June 2022

RHODE ISLAND ENERGY FACILITY SITING BOARD PROJECT SITING REPORT

L190 Asset Condition Refurbishment Project

East Greenwich, North Kingstown, Exeter and South Kingstown, Rhode Island

Volume I

PREPARED FOR:

THE NARRAGANSETT ELECTRIC COMPANY
280 MELROSE STREET
PROVIDENCE, RI 02907

FOR SUBMITTAL TO:

STATE OF RHODE ISLAND ENERGY FACILITY SITING BOARD
89 JEFFERSON BOULEVARD
WARWICK, RI 02888

PREPARED BY:

POWER ENGINEERS CONSULTING, PC
2 HAMPSHIRE STREET
SUITE 301
FOXBOROUGH, MA 02035

POWER ENGINEERS CONSULTING, PC

This page intentionally blank.

Rhode Island Energy Facility Siting Board Project Siting Report

PREPARED FOR: ***THE NARRAGANSETT ELECTRIC COMPANY***
280 MELROSE STREET
PROVIDENCE, RHODE ISLAND 02907

FOR SUBMITTAL TO: ***STATE OF RHODE ISLAND ENERGY FACILITY SITING BOARD***
89 JEFFERSON BOULEVARD
WARWICK, RHODE ISLAND 02888

PREPARED BY: ***POWER ENGINEERS CONSULTING, PC***
2 HAMPSHIRE STREET
SUITE 301
FOXBOROUGH, MA 02035

JUNE 2022

This page intentionally blank.

TABLE OF CONTENTS – VOLUME I

TABLES:

FIGURES:

*Figures denoted with an asterisk are located within the text of the document, the others are bound separately in Volume II.

APPENDICES:

This page intentionally blank.

GLOSSARY OF TERMS

ACSR	Aluminum Conductor Steel Reinforced
ANSI	American National Standards Institute
ASF	Area Subject to Flooding
ASSF	Area Subject to Storm Flowage
BMPs	Best Management Practices
BPS	Bulk Power Supply
Circuit	A system of conductors (three conductors or three bundles of conductors) through which an electric current flows.
Company	The Narragansett Electric Company
Conductor	A metallic wire which serves as a path for electric current to flow.
Demand	The total amount of electric power required at any given time by an electric supplier's customers.
Distribution Line or System	Power lines that operate under 69 kV.
EFSB	Rhode Island Energy Facility Siting Board
EFSB Rules	State of Rhode Island and Providence Plantations Energy Facility Siting Board Rules of Practice and Procedure, effective; April 11, 1996.
Electric Field	A field produced as a result of voltages applied to electrical conductors and equipment; usually measured in units of kilovolts per meter.
Electric Transmission	Facilities (≥ 69 kV) that transmit electrical energy from generating plants to substations, or from substation to substation.
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.
ESA	Endangered Species Act
HUC	Hydrologic Unit Code
Hz	Hertz, a measure of the frequency of alternating current; expressed in units of cycles per second.
IPaC	Information for Planning and Conservation
ISO	Independent System Operator
ISO-NE	ISO New England Inc., the independent system operator of the New England electric transmission system.
kcmil	One thousand circular mils, approximately 0.0008 square inches, a measure of conductor cross-sectional area.
kV	Kilovolt - one kV equals 1,000 volts

kV/m	Kilovolts per meter
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).
LTE	Long-Term Emergency
MVA	Megavolt Ampere. Measure of electrical capacity equal to the product of the line-to-line voltage, the current and the square root of 3 for three-phase systems; electrical equipment capacities are sometimes stated in MVA.
mG	milligauss, a measure of magnetic field intensity.
NERC	North American Electric Reliability Corporation
NOI	Notice of Intent
NPCC	Northeast Power Coordinating Council
OPGW	Optical Ground Wire
POWER	POWER Engineers Consulting, PC.
Project	L190 Asset Condition Refurbishment Project
Project Area	The area immediately adjacent to the Project Route between Davisville Tap and West Kingston Substation.
Report	Project Siting Report
Reconductor	Replacement of existing conductors with new conductors, and any necessary structure reinforcements or replacements.
RIDEM	Rhode Island Department of Environmental Management
RIDOT	Rhode Island Department of Transportation
RIGIS	Rhode Island Geographic Information System
RIGL	Rhode Island General Laws
RIHPHC	Rhode Island Historical Preservation & Heritage Commission
ROW	Right-of-Way. Corridor of land within which a utility company holds legal rights necessary to build, operate, and maintain power lines.
SRPW	Special Resource Protection Water
Study Area	A 5,000-foot-wide corridor measured 2,500 feet on either side of the subject underground cables.
TMDL	Total Maximum Daily Load
TNEC	The Narragansett Electric Company
TOs	Transmission Operators
Transmission Line	An electric power line operating at 69,000 volts or more.
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
V/m	Volts per meter
Watercourses	Rivers, streams, brooks, waterways, lakes, ponds, swamps, bogs and all other bodies of water, natural or artificial, public or private.

