et al., 2014; Pedersen et al., 2014). The French study, which was discussed in the previous update, included 2,779 cases of childhood leukemia diagnosed between 2002 and 2007 and 30,000 control children (Sermage-Faure et al., 2013). The authors used geocoded information on residential address at the time of diagnosis for cases and at time of selection for controls. They reported no statistically significant increase in leukemia risk with distance to power lines. The authors, however, noted a statistically non-significant risk increase in a sub-analysis within 50 meters of 225-400 kV lines, but this was based on a small number of cases (n=9). The ensuing scientific correspondence following the publication of the study focused on the magnitude of inaccuracies in distance assessment with geocoding as a main limitation of the study, and its implication on the inference that can be drawn from the study. The correspondence also addressed the statistical uncertainties of the results that are based on small numbers (Bonnet-Belfais et al. 2013; Magana Torres and Garcia, 2013).

A similar study from Denmark identified 1,698 cases of childhood leukemia from the Danish Cancer Registry and 3,396 individually matched healthy control children from the Danish Central Population Registry (Pedersen et al., 2014). The investigators used geographical information systems to determine the distance between birth addresses and the 132-400 kV overhead transmission lines of the seven Danish transmission companies. The authors reported no risk increases for childhood leukemia with residential distance to power lines; the reported ORs were 0.76 (95 % CI 0.40–1.45) and 0.92 (95% CI 0.67–1.25) for children who lived 0–199 meters and for those who lived 200–599 meters from the nearest power line compared to children who lived more than 600 meters away.

The third study by Bunch et al. (2014) provided an update and extension of the 2005 study conducted by Draper et al. (2005) in the United Kingdom. The update included 13 additional years of data, included Scotland in addition to England and Wales, and included 132-kV lines in addition to 275-kV and 400-kV transmission lines. Bunch et al. included over 53,000 childhood cancer cases, diagnosed between 1962 and 2008, and over 66,000 healthy children as controls, representing the largest study to date in this field of study. The authors reported no overall association with residential proximity to power lines with any of the voltage categories. The statistical association that was reported in the earlier study (Draper et al., 2005) was no longer apparent in the updated and extended study. An analysis by calendar time revealed that the association was apparent only in the earlier decades (1960s and 1970s) but not in the later decades starting from the 1980s (Bunch et al., 2014). This observation does not support the hypothesis that the associations observed earlier were due to the effects of magnetic-fields.

These three studies had a large sample size and they were population-based studies requiring no subject participation, which minimizes the potential for selection bias. The main limitation of all of these studies was the reliance on distance to power lines as the main exposure metric. Estimated distance to power lines is known to be a poor predictor of actual residential magnetic field exposure. Chang et al. (2014) recently provided a detailed discussion on exposure assessment methods based on geographical information systems and their potential to result in severe bias. Using data from the UK study, Swanson et al. (2014a) also showed that geocoding data may not be sufficiently reliable to accurately predict actual magnetic-field exposures due to inaccuracies in distance assessment, especially when the exact address is not available.

The meta-analysis conducted by Zhao et al. (2014a) included nine case-control studies of EMF exposure and childhood leukemia published between 1997 and 2013. Zhao et al. reported a statistically significant association between average exposure above 4 mG and all types of childhood leukemia (OR 1.57; 95% CI 1.03-2.4). The meta-analysis relied on published results from some of the same studies included in previous pooled analyses, and thus, provided little new insight.

Swanson et al. (2014b) investigated the potential role of corona ions from power lines in childhood cancer development in the largest-to-date epidemiologic study of childhood cancer conducted in the United Kingdom. The authors used an improved model to predict exposure to corona ions using meteorological data on wind conditions, power line characteristics and proximity to residential address. Swanson et al. concluded that their results provided no empirical support for the corona ion hypothesis

Methodological studies have also examined the potential role of alternative, non-causal explanations for the reported epidemiologic associations. Swanson (2013) examined differences in residential mobility among residents who lived at varying distances from power lines. Swanson attempted to assess if these differences in mobility may explain the statistical association of leukemia with residential proximity to power lines. Although some variations in residential mobility were observed, these were “only small ones, and not such as to support the hypothesis.” Scientists in California evaluated whether selection bias may influence the association in an epidemiologic study of childhood leukemia and residential magnetic-field exposure (Slusky et al., 2014). Wire code categories were used to assess exposure among participant and nonparticipant subjects in the Northern California Childhood Leukemia Study. The authors reported systematic differences between participant and nonparticipant subjects in both wire code categories and socioeconomic status and concluded that these differences did not appear to explain the lack of an association between childhood leukemia and exposure estimates in this study. The main limitation of the study is the use of wire code categories for exposure assessment; wire code categories are known to be poor predictors for actual magnetic-field exposure.

In a recent review, Grellier et al. (2014) estimated that, if the association was causal, ~1.5% to 2% of leukemia cases might be attributable to ELF EMF in Europe. They conclude that “this contribution is small and is characterized by considerable uncertainty.”

Assessment

While some of the recently published large and methodologically advanced studies showed no association (e.g., Bunch et al., 2014; Pedersen et al., 2014), and one showed weak associations in selected subgroups (Sermage-Faure et al., 2013), the previously observed association between childhood leukemia and magnetic fields reported in some studies (e.g., Ahlbom et al., 2000; Greenland et al., 2000; Kheifets et al., 2010) remains unexplained. Overall, the results of recent studies do not change the classification of the epidemiologic data as limited, which is consistent with the most recent assessment conducted by the Scientific Committee on Newly-Identified Health Risks (SCENIHR) in 2015.

One of the major limitations of recent work remains the limited validity of the exposure assessment methods. Magnetic-field estimates have largely been based on calculated levels from nearby power lines, distance from nearby power lines, and measured, short-term residential levels. Recent analyses (e.g., Swanson et al., 2014a) have further demonstrated the limitations of distance assessment in childhood cancer epidemiologic studies basing the exposure assessment on distance from power lines. Scientists have continued to examine the role of selection bias in the childhood leukemia association, but no conclusive evidence has emerged that could attribute the entire observed association to bias (e.g., Swanson, 2013; Slusky et al., 2014). Some scientists have opined that epidemiology has reached its limits in this area and any future research must demonstrate a significant methodological advancement (e.g., an improved exposure metric or a large sample size in high exposure categories) to be justified (Savitz, 2010; Schmiedel and Blettner, 2010).

The findings from the recent literature do not alter previous conclusions of the WHO and other reviews, including ours, that the epidemiologic evidence on magnetic fields and childhood leukemia is "limited" from the perspective of the IARC classification. Chance, confounding, and several sources of bias still cannot be ruled out. Conclusions from several published reviews (Kheifets and Oksuzyan, 2008; Pelissari et al., 2009; Schüz and Ahlbom, 2008; Calvente et al., 2010; Eden, 2010; Schüz, 2011) and scientific organizations (SSI, 2007; SSI, 2008; HCN, 2009a; SCENIHR, 2015; EFHRAN, 2012; SSM, 2013) support this conclusion.

Researchers will continue to investigate the association between exposure to magnetic fields and childhood leukemia. In recent assessments of the epidemiologic evidence of magnetic-field exposure and childhood leukemia, it has been concluded that only 1% to 3% of all childhood leukemia cases in Europe and North America could be due to magnetic-field exposure, should a causal relationship exist (Schüz, 2011; Grellier et al., 2014).

It is important to note that magnetic fields are just one area of study in the extensive body of research on the possible causes of childhood leukemia. There are several other hypotheses under investigation that point to possible genetic, environmental, and infectious explanations for childhood leukemia (e.g., McNally and Parker, 2006; Belson et al., 2007; Rossig and Juergens, 2008; Urayama et al., 2010; Bartley et al., 2010 [diagnostic x-rays]; Amigou et al., 2011 [road traffic]; Swanson, 2013).

Table 2. Relevant studies of childhood leukemia

Author	Year	Study Title
Bunch et al.	2014	Residential distance at birth from overhead high-voltage powerlines: childhood cancer risk in Britain 1962-2008.
Grellier et al.	2014	Potential health impacts of residential exposures to extremely low frequency magnetic fields in Europe
Pedersen et al.	2014	Distance from residence to power line and risk of childhood leukemia: a population-based case-control study in Denmark
Sermage-Faure et al.*	2013	Childhood leukaemia close to high-voltage power lines – the Geocap study, 2002–2007
Slusky et al.	2014	Potential role of selection bias in the association between childhood leukemia and residential magnetic fields exposure: a population-based assessment
Swanson	2013	Residential mobility of populations near UK power lines and implications for childhood leukaemia
Swanson et al.	2014a	Relative accuracy of grid references derived from postcode and address in UK epidemiological studies of overhead power lines

Author	Year	Study Title
Swanson et al.	2014b	Childhood cancer and exposure to corona ions from power lines: an epidemiological test
Zhao et al.	2014a	Magnetic fields exposure and childhood leukemia risk: a meta-analysis based on 11,699 cases and 13,194 controls
*Comments and Replies on Sermage-Faure et al.:		
Bonnet-Belfais et al.	2013	Comment: childhood leukaemia and power lines--the Geocap study: is proximity an appropriate MF exposure surrogate?
Magana Torres and Garcia	2013	Comment on 'Childhood leukaemia close to high-voltage power lines--the Geocap study, 2002-2007'--odds ratio and confidence interval.
Clavel and Hemon	2013	Reply: Comment on 'Childhood leukaemia close to high-voltage power lines--the Geocap study, 2002-2007'--odds ratio and confidence interval
Clavel et al.	2013	Reply: Comment on 'Childhood leukaemia close to high-voltage power lines--the Geocap study, 2002-2007'--is proximity an appropriate MF exposure surrogate?

Childhood brain cancer

Compared to the research on magnetic fields and childhood leukemia, there have been fewer studies of childhood brain cancer. The data are less consistent and limited by even smaller numbers of exposed cases compared with studies of childhood leukemia. The WHO review recommended the following:

> As with childhood leukaemia, a pooled analysis of childhood brain cancer studies should be very informative and is therefore recommended. A pooled analysis of this kind can inexpensively provide a greater and improved insight into the existing data, including the possibility of selection bias and, if the studies are sufficiently homogeneous, can offer the best estimate of risk (WHO 2007, p. 18).

Recent studies (July 2013 to November 2014)

There has been one new publication that specifically examined the potential relationship between residential proximity to transmission lines and childhood brain cancer among other childhood cancers. The Bunch et al. (2014) study, described above, also included cases of brain cancer (n=11,968) and other solid tumors (n=21,985) among children in the United Kingdom between 1962 and 2008. No association was reported by the authors for either brain cancer or for other cancers.

The results of the methodological study that investigated the accuracy of distance assessment in childhood cancer studies (Swanson et al., 2014a) are also relevant for childhood brain cancer. The study that investigated the role of corona ions in childhood cancer development, similarly to childhood leukemia, reported no consistent associations for childhood brain cancer (Swanson et al., 2014b).

Assessment

Overall, the weight-of-evidence does not support an association between magnetic-field exposures and the development of childhood brain cancer. The results of recent studies do not alter the classification of the epidemiologic data in this field as "inadequate."

Table 3. Relevant studies of childhood brain cancer

Authors	Year	Study
Bunch et al.	2014	Residential distance at birth from overhead high-voltage powerlines: childhood cancer risk in Britain 1962-2008.
Swanson et al.	2014a	Relative accuracy of grid references derived from postcode and address in UK epidemiological studies of overhead power lines
Swanson et al.	2014b	Childhood cancer and exposure to corona ions from power lines: an epidemiological test

Adult health outcomes

Breast cancer

The WHO reviewed studies of breast cancer and residential magnetic-field exposure, electric blanket usage, and occupational magnetic-field exposure. These studies did not report consistent associations between magnetic-field exposure and breast cancer. The WHO concluded that the recent body of research on this topic was less susceptible to bias compared with previous studies, and, as a result, it provided strong support to previous consensus statements that magnetic-field exposure does not influence the risk of breast cancer. Specifically, the WHO stated:

> Subsequent to the IARC monograph a number of reports have been published concerning the risk of female breast cancer in adults associated with ELF magnetic field exposure. These studies are larger than the previous ones and less susceptible to bias, and overall are negative. With these studies, the evidence for an association between ELF exposure and the risk of breast cancer is weakened considerably and does not support an association of this kind (WHO 2007, p. 307).

The WHO recommended no specific research with respect to breast cancer and magnetic-field exposure.

Recent studies (July 2013 to November 2014)

A Dutch study, that included a cohort of about 120,000 men and women in the Netherlands Cohort, investigated occupational exposure to ELF magnetic fields and cancer development (Koeman et al., 2014). The study was a case-cohort analysis of 2,077 breast cancer cases among women (no breast cancer was identified among men in the cohort). Job titles were used to assign estimates of ELF magnetic field exposures using a JEM. No association was reported for breast cancer with the level of estimated ELF magnetic-field exposure, the length of employment, or cumulative exposure in the exposed jobs.

A nested case-cohort analysis of breast cancer incidence was conducted in a large cohort of more than 267,000 female textile workers in Shanghai (Li et al., 2013). A total of 1,687 incident breast cancer cases were identified in the cohort between 1989 and 2000; their estimated exposure was compared with the estimated exposure of 4,702 non-cases. Exposure was assigned based on complete work history and a JEM specifically developed for the cohort. No association was reported between cumulative exposure and risk of breast cancer regardless of age, histological type, and whether a lag period was used or not. An accompanying editorial opined that this well-designed study further adds to the already large pool of data not supporting an association between ELF EMF and breast cancer (Feychting, 2013). The editorial suggests that further studies in breast cancer "have little new knowledge to add," following the considerable improvement in study quality over time in breast cancer epidemiologic studies, and with the evidence being "consistently negative."