1.0 INTRODUCTION

1.1 Project Overview

This Project Siting Report (Report) has been prepared in accordance with Rule 1.6(F) of the *Rhode Island Energy Facility Siting Board's* (EFSB) *Rules of Practice and Procedure* (EFSB Rules) to support a 90-day Notice of Intent (NOI) application for the proposed rebuild of the existing L190 115 kilovolt (kV) electric transmission line (the "L190 Asset Condition Refurbishment Project" or the "Project"), owned and operated by The Narragansett Electric Company (TNEC or Company).

The Project involves replacing the existing assets on approximately 14 miles of the L190 115 kV Transmission Line (L190 or L190 Line) in East Greenwich, North Kingstown, Exeter, and South Kingstown, Rhode Island. The proposed upgrades will extend primarily from the Davisville Tap location in East Greenwich to the West Kingston Substation in South Kingstown, including the taps to the Wickford Junction and Tower Hill Substations. Additionally, approximately 200 feet of existing conductor will be replaced as a component of this Project on the L190 Line tie-in into the Old Baptist Road Substation in North Kingstown (Old Baptist Tap).[1]

The proposed work activities will be located within the limits of the existing right-of-way (ROW) held by TNEC. Refer to Volume II Mapping, Figure 1-1, Project Overview Map. The existing L190 was constructed in several phases from the early 1960s to 2007. Most of the existing L190 structures consist of the original wood H-frame and 3-pole structures installed between 1963 and 1966 which have reached the end of their expected service life. The existing L190 Tower Hill Tap was constructed in 2007 and consists of weathered steel H-frame and single pole steel structures installed on concrete foundations.

The purpose of the Project is to upgrade existing assets and to provide communication paths between interconnected substations on the L190 Line.

For the reasons discussed in this Report, no significant environmental or social impacts will result from the Project described herein.

1.2 Project Team

This Report has been prepared by Company employees and consultants retained by the Company, including planners, engineers, and legal personnel. The description of the affected natural and social environments, and impact analyses were prepared by POWER Engineers Consulting, PC. (POWER); POWER's Transmission Line Engineering prepared the Project engineering and design documents and modeled and calculated Electric and Management Fields (EMF); and Exponent, Inc. prepared the analysis of the health effects of EMF.

---

[1] Structure work along the Old Baptist Tap will be a component of a separate project scope related to transmission line upgrades for the Revolution Wind Farm Project extending from the Drumrock Substation to the Davisville Substation. This work will be submitted and reviewed by the EFSB independently. Environmental review and impact assessment from the structure work on the Old Baptist Tap will be included for review under that separate filing.

1.3 Compliance with EFSB Requirements

This Report is being submitted to satisfy the applicable requirements of Rhode Island General Laws (RIGL) §§ 42-98-1 et seq., the Energy Facility Siting Act. Section 4 of the Energy Facility Siting Act states that, "[n]o person shall site, construct, or alter a major energy facility within the state without first obtaining a license from the siting board pursuant to this chapter." Transmission lines with a design rating of greater than or equal to 69 kV are classified as major energy facilities. The EFSB application filing requirements and associated procedures for alterations to major energy facilities are established in the EFSB Rules.

This Report has been prepared in accordance with Rule 1.6(F) of the EFSB Rules, which requires TNEC to file a NOI for the "…modification or relocation of a powerline with a capacity of 69 kV or more … at least 90 days prior to commencing construction."