Zhao et al. (2014b) reported the results of their meta-analysis of 16 case-control epidemiologic studies of ELF EMF and breast cancer published between 2000 and 2007. They reported a weak but statistically significant association, which appeared to be stronger among non-menopausal women. The conclusion of the authors that ELF magnetic fields might be related to breast cancer is contrary to the conclusion of the WHO and other risk assessment panels. This may be due to the inclusion of earlier and methodologically less advanced studies in the meta-analysis.

Assessment

The two large recently published studies (Li et al., 2013; Koeman et al., 2014) support the growing body of scientific evidence against a causal role for magnetic fields in breast cancer. The meta-analyses by Zhao et al. (2014b) include numerous limitations and therefore should be interpreted with great caution due to flaws within the individual studies and the crude pooling of data with a vast range of exposure definitions and cut-points. Several review papers (Feychting and Forssén 2006; Hulka and Moorman, 2008) and expert groups (SCENIHR, 2009) support the previous WHO (2007) conclusion that magnetic-field exposure does not influence the risk of breast cancer.

Table 4. Relevant studies of breast cancer

Authors	Year	Study
Koeman et al.	2014	Occupational extremely low-frequency magnetic field exposure and selected cancer outcomes in a prospective Dutch cohort
Feytching	2013	Invited commentary: extremely low-frequency magnetic fields and breast cancer--now it is enough!
Li et al	2013	Occupational exposure to magnetic fields and breast cancer among women textile workers in Shanghai, China
Zhao et al.	2014b	Relationship between exposure to extremely low-frequency electromagnetic fields and breast cancer risk: a meta-analysis.

Adult brain cancer

Brain cancer was studied along with leukemia in many of the occupational studies of ELF EMF. The findings were inconsistent, and there was no pattern of stronger findings in studies with more advanced methods, although a small association could not be ruled out. The WHO classified the epidemiologic data on adult brain cancer as inadequate and recommended (1) updating the existing cohorts of occupationally-exposed individuals in Europe and (2) pooling the epidemiologic data on brain cancer and adult leukemia to confirm the absence of an association.

The WHO stated the following:

> In the case of adult brain cancer and leukaemia, the new studies published after the IARC monograph do not change the conclusion that the overall evidence for an association between ELF [EMF] and the risk of these disease remains inadequate (WHO 2007, p. 307).

Recent studies (July 2013 to November 2014)

Epidemiology studies published since our last review on adult brain cancer and ELF EMF exposure are listed in Table 5 and include two cohort studies and one case-control study.

The large cohort study of occupational ELF EMF exposure in the Netherlands (Koeman et al., 2014) also investigated adult brain cancer development. The authors reported no association with adult brain cancer for any of the exposure metrics investigated for EMF exposure for either men or women.

Sorahan (2014a) reported the analysis of brain cancer incidence between 1973 and 2010 among more than 70,000 British electricity supply workers in a cohort analysis. The study reported no consistent association between brain cancer risk (glioma and meningioma) and estimated cumulative, recent and distant occupational exposure to ELF EMF.

Turner et al. (2014) investigated the association between occupational exposure to ELF EMF and brain cancer in a large international case-control epidemiologic study. While the authors reported both an increase (with exposure 1-4 years prior to diagnosis) and a decrease (with the highest maximum exposure) in associations with brain cancer in some of the sub-analyses, overall there was no association with lifetime cumulative or average exposure for either main type of brain cancer (glioma or meningioma).

Assessment

Findings from the recent literature predominantly support no association between exposure to ELF EMF and brain cancer in adults, but remain limited due to the exposure assessment methods and insufficient data available on specific brain cancer subtypes. Currently, the literature provides very weak evidence of an association in some studies, if any, between magnetic fields and brain cancer.[11] The overall evidence for brain cancer has not materially changed and remains inadequate as classified by the WHO in 2007.

Table 5. Relevant studies of adult brain cancer

Authors	Year	Study
Koeman et al.	2014	Occupational extremely low-frequency magnetic field exposure and selected cancer outcomes in a prospective Dutch cohort
Sorahan	2014a	Magnetic fields and brain tumour risks in UK electricity supply workers.
Turner et al	2014	Occupational exposure to extremely low frequency magnetic fields and brain tumour risks in the INTEROCC study

Adult leukemia

There is a vast amount of literature on adult leukemia and ELF EMF, most of which is related to occupational exposure. Overall, the findings of these studies are inconsistent—with some studies reporting a positive association between measures of ELF EMF and leukemia and other studies showing no association. No pattern has been identified whereby studies of higher quality or design are more likely to produce positive or negative associations. The WHO subsequently classified the epidemiologic evidence for adult leukemia as "inadequate." They recommended updating the existing European occupation cohorts and updating a meta-analysis on occupational magnetic-field exposure.

Recent studies (July 2013 to November 2014)

The Dutch cohort study previously discussed (Koeman et al., 2014) identified 761 and 467 malignancies of the hematopoietic system among men and women, respectively. Overall, no increases in risk or trends were observed in association with cumulative exposure to ELF magnetic fields or duration of exposure among either men or women. In some sub-analyses by subtype, however, statistically significant associations were noted for acute myeloid leukemia and follicular lymphoma among men.

Sorahan also completed detailed analyses for leukemia incidence in the cohort of over 70,000 British electricity supply employees (Sorahan, 2014b). For all leukemias overall, there was no indication for risk increases with cumulative, recent or distant occupational exposure to magnetic fields. In some sub-analyses, however, the authors reported a statistically significant association for adult ALL.

Assessment

Recent studies of adult leukemia have not provided new evidence to support an association of magnetic field exposure with adult leukemia overall or with any leukemia sub-type. Thus, there

11 A consensus statement by the National Cancer Institute's Brain Tumor Epidemiology Consortium confirms this statement. They classified residential power frequency EMF in the category "probably not risk factors" and described the epidemiologic data as "unresolved" (Bondy et al., 2008, p. 1958).

is no new evidence to alter the overall conclusion and the evidence remains inadequate for adult leukemia.

Table 6. Relevant studies of adult leukemia

Authors	Year	Study
Koeman et al.	2014	Occupational extremely low-frequency magnetic field exposure and selected cancer outcomes in a prospective Dutch cohort
Sorahan	2014b	Magnetic fields and leukaemia risks in UK electricity supply workers.

Reproductive and developmental effects

Two studies in the past have received considerable attention because of a reported association between peak magnetic-field exposure greater than approximately 16 mG and miscarriage—a prospective cohort study of women in early pregnancy (Li et al., 2002) and a nested case-control study of women who miscarried compared to their late-pregnancy counterparts (Lee et al., 2002).

These two studies improved on the existing body of literature because average exposure was assessed using 24-hour personal magnetic-field measurements (early studies on miscarriage were limited because they used surrogate measures of exposure, including visual display terminal use, electric blanket use, or wire code data). Following the publication of these two studies, however, a hypothesis was put forth that the observed association may be the result of behavioral differences between women with "healthy" pregnancies that went to term (less physically active) and women who miscarried (more physically active) (Savitz, 2002). It was proposed that physical activity is associated with an increased opportunity for peak magnetic-field exposures, and the nausea experienced in early, healthy pregnancies and the cumbersomeness of late, healthy pregnancies would reduce physical activity levels, thereby decreasing the opportunity for exposure to peak magnetic fields. Furthermore, nearly half of women who had miscarriages reported in the cohort by Li et al. (2002) had magnetic-field measurements taken after miscarriage occurred, when changes in physical activity may have already occurred, and all measurements in Lee et al. (2002) occurred post-miscarriage.

The scientific panels that have considered these two studies concluded that the possibility of this bias precludes making any conclusions about the effect of magnetic fields on miscarriage (NRPB, 2004; FPTRPC, 2005; WHO, 2007). The WHO concluded, "There is some evidence for increased risk of miscarriage associated with measured maternal magnetic-field exposure, but this evidence is inadequate" (WHO 2007, p. 254). The WHO stated that, given the potentially high public health impact of such an association, further epidemiologic research is recommended.

Recent studies (July 2013 to November 2014)

Two epidemiologic studies investigated the potential association between ELF EMF exposure and miscarriage or stillbirth. A hospital-based case-control study from Iran included 58 women with spontaneous abortion and 58 pregnant women (Shamsi Mahmoudabadi et al., 2013). The authors reported that measured magnetic-field levels were statistically significantly higher among the cases than among controls. The study was small and provided little information on subject recruitment, exposure assessment, type of metric used to summarize exposure, and potential confounders; thus, it contributes little weight to an overall assessment.

A Chinese study identified 413 pregnant women at 8 weeks of gestation between 2010 and 2012 (Wang et al., 2013). Magnetic-field levels were measured at the front door and the alley in front of the participants' homes. No statistically significant association was seen with average exposure at the front door, but the authors reported an association with maximum magnetic-field values measured in the alleys in front of the homes. The study provides a fairly limited contribution to our current knowledge as magnetic-field levels measured at the front door or outside the home are very poor predictors of in-home and personal exposures.

Two studies examined various birth outcomes in relation to ELF EMF exposure. A study from the United Kingdom investigated birth outcomes in relation to residential proximity to power lines during pregnancy between 2004 and 2008 in Northwest England (de Vocht et al., 2014). The researchers examined hospital records of over 140,000 births, and distance to the nearest power lines were determined using geographical information systems. The authors reported moderately lower birth weight within 50 meters of power lines, but observed no statistically significant increase in risk of any adverse clinical birth outcomes (such as preterm birth, small for gestational age, or low birth weight). The limitations of the study include its reliance on distance for exposure assessment and the potential for confounding by socioeconomic status, as also discussed by the authors. A study from Iran reported no association between ELF EMF and pregnancy and developmental outcomes, such as duration of pregnancy, birth weight and length, head circumference, and congenital malformations (Mahram and Ghazavi, 2013). The study, however, provided little information on subject selection and recruitment; thus, it is difficult to assess its quality.

Su et al. (2014) conducted a cross-sectional study in Shanghai to examine correlations between magnetic-field exposure and embryonic development. The authors identified 149 pregnant women who were seeking induced termination of pregnancy during the first trimester. Personal 24-hour measurements were conducted for women within four weeks of the termination. Ultrasound was used to determine embryonic bud and embryonic sac length prior to the termination. The authors reported an association with maternal daily magnetic-field exposure and embryonic bud length. The study has a number of severe limitations, including the cross-sectional design, which cannot distinguish if exposure measured after termination describes that experienced during the first trimester; thus, it is impossible to assess causality. Additionally, the lack of careful consideration for gestational age, which is a major determinant of embryonic bud length, is an issue. Overall, the study provides little, if any, weight in a weight-of-evidence assessment.

Lewis et al. (2014) analyzed magnetic field exposure data over 7 consecutive days among 100 pregnant women from an earlier study. They reported that measures of central tendency (e.g., mean, median) were relatively well correlated day-to-day, and a measurement on one day could be used reasonably well to predict exposure on another day. Peak exposure measures (e.g., maximum value) showed poorer performance. The study did not examine the outcomes of the pregnancies, but these results have implications for earlier studies that reported association for spontaneous abortions with peak measures but not with measures of central tendency.

Assessment

The recent epidemiologic studies have not provided sufficient evidence to alter the conclusion that the evidence for reproductive or developmental effects is inadequate.

Table 7. Relevant studies of reproductive and developmental effects

Authors	Year	Study
de Vocht et al.	2014	Maternal residential proximity to sources of extremely low frequency electromagnetic fields and adverse birth outcomes in a UK cohort
Lewis et al.	2014	Temporal variability of daily personal magnetic field exposure metrics in pregnant women.
Mortazavi et al.	2013	The study of the effects of ionizing and non-ionizing radiations on birth weight of newborns to exposed mothers
Shamsi Mahmoudabadi et al.	2013	Exposure to Extremely Low Frequency Electromagnetic Fields during Pregnancy and the Risk of Spontaneous Abortion: A Case-Control Study
Su et al.	2014	Correlation between exposure to magnetic fields and embryonic development in the first trimester
Wang et al.	2013	Residential exposure to 50 Hz magnetic fields and the association with miscarriage risk: a 2-year prospective cohort study

Neurodegenerative diseases

Research into the possible effect of magnetic fields on the development of neurodegenerative diseases began in 1995, and the majority of research since then has focused on Alzheimer's disease and a specific type of motor neuron disease called amyotrophic lateral sclerosis (ALS), which is also known as Lou Gehrig's disease. Early studies on ALS, which had no obvious biases and were well conducted, reported an association between ALS mortality and estimated occupational magnetic-field exposure. The review panels, however, were hesitant to conclude that the associations provided strong support for a causal relationship. Rather, they felt that an alternative explanation (i.e., electric shocks received at work) may be the source of the observed association.

The majority of the more recent studies discussed by the WHO reported statistically significant associations between occupational magnetic-field exposure and mortality from Alzheimer's disease and ALS, although the design and methods of these studies were relatively weak (e.g., disease status was based on death certificate data, exposure was based on incomplete occupational information from census data, and there was no control for confounding factors). Furthermore, there were no biological data to support an association between magnetic fields and neurodegenerative diseases. The WHO panel concluded that there is "inadequate" data in support of an association between magnetic fields and Alzheimer's disease or ALS. The panel recommended more research in this area using better methods; in particular, studies that enrolled incident Alzheimer's disease cases (rather than ascertaining cases from death certificates) and studies that estimated electrical shock history in ALS cases were recommended. Specifically, the WHO concluded, "When evaluated across all the studies, there is only very limited evidence of an association between estimated ELF exposure and [Alzheimer's] disease risk" (WHO 2007, p. 194).