1.4 Organization of the Report

This Report has been prepared in accordance with the EFSB Rules to provide information on the potential impacts of the electric transmission system improvements proposed by TNEC. The Purpose and Need for the Project is detailed in Section 2.0 of this Report. Section 3.0 provides a detailed description of the components of the Project, and discusses construction practices, ROW maintenance practices, safety and public health considerations, estimated costs for the Project, and anticipated Project schedule. An analysis of the alternatives to the Project, together with reasons for the rejection of those alternatives, is presented in Section 4.0. Detailed descriptions of the characteristics of the natural and social environment within and immediately surrounding the Project location are included in Sections 5.0 and 6.0, respectively. Section 7.0 of this report identifies the potential impacts of the Project on the natural and social environments. Section 8.0 summarizes proposed mitigation measures which are intended to offset or eliminate the potential impacts associated with the Project. This Report also contains supporting mapping, figures, reports and agency correspondence, as applicable.

2.0 PROJECT NEED

2.1 Introduction

TNEC strives to provide its customers with high quality and 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.

The interconnected electric power system is a complex network of generation, transmission and distribution facilities which must reliably deliver electrical power to utility customers. To be reliable, the system must provide acceptable performance when components are out of service for maintenance or due to unexpected failures of equipment. Performance is typically measured in terms of transmission equipment thermal loading, nominal voltage and voltage variation, power transfers (transfers), generator stability response, and available short-circuit current.

The Company routinely undertakes transmission planning studies to determine whether new or upgraded transmission facilities are needed within a specified timeframe (typically ten years) to maintain reliable electric power within a specific geographic area. 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. National Grid Transmission Group Procedure 28 – Transmission Planning Guide (Transmission Planning Guide) which is based on Independent System Operator (ISO) New England, Inc. (ISO-NE), New England Power Pool (NEPOOL), Northeast Power Coordinating Council (NPCC) and North American Electric Reliability Corporation (NERC) standards, identify the range of conditions which need to be considered in a particular transmission planning study. 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. The contingency analysis is carried out for various system generation dispatches and system transfer levels in order to ensure that the area of interest is tested under conditions that reasonably maximize the electrical stress to the area.

It is therefore necessary to determine specific conditions that need to be studied which address the adequacy of the system. The identification of conditions which need to be considered is accomplished with design criteria and guidelines which generically define “deterministic conditions” that reasonably stress the system. Deterministic conditions recognize the state (i.e., in-service, out-of-service) of the equipment, but not the probability of the state. The capability of the system under these conditions is studied using computer simulations which model the electrical parameters of the system.

All of the Company’s transmission facilities are designed in accordance with the reliability criteria contained in the Transmission Planning Guide, ISO-NE and NEPOOL standards, the NPCC criteria, and the NERC Reliability Standards (collectively, the “Planning Documents”).

In summary, the purpose of performing computer simulated studies is part of an effort to maintain firm and reliable operation of the electric power system as the system continues to evolve and grow.

2.2 Need

In 2019, the L190 Line was identified as in need to be rebuilt because it is one of the worst performing circuits. The existing wood poles are showing signs of deterioration due to pole top rot and aging. Several locations along the existing transmission line contain poor lightning shielding and do not meet current insulation standards. Between 2015 and 2020, there were eight operations: one lockout due to insulator failure, four trip and reclose due to lightning, and 3 trip and reclose due to adjacent sub transmission structure.

In addition to addressing the asset conditions, the Project was engineered with an increased capacity to address thermal overloads that were identified in the ISO-NE’s Eastern Connecticut (ECT) 2029 Need Assessment. The ISO-NE study identified a need to increase capacity from the Davisville Tap to the Tower Hill Substation to 303 Megavolt Ampere (MVA), and from the Tower Hill Substation to the West Kingston Substation to 347 MVA summer Long-Term Emergency (LTE) capacity to fulfil the requirements of the most-loaded sections. Both of these sections of the L190 have the original vintage 795 AAC “ARBUTUS” conductor.

A fiber optic path between the Kent County Substation and the West Kingston Substation is also needed to meet NPCC Director 1 Phase 5 requirements.

2.3 Conclusion

If the L190 Line is not rebuilt the supply to the area may face future reliability issues resulting from the asset conditions of the L190. The Project is needed to address the asset condition issues of the current line but it is also needed to upgrade the lines to address the thermal overloads identified in ISO-NE’s Eastern Connecticut (ECT) 2029 Need Assessment.