Recent studies (July 2013 to November 2014)

Davanipour et al. (2014) have reported on a study of severe cognitive dysfunction and occupational ELF magnetic-field exposure, in which "[t]he study population consisted of 3,050 Mexican Americans, aged 65+, enrolled in Phase I of the Hispanic Established Population for the Epidemiologic Study of the Elderly (H-EPESE) study." Occupational history, along with data on other socio-demographic information, was obtained via in-home personal interviews. Occupational exposure to magnetic fields was classified as low, medium, and high. Cognitive function was evaluated with the use of a mini-mental state exam and cognitive dysfunction was defined as an exam score below 10. While the authors describe their study as a population-based case-control study, based on the provided description in the paper, the study appears to be a cross-sectional study. Based on their analyses, the authors reported a statistically significant association between estimated occupational magnetic-field exposure and severe cognitive dysfunction. This study had a number of limitations, including the cross-sectional study design, the lack of clear clinical diagnosis for case-definition, and the crude assessment of occupational exposure.

Seelen et al. (2014) conducted a large population-based case-control study of ALS and residential proximity to high-voltage power lines in the Netherlands. The authors included 1,139 ALS cases diagnosed between 2006 and 2013 and 2,864 frequency-matched controls selected from general practitioners' rosters. Lifetime residential history was determined for all cases and controls using data from the Municipal Personal Records Database. Addresses were geocoded and the shortest distance to a high-voltage power was determined for each address. High-voltage power lines with voltages between 50 kV and 150 kV (high voltage) and between 220 kV and 380 kV were analyzed. No statistically significant association was reported for ALS with residential proximity to power lines with any of the voltages included. The authors also conducted a meta-analysis including their own results along with those of two previously published studies (Marcilio et al., 2011; Frei et al., 2013) and reported an overall OR of 0.9 (95% CI 0.7-1.1) for living within 200 meters of a high voltage power line. Similar to the previous power-line studies, the main limitation of the current study is the use of distance to power lines as a surrogate for magnetic-field exposure. The authors, however, reconstructed lifetime residential history, which represents a methodological improvement.

The role of electric shocks in development of neurodegenerative diseases has been examined in three recent studies. Electric shocks have been hypothesized to be a potential etiologic agent, primarily for ALS, based on the observation that linked "electric occupations," but not estimates of magnetic-field exposure to ALS (Vergara et al., 2013). Researchers in the Netherlands conducted a hospital-based case-control study of Parkinson's disease and occupational exposure to electric shocks and ELF magnetic fields (van der Mark et al., 2014). The study included 444 cases of Parkinson's disease and 876 matched controls. Occupational history was determined based on telephone interviews. JEMs were used to categorize jobs for exposure to both electric shocks and magnetic fields. The authors reported no risk increases with any of the two investigated exposures and concluded that their results suggest no association with Parkinson's disease.

A mortality case-control study using death certificates between 1991 and 1999 was conducted in the United States (Vergara et al., 2014). The study analyzed 5,886 ALS deaths and 10-times as many matched control deaths. Exposure to electric shocks and ELF magnetic fields was classified based on job titles reported on the death certificates and using corresponding JEMs. While a statistically significant association was reported for "electrical occupations," no consistent associations were observed for either magnetic field or electric shock exposures. The main limitation of the study is its reliance on death certificates that may result in disease and exposure misclassifications.

Huss et al. (2014) reported results of their analysis of ALS mortality in the Swiss National Cohort between 2000 and 2008. The cohort included about 2.2 million workers with high, medium, or low exposure to ELF magnetic fields and electric shocks. For exposure classification, JEMs for magnetic-field exposure and electric shocks were applied to occupations reported by the subjects at the 1990 and 2000 censuses. The authors reported a statistically significant association of ALS mortality with estimated medium or high occupational magnetic-field exposure based at both censuses, but not with estimates of electric shock exposure. The main limitations of the study include the reliance on mortality data, which may result in disease misclassification, and the use of census data for exposure assessment, which may result in exposure misclassification.

Assessment

Overall, the recent literature does not alter the conclusion that there are "inadequate" data for a causal link between exposure to ELF magnetic fields and neurodegenerative diseases. Most of the recent studies provided no support for a potential association. Several recent studies have investigated the potential role of electric shocks in neurodegenerative disease development. None of these studies reported results that would support the hypothesis that electric shocks play an etiologic role.

With respect to Alzheimer's disease, the main limitations of the available literature remains: the difficulty in diagnosing Alzheimer's disease; the difficulty of identifying a relevant exposure window given the long and nebulous course of this disease; the difficulty of estimating magnetic-field exposure prior to the appearance of the disease; the under-reporting of Alzheimer's disease on death certificates; crude exposure evaluations that are often based on the recollection of occupational histories by friends and family given the cognitive impairment of the study participants; and the lack of consideration of both residential and occupational exposures or confounding variables.

Although the most-recently published studies on this topic in Table 8 below were not available for inclusion in the SCENIHR opinion (their cut-off date was June 2014), the authors concluded that "[a]lthough the new studies in some cases have methodological weaknesses, they do not provide support for the previous conclusion that ELF MF exposure increases the risk for Alzheimer´s disease" (SCENIHR, 2015, p. 166).

Table 8. Relevant studies of neurodegenerative disease

Authors	Year	Study
Davanipour et al.	2014	Severe cognitive dysfunction and occupational extremely low frequency magnetic field exposure among elderly Mexican Americans.
Huss et al.	2014	Occupational exposure to magnetic fields and electric shocks and risk of ALS: The Swiss National Cohort.
Seelen et al.	2014	Residential exposure to extremely low frequency electromagnetic fields and the risk of ALS
Van der Mark et al.	2014	Extremely low-frequency magnetic field exposure, electrical shocks and risk of Parkinson's disease
Vergara et al.	2014	Case-control study of occupational exposure to electric shocks and magnetic fields and mortality from amyotrophic lateral sclerosis in the US, 1991–1999

Cardiovascular disease

It has been hypothesized that magnetic-field exposure reduces heart rate variability, which in turn increases the risk for AMI. In a large cohort of utility workers, Savitz et al. (1999) reported an association with arrhythmia-related deaths and deaths due to AMI among workers with higher magnetic field exposure. Previous and subsequent studies did not report a statistically significant increase in cardiovascular disease mortality or incidence related to occupational magnetic-field exposure (WHO, 2007).

The WHO concluded:

> Experimental studies of both short- and long-term exposure indicate that, while electric shock is an obvious health hazard, other hazardous cardiovascular effects associated with ELF fields are unlikely to occur at exposure levels commonly encountered environmentally or occupationally. Although various cardiovascular changes have been reported in the literature, the majority of effects are small and the results have not been consistent within and between studies. With one exception [Savitz et al., 1999], none of the studies of cardiovascular disease morbidity and mortality has shown an association with exposure. Whether a specific association exists between exposure and altered autonomic control of the heart remains speculative. Overall, the evidence does not support an association between ELF exposure and cardiovascular disease." (WHO, 2007, p. 220)

Recent studies (July 2013 to November 2014)

Since our last review in July 2013, no newly published studies of ELF EMF and cardiovascular diseases have been identified by our literature search.

Assessment

The conclusion that there is no association between magnetic fields and cardiovascular diseases has not changed.