3.0 PROJECT DESCRIPTION AND PROPOSED ACTION

3.1 Introduction

This section identifies the scope of the Project, the proposed facilities, and estimated Project costs; describes TNEC's construction practices; and discusses the anticipated Project schedule.

3.2 Description of the Existing Transmission Lines

The L190 Line parallels the existing G185S 115 kV Transmission Line (G185S Line) for the entirety of the Project corridor from the Davisville Tap to its termination at the West Kingston Substation, a total length of approximately 13 miles. The Tower Hill Tap consists of a one mile in-and-out (north and south taps) that connects the L190 Line into the Tower Hill Substation in North Kingstown. The existing L190 Line is supported by single-circuit structures consisting of a combination of roundwood pole structures supporting 795 kcmil 37-strand "Arbutus" single bundle conductor from the Davisville Tap to West Kingston Substation, and galvanized steel pole structures supporting 795 kcmil 26/7 "Drake" ACSR single bundle conductor along the Tower Hill Tap.

The existing ROW from the Davisville Tap to West Kingston Substation varies from approximately 200 to 300 feet wide and has been held in-fee or by easement by TNEC since the 1960s. The Tower Hill Tap is primarily held in fee with a maintained ROW width of approximately 125 feet.

3.3 Scope of the Project

The scope of the Project includes rebuilding the existing assets on the L190 Line as shown on Figure 3-1 and described further below.

- Replace approximately 146 existing single-circuit wood pole H-frame and 3-pole structures with primarily weathering steel pole equivalent structures for approximately 12.5 miles from the Davisville Tap to the West Kingston No. 62 Substation.2
- Reconductor with new single 795 kcmil "Drake" ACSS conductor and replace the existing shield wire with Optical Ground Wire (OPGW) from the Davisville Tap to West Kingston No. 62 Substation, along 200 feet along the Old Baptist Tap, and on the Tower Hill Tap North and South circuits (co-located in a 0.5-mile-long ROW corridor).
- Replace existing shield wire into Wickford Junction No. 30 Substation with OPGW.
- Maintain and upgrade access roads, signage, and grounding to the latest TNEC standards, as applicable.

The proposed structure replacements will be single-circuit steel H-Frame suspension, H-Frame dead-end, and 3-pole dead-end structures. Tangent structures will be light-duty steel pole structures with direct embedded foundations and dead-end structures will be engineered steel pole structures with concrete caisson foundations. The proposed structure replacements will be located on or near the center of the existing transmission line, although minor offsets may be required in angle locations to maintain circuit-to-circuit clearances within the corridor with the proposed structure configurations, allowing foundation installation to commence ahead of (and limiting) line outages. Typical structure

[2] A few poles in extremely wet areas may be replaced with brown galvanized light-duty steel poles.

details are shown on Figure 3-2 and representative photographs of the existing and proposed structures are shown on Figure 3-3.

3.4 Construction and Maintenance Practices

3.4.1 Construction Sequence

The Project will be constructed using conventional overhead electric transmission line construction techniques. TNEC and its consultants conducted detailed constructability field reviews to determine access and workspace requirements, and to evaluate measures to avoid or minimize environmental impacts. The Project will generally progress in the following sequence of activities:

1. Removal of vegetation and ROW mowing in advance of construction;
2. Installation of soil erosion and sediment controls;
3. Access road and work pad maintenance or construction;
4. Installation of replacement structures and transfer or installation of conductors and OPGW;
5. Removal and disposal of existing transmission line components; and
6. Restoration of the ROW.

3.4.2 Construction Traffic and Mitigation

Intermittent traffic associated with Project construction will occur over the entire construction period. Construction equipment typically will gain access to the ROW from public roadways crossing the ROW in various locations along the route. Because each of the construction tasks will occur at different times and locations over the course of the construction, traffic will be intermittent at these entry roadways. Traffic will consist of vehicles ranging from pick-up trucks to heavy construction equipment to large trailers delivering poles. The proposed access roads are identified on Figure 3-1.

TNEC's contractors will coordinate closely with the municipalities of East Greenwich, North Kingstown, Exeter, and South Kingstown, and the Rhode Island Department of Transportation (RIDOT) to develop Traffic Management Plans for work within state and local roads. At locations where construction equipment must be staged in the road, the contractors will follow a pre-approved work zone traffic control plan with appropriate police details. TNEC will comply with all required measures to ensure a safe environment for traffic flow and construction crews in and around the roadways. Appropriate safety measures will be implemented to allow safe traffic patterns for vehicles, bicyclists and pedestrians.

3.4.3 Construction Work Hours

Proposed construction work hours for the Project will be between 7:00 a.m. and 7:00 p.m. Monday through Friday when daylight permits and between 7:00 a.m. and 5:00 p.m. on Saturday. Some limited construction may occur outside of standard work hours when needed to complete certain activities. For example, some work tasks such as pulling in new conductor, once started, must be continued 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. Availability of these outages, which is dictated by the ISO-NE based on regional system load and weather conditions, can be limited. Such scheduled outages will have no effect on electric service to local customers. 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 on Sundays and holidays.

Prior to and during construction, TNEC will notify landowners, abutting property owners, municipal officials, the Departments of Public Works, and Police and Fire Chiefs of the details of planned construction including the normal work hours and any extended work hours.

3.4.4 Environmental Compliance Monitoring

Throughout the entire construction process, TNEC will retain the services of an environmental monitor who will verify and report on compliance with all federal, state, and local permit requirements and TNEC's policies and procedures. At regular intervals and during periods of prolonged precipitation, the environmental monitor will inspect all locations to determine whether the environmental controls are functioning properly. Prior to the start of construction, all Project personnel will be trained on Project environmental requirements and permit conditions, including rare species, storm water management, and cultural resources. Refresher training will be held as new crew members join the Project work force and as otherwise necessary. TNEC will conduct regular construction progress meetings to reinforce the construction team's awareness of these issues. Pre-construction "look-ahead meetings" will take place in the field with appropriate Project personnel. TNEC's environmental monitor will attend these meetings to provide feedback on environmental requirements and compliance to construction personnel.

In addition to retaining the services of an environmental monitor, TNEC will require the construction team to designate an individual to be responsible for the daily inspection and maintenance 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, appropriate work methods, driving safety, and good house-keeping practices along the ROW.

3.4.5 Safety and Public Health Considerations

TNEC will design, build, and maintain the Project so that the health and safety of the public are protected. This will be accomplished through adherence to all applicable regulations, and industry standards and guidelines established for the protection of the public. Specifically, the Project will be designed, built and maintained in accordance with the Company's own standards as well as the National Electric Safety Code. 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, the American Society of Civil Engineers, the American Concrete Institute, 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 for construction traffic on busy streets to maintain safe driving conditions, restricting public access to work areas, noise and dust control, and coordination with the municipalities of East Greenwich, North Kingstown, Exeter, and South Kingstown during construction.

A discussion of the status of the health research relevant to exposure to EMF was prepared by Exponent, Inc. and is attached as Appendix A.

3.4.6 Public Outreach

TNEC believes in and has committed to a fully open, transparent, and regular two-way dialogue with project stakeholders throughout the life of its projects. TNEC will launch - and has already undertaken efforts in this regard - a comprehensive stakeholder outreach campaign to educate and inform neighborhood residents, municipal officials, and businesses about the full scope of work to be undertaken to support this Project. Pre-construction outreach activity has included notifications to abutters and conversations with dozens of project stakeholders regarding a variety of topics including grants of access, environmental matting needs, proposed structure locations, vegetation management, etc. We are committed to maintaining those conversations throughout the project.

Public outreach will also include, but is not necessarily limited to:

- Meetings with municipalities and relevant governmental organizations with interest in the Project scope;
- Community Open House events;
- Community outreach (e.g. door-to-door);
- A user-friendly, interactive website;
- A Project hotline;
- Fact sheets, door hangers, FAQs, timelines, etc.; and
- Advertising.

The team will continue to maintain a high level of outreach to discuss the Project, receive comments, and answer questions throughout the permitting and construction phases.