In vivo studies related to carcinogenesis

In the field of ELF EMF research, a number of research laboratories have exposed rodents, including those with a particular genetic susceptibility to cancer, to high levels of magnetic fields over the course of the animals' lifetime and performed tissue evaluations to assess the incidence of cancer in many organs. In these studies, magnetic-field exposure has been administered alone (to test for the ability of magnetic fields to act as a complete carcinogen), in combination with a known carcinogen (to test for a promotional or co-carcinogenetic effect), or in combination with a known carcinogen and a known promoter (to test for a co-promotional effect).

The WHO review described four large-scale, long-term studies of rodents exposed to magnetic fields over the course of their lifetime that did not report increases in any type of cancer (Mandeville et al., 1997; Yasui et al., 1997; Boorman et al., 1999a, 1999b; McCormick et al., 1999). No directly relevant animal model for childhood ALL existed at the time of the WHO report. Some animals, however, develop a type of lymphoma similar to childhood ALL and studies exposing predisposed transgenic mice to ELF magnetic fields did not report an increased incidence of this lymphoma type (Harris et al., 1998; McCormick et al., 1998; Sommer and Lerchel, 2004).

Studies investigating whether exposure to magnetic fields can promote cancer or act as a co-carcinogen used known cancer-causing agents, such as ionizing radiation, ultraviolet radiation, or other chemicals. No effects were observed for studies on chemically-induced preneoplastic liver lesions, leukemia or lymphoma, skin tumors, or brain tumors; however, the incidence of 7,12-dimethylbenz[a]anthracene (DMBA)-induced mammary tumors was increased with magnetic-field exposure in a series of experiments in Germany (Löscher et al., 1993, 1994, 1997; Mevissen et al., 1993a,1993b, 1996a, 1996b, 1998; Baum et al., 1995; Löscher and Mevissen, 1995), suggesting that magnetic-field exposure increased the proliferation of mammary tumor cells. These results were not replicated in a subsequent series of experiments in a laboratory in the United States (Anderson et al., 1999; Boorman et al.1999a, 1999b), possibly due to differences in experimental protocol and the species strain. In Fedrowitz et al. (2004), exposure enhanced mammary tumor development in one sub-strain (Fischer 344 rats), but not in another sub-strain that was obtained from the same breeder, which argues against a promotional effect of magnetic fields.[12]

Some studies have reported an increase in genotoxic effects among exposed animals (e.g., DNA strand breaks in the brains of mice [Lai and Singh, 2004]), although the results have not been replicated.

[12] The WHO concluded with respect to the German studies of mammary carcinogenesis, "Inconsistent results were obtained that may be due in whole or in part to differences in experimental protocols, such as the use of specific substrains" (WHO 2007, p. 321).

In summary, the WHO concluded the following with respect to *in vivo* research: "There is no evidence that ELF [EMF] exposure alone causes tumours. The evidence that ELF field exposure can enhance tumour development in combination with carcinogens is inadequate" (WHO, 2007, p. 322). Recommendations for future research included the development of a rodent model for childhood ALL and the continued investigation of whether magnetic fields can act as a promoter or co-carcinogen.

Recent studies (July 2013 to November 2014)

No new animal bioassays of tumor development due to magnetic-field exposure alone or in combination with known cancer initiators have been conducted since the study by Bernard et al. (2008) that was the first study to use an animal model of ALL, the most common leukemia type in children, reviewed in the previous update. Instead, various *in vivo* studies examining potential mechanisms that could precipitate cancer development have been conducted. These studies are listed in Table 9.

Two recent animal studies examined the ability of magnetic-field exposure to cause DNA damage. Saha et al. (2014) exposed pregnant mice to one of three different magnetic field (50-Hz) exposure conditions: 1,000 mG for 2 hours on day 13.5 of gestation, 3,000 mG (continuous) for 15 hours on day 12.5 of gestation, or 3,000 mG (intermittent: 5 minutes on, 10 minutes off) for 15 hours on day 12.5 of gestation. Controls were either untreated or sham-exposed under these same conditions, but with the exposure equipment turned off. Additional animals were exposed to either 10 or 25 Gray of X-irradiation on day 13.5 of gestation; however, the amount of time for which these treatments were given is not known. Although X-irradiation was associated with increased DNA double strand breaks and cell apoptosis in the embryonic brain cells of the ventricular and subventricular zones, none of the magnetic field conditions had a significant effect on these parameters. These analyses were not conducted in a blinded manner; however, the potential influence of the animal litter was taken into account in the statistical analysis.

In a related study, Korr et al. (2014) continuously exposed mice for 8 weeks to either 1,000 mG or 10,000 mG, 50-Hz magnetic fields. Controls were not sham-exposed, but maintained in the same room as the magnetic-field-exposed animals. At the end of the exposure period, the animals were injected with radiolabeled thymidine to look for DNA single-strand breaks and unscheduled DNA synthesis in the liver, kidneys, and brain using an autoradiographic method. A slight reduction in mitochondrial DNA synthesis was observed in the epithelial cells of the kidney collecting ducts at 1,000 mG, but no increase in DNA single-strand breaks was observed. At 10,000 mG, a slight reduction in unscheduled DNA synthesis (likely related to reduced mitochondrial DNA synthesis) was observed in the epithelial cells of the choroid plexus of the brain's fourth ventricle and the kidney collecting duct, but again, there was no difference in the degree of DNA single-strand breaks observed between treated and control animals. These investigations were conducted in a blinded manner.

Oxidative stress is a condition in which oxygen free radical levels in the body are elevated and is one mechanism by which DNA damage, as well as other forms of cellular damage, may occur. Numerous recent *in vivo* studies have evaluated whether magnetic-field exposure may be associated with oxidative stress, with mixed results. Seifirad et al. (2014) examined the expression of various markers, including the lipid peroxidation markers malondialdehyde, conjugated dienes, and total antioxidant capacity, in the blood following exposure of rats to a 5,000 mG, 60-Hz magnetic fields for either 4 hours (acute) or 14 days (chronic). The acute exposure was associated with increased total antioxidant capacity, while the chronic exposure was associated with increased malondialdehyde levels and a reduced total antioxidant capacity. Although the controls were reportedly sham-exposed, it is not known if this was for the acute or chronic exposure condition, making interpretation difficult. Blinded analyses and control of environmental conditions also were not reported.

In another study, Glinka et al. (2013) examined the expression of various antioxidant markers in the blood and liver of male rats following 30 minutes of exposure to 100,000 mG, 40-Hz magnetic fields, for 6, 10, or 14 days. The purpose of this analysis was to examine the potential role of magnetic fields in the treatment of wounds; thus, the rats were first wounded surgically prior to exposure. Controls were sham exposed, but blinded analyses were not reported. Further, no details on the preparation of liver homogenates or the methods used to analyze the various samples were reported. Differences from control in the expression of the antioxidant markers superoxide dismutase, glutathione peroxidase, and malondialdehyde were reported in either the blood or the liver on various days, but no clear pattern of expression was apparent. No differences in the expression of glutathione S-transferase was observed. It should be noted, however, that control values varied considerably across the different study days, which may be related to a confounding effect associated with the wound healing process.

Hassan and Abdelkawi (2014) exposed male rats to 100,000 mG, 50-Hz magnetic fields for 1 hour per day for 30 days. Other groups of rats were treated with cadmium chloride or both cadmium chloride and magnetic-field exposure. Although it was reported that the controls were sham-exposed, based on the methods description, this does not appear to be the case; also, analyses were not conducted in a blinded manner. Both magnetic-field exposure and cadmium treatment were reported to increase the total oxidant status and protein carbonyls present in the blood; both exposures combined results in an increased response over either single condition alone. Deng et al. (2013) conducted a similar study in which mice were exposed to 20,000 mG, 50-Hz magnetic fields for 4 hours per day, 6 days per week for 8 weeks. In this case, other treatment groups were exposed to aluminum or both magnetic fields and aluminum. Control mice were not reported to have been sham-exposed and analyses were not reported to have been conducted in a blinded manner. Both brain and serum levels of superoxide dismutase were reported to be lower in all exposure conditions compared to controls. In contrast, malondialdehyde levels were increased in all exposure groups. Other analyses looking at behavior and brain pathology were also conducted in this study, but are not reported here.

Manikonda et al. (2014) looked at the effects in rats of continuous, 90-day exposure to much lower magnetic field strengths (500 mG and 1,000 mG, 50-Hz). Controls were sham exposed in a similar exposure apparatus, but with the equipment turned off. Analyses were not reported to have been conducted in a blinded manner. Reactive oxygen species, thiobarbituric acid reactive substances (a marker of lipid peroxidation), and glutathione peroxidase were significantly increased compared to control levels in the hippocampus and cerebellum with both exposure conditions; they were also increased in the cortex, but at 1,000 mG only. Superoxide dismutase levels were also increased in all three tissues at 1,000 mG, while the thiol status (GSH/GSSG) was reduced with exposure in these tissues. Generally, the cortex was less responsive than the other brain tissues examined. It should be noted, however, that the exposed rats showed significantly higher levels of physical activity than the controls, which may have confounded the study results. Finally, Akdag et al. (2013) examined the effects of more long-term magnetic-field exposure. Rats were continuously exposed to a 1,000 or 5,000 mG, 50-Hz magnetic field for 2 hours per day for 10 months. Control rats were sham exposed (with the exposure system turned off) and analyses were reported to have been conducted in a blinded manner. Neither exposure condition affected the expression of various oxidant/anti-oxidant markers in the testes, although expression of an apoptosis marker seemed to be increased in an exposure-related manner.

Overall, it is hard to draw any conclusions from these studies of oxidative stress markers because the numbers of animals per group were generally low, the exposure parameters and oxidative stress markers examined varied across the studies, reported effects were contradictory across studies in some cases, and none of the analyses (with the exception of that by Akdag et al., 2013) were reported to have been conducted in a blinded manner. The equivocal nature of these data is similar to that of earlier studies investigating the influence of magnetic-field exposure on the expression of oxidative stress markers. Independent replications of findings in studies with greater sample sizes and blinded analyses are needed as well as a better understanding of how such markers may be related to health and disease processes.

Assessment

As previously noted, no new animal bioassays of long-term magnetic-field exposure as a possible carcinogen or co-carcinogen have been conducted since the last update. Rather, more recent animal studies have investigated two potential mechanisms related to carcinogenesis: genotoxicity and oxidative stress. The studies of oxidative stress generally suffer from various methodological deficiencies, including small samples sizes, the absence of sham-exposure treatment groups, and analyses that were not conducted in a blinded manner. Further, the results are generally inconsistent across the body of studies, with some studies reporting effects and other studies showing no change. Even in the studies showing alterations, these changes are not necessarily consistent from one study to the next. While these dissimilarities could be a function of the differences in exposure conditions employed across the body of studies, the equivocal nature of the findings on oxidative stress is consistent with that of earlier studies.

One particularly well-conducted study on genotoxicity found no effect of magnetic-field exposure on DNA double strand breaks. This study employed positive control X-irradiation, sham exposure of negative controls, and blinded analyses. Further, the results are generally consistent with those of another recent investigation that found no influence of magnetic-field exposure on the induction of DNA single strand breaks in the brain, liver, or kidneys of exposed mice.

Overall, the *in vivo* studies published since the last update do not alter the previous conclusion of the WHO that there is inadequate evidence of carcinogenicity due to ELF EMF exposure. Further, the limited recent investigations suggest that DNA single and double strand breaks do not occur as a result of magnetic-field exposure.

Table 9. Relevant *in vivo* studies related to carcinogenesis

Authors	Year	Study
Akdag et al.	2013	Can safe and long-term exposure to extremely low frequency (50 Hz) magnetic fields affect apoptosis, reproduction, and oxidative stress?
Deng et al.	2013	Effects of aluminum and extremely low frequency electromagnetic radiation on oxidative stress and memory in brain of mice
Glinka et al.	2013	Influence of extremely low-frequency magnetic field on the activity of antioxidant enzymes during skin wound healing in rats
Hassan and Abdelkawi	2014	Assessing of plasma protein denaturation induced by exposure to cadmium, electromagnetic fields and their combined actions on rat
Korr et al.	2014	No evidence of persisting unrepaired nuclear DNA single strand breaks in distinct types of cells in the brain, kidney, and liver of adult mice after continuous eight-week 50 Hz magnetic field exposure with flux density of 0.1 mT or 1.0 mT
Manikonda et al.	2014	Extremely low frequency magnetic fields induce oxidative stress in rat brain
Saha et al.	2014	Increased apoptosis and DNA double-strand breaks in the embryonic mouse brain in response to very low-dose X-rays but not 50 Hz magnetic fields
Seifirad et al.	2014	Effects of extremely low frequency electromagnetic fields on paraoxonase serum activity and lipid peroxidation metabolites in rat

7 Reviews Published by Scientific Organizations

A number of national and international scientific organizations have published reports or scientific statements with regard to the possible health effects of ELF EMF since January 2006. Although none of these documents represents a cumulative weight-of-evidence review of the caliber of the WHO review published in June 2007, their conclusions are of relevance. In general, the conclusions of these reviews are consistent with the scientific consensus articulated in Section 6.

The following list indicates the scientific organization and a link to the online reports or statements.

- **The European Health Risk Assessment Network on Electromagnetic Fields Exposure**
    - http://efhran.polimi.it/docs/D2_Finalversion_oct2012.pdf (EFHRAN, 2012 [human exposure])
    - http://efhran.polimi.it/docs/IMS-EFHRAN_09072010.pdf (EFHRAN, 2010 [*in vitro* and *in vivo* studies])
- **The Health Council of Netherlands**
    - http://www.gezondheidsraad.nl/sites/default/files/200902.pdf (HCN, 2009a)
    - http://www.gezondheidsraad.nl/en/publications/advisory-letter-power-lines-and-alzheimer-s-disease (HCN, 2009b)
    - http://www.gezondheidsraad.nl/en/publications/bioinitiative-report-0 (HCN, 2008a)
    - http://www.gezondheidsraad.nl/en/publications/high-voltage-power-lines-0 (HCN, 2008b)
- **The Health Protection Agency (United Kingdom)**
    - http://www.hpa.org.uk/Publications/Radiation/DocumentsOfTheHPA/RCE01PowerFrequencyElectromagneticFieldsRCE1/ (HPA, 2006)
- **The International Commission on Non-Ionizing Radiation Protection**
    - http://www.icnirp.de/documents/LFgdl.pdf (ICNIRP, 2010)

- **The Scientific Committee on Emerging and Newly Identified Health Risks (European Union)**
    - http://ec.europa.eu/health/ph_risk/committees/04_scenihr/docs/scenihr_o_007.pdf (SCENIHR, 2007)
    - http://ec.europa.eu/health/ph_risk/committees/04_scenihr/docs/scenihr_o_022.pdf (SCENIHR, 2009)
    - http://ec.europa.eu/health/scientific_committees/emerging/docs/scenihr_o_041.pdf (SCENIHR, 2015)

  The Swedish Radiation Protection Authority
    - http://www.who.int/peh-emf/publications/reports/SWEDENssi_rapp_2006.pdf (SSI, 2007)
    - http://www.who.int/peh-emf/publications/reports/SWEDENssi_rapp_2007.pdf (SSI, 2008)
- **The Swedish Radiation Safety Authority**
    - http://www.stralsakerhetsmyndigheten.se/Global/Publikationer/Rapport/Stralskydd/2009/SSM-Rapport-2009-36.pdf (SSM, 2009)
    - http://www.stralsakerhetsmyndigheten.se/Global/Publikationer/Rapport/Stralskydd/2010/SSM-Rapport-2010-44.pdf (SSM, 2010)
    - http://www.stralsakerhetsmyndigheten.se/Publikationer/Rapport/Stralskydd/2013/201319/ (SSM, 2013)

8 Standards and Guidelines

Following a thorough review of the research, scientific agencies develop exposure standards to protect against known health effects. The major purpose of a weight-of-evidence review is to identify the lowest exposure level below which no health hazards have been found (i.e., a threshold). Exposure limits are then set well below the threshold level to account for any individual variability or sensitivities that may exist.

Several scientific organizations have published guidelines for exposure to ELF EMF based on acute health effects that can occur at very high field levels. [13] The ICNIRP reviewed the epidemiologic and experimental evidence and concluded that there was insufficient evidence to warrant the development of standards or guidelines on the basis of hypothesized long-term adverse health effects such as cancer; rather, the guidelines put forth in their 2010 document set limits to protect against acute health effects (i.e., the stimulation of nerves and muscles) that occur at much higher field levels. The ICNIRP recommends a residential screening value of 2,000 mG and an occupational exposure screening value of 10,000 mG (ICNIRP, 2010). If exposure exceeds these screening values, then additional dosimetry evaluations are needed to determine whether basic restrictions on induced current densities are exceeded. For reference, in a national survey conducted by Zaffanella and Kalton (1998) for the National Institute for Environmental Health and Safety's EMF Research and Public Information Dissemination program, only about 1.6% of the general public in the United States experienced exposure to magnetic fields of at least 1,000 mG during a 24-hour period.

The ICES also recommends limiting magnetic field exposures at high levels because of the risk of acute effects, although their guidelines are higher than ICNIRP's guidelines; the ICES recommends a residential exposure limit of 9,040 mG and an occupational exposure limit of 27,100 mG (ICES, 2002). Both guidelines incorporate large safety factors.

The ICNIRP and ICES guidelines provide guidance to national agencies and only become legally binding if a country adopts them into legislation. The WHO strongly recommends that countries adopt the ICNIRP guidelines, or use a scientifically sound framework for formulating any new guidelines (WHO, 2006).

There are no national or state standards in the United States limiting exposures to ELF EMF based on health effects. Two states, Florida and New York, have enacted standards to limit magnetic fields at the edge of the right-of-way from transmission lines (NYPSC, 1978; FDER, 1989; NYPSC, 1990; FDEP, 1996), however, the basis for these limits was to maintain the "status quo" so that fields from new transmission lines would be no higher than those produced by existing transmission lines.

[13] Valberg et al. (2011) provides a listing of guidelines provided by health and safety organizations.

Neither Rhode Island nor Massachusetts has EMF standards for transmission lines but the Energy Facility Siting Boards have encouraged the use of practical and cost-effective designs to minimize magnetic field levels along the edges of transmission rights-of-way. This approach is consistent with recommendations of the WHO (2007) for addressing ELF EMF.

Table 10. Screening guidelines for EMF exposure

Organization	Exposure (60 Hz)	Magnetic field
ICNIRP	Occupational	10,000 mG
	General Public	2,000 mG
ICES	Occupational	27,100 mG
	General Public	9,040 mG

Sources: ICNIRP, 2010; ICES, 2002

9 Summary

A significant number of epidemiology and *in vivo* studies have been published on ELF EMF and health since the WHO 2007 report was released in June 2007. The weak statistical association between high, average magnetic fields and childhood leukemia has not been appreciably strengthened or substantially diminished by subsequent research, although the most recent studies tended to show no overall associations. The previously reported association remains unexplained and unsupported by the experimental data. The recent *in vivo* studies confirm the lack of experimental data supporting a leukemogenic risk associated with magnetic-field exposure. Recent publications on other cancer and non-cancer outcomes provided no substantial new information to alter the previous conclusion that the evidence is inadequate to link outcomes to ELF EMF exposure.

In conclusion, recent studies when considered in the context of previous research do not provide evidence to alter the conclusion that ELF EMF exposure is not a cause of cancer or any other disease process at the levels we encounter in our everyday environment.

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APPENDIX B:

AGENCY COORDINATION DOCUMENTATION

Stephen J. Rourke
Vice President, System Planning

September 9, 2014

Mr. Raman Somayajulu
New England Power Company
40 Sylvan Road – E1.493
Waltham, MA 02451-1120

Subject: V-148N 115 kV Line Reconductoring Project Proposed Plan Application (PPA) NEP-14-T09

Dear Mr. Somayajulu:

This letter is to inform you that, pursuant to review under Section I.3.9 of the ISO Tariff, no significant adverse effect has been identified with regard to the following PPA:

NEP-14-T09 – Transmission application from New England Power Company (NEP) on behalf of Narragansett Electric for the V-148N 115 kV Line Reconductoring Project

The in-service date of the project is June 1, 2017. The Reliability Committee (RC) reviewed the materials presented in support of the proposed project and did not identify a significant adverse effect on the reliability or operating characteristics of the transmission facilities of NEP, the transmission facilities of another Transmission Owner or the system of any other Market Participant.

Having given due consideration to the RC review, ISO New England has determined that implementation of the plan will not have a significant adverse effect upon the reliability or operating characteristics of the Transmission Owner's transmission facilities, the transmission facilities of another Transmission Owner, or the system of a Market Participant.

A determination under Section I.3.9 of the ISO Tariff is limited to a review of the reliability impacts of a proposed project as submitted by Participants and does not constitute an approval of a proposed project under any other provisions of the ISO Tariff.

Sincerely,

Stephen J. Rourke
Vice President, System Planning

cc: Proposed Plan Applications