State and Local Meetings

The Project team has met, and will continue to meet as needed, with all relevant governmental bodies with interest in, or impacted by, the Project scope. In advance of the filing, the Project team has met with Town representatives of East Greenwich, Exeter, North Kingstown, and South Kingstown RI to outline the Project need, benefits and high-level details around proposed Project routes, local impacts, and tentative Project schedule. In addition, the Project team has briefed RIDOT and other relevant state agencies. The Project team will continue to meet regularly with all governmental stakeholders throughout the Project schedule to ensure a timely flow of information and provide opportunities for input.

Open Houses/Community Outreach

TNEC is fully committed to providing the community with the opportunity to see the Project plans and responding to questions and concerns. There will be community open house meetings held in the Project footprint to provide interested parties with an opportunity to learn more about the Project and ask questions of Project subject matter experts. All information about Company-hosted meetings will also be made available on the Project website.

Project Website

A Project website will be developed. This website provides Project information, including background, updates, and contact resources. TNEC will keep the Project website up to date for the duration of the Project. A dedicated e-mail address will be made available for interested parties to send questions or comments. The Project e-mail is listed in all Project outreach materials, including fact sheets, mailings, the website, and signage at community events.

Project Hotline

A toll-free phone number and a local phone number will be designated as the Project Hotline for the Project. The Project Hotline numbers will be listed in all Project outreach materials, including fact sheets, mailings, the website, and signage at community events. A Project representative staffs the toll-free hotline and TNEC pledges to respond within two businesses days to all inquiries – most often on the same business day whenever practical.

Abutter Communications

TNEC representatives expect to meet individually with any Project abutters who have questions specific to their properties through the life of the Project. In addition, the project team will be sending letters via U.S. Mail to keep them abreast of Project developments throughout the Project schedule.

Door-to-Door Outreach

TNEC will engage in a door-to-door outreach campaign, canvassing all residents and any businesses adjacent to Project activities. The purpose of this outreach is to provide information and answers to questions. If a resident is not available, a TNEC representative will leave Project-related information at the door. A similar effort will be undertaken with affected businesses along the project route.

Construction Communication Plan

Building off the existing outreach and communications plan, TNEC will develop a comprehensive construction communication plan to update residents, businesses, fire, police, emergency personnel, and municipal officials on work schedules, work locations, and construction activities. In addition to the Project website, hotline, and email, this plan will include, as needed, work area signage, construction notifications, and direct contact with Project abutters.

TNEC's Project representatives will be responsible for coordinating outreach during construction and serving as a single point of contact for the public. The Project website will be kept up to date throughout Project construction. Project information also will be communicated through various town and businesses websites as permitted.

Advertising

TNEC will, in addition to the efforts outlined in the sections above, advertise Project Open Houses, and important Project information to augment and support these communications efforts. For this project, advertising will be placed in local media, including with the Southern RI Newspapers group (*East Greenwich Pendulum, North Kingstown Standard-Times)*, which serve as the community newspapers of record and other publications, as needed, to ensure maximum visibility in the community.

Project Collateral

TNEC will also produce project collateral – fact sheets, frequently asked questions and other background materials for dissemination to affected project abutters and elected officials. This Project collateral will also be placed on the Project website to optimize availability of the Project information.

3.4.7 Estimated Project Costs

TNEC has prepared Project cost estimates as identified in Table 3-1. The cost estimates presented have an accuracy of +/- 25%. Estimated costs include costs of materials, labor and equipment, escalation, contingency and risk.

TABLE 3-1 ESTIMATED PROJECT COSTS

PROJECT COMPONENTS	ESTIMATED COST ($M)
L190 Transmission Line Facilities	$56.9

3.4.8 Project Schedule

The overall construction of the Project is expected to take approximately 18 months to complete. The Company expects final engineering and the licensing and permitting process to continue through the third quarter 2022. Construction is anticipated to begin in the fourth quarter 2022 with completion in the third quarter 2024.

TNEC has developed a preliminary schedule based on time estimates for planning and engineering, permitting and licensing, and construction (Table 3-2). The overall ready for load date is anticipated by second quarter 2024.

TABLE 3-2 PRELIMINARY PROJECT SCHEDULE

ACTIVITY	ESTIMATED START DATE	ESTIMATED COMPLETION DATE
Planning and Engineering	Q2 2019	Q3 2022
Permitting and Licensing	Q1 2021	Q3 2022
Construction	Q4 2022	Q3 2024
Facilities Ready for Load	Q2 2024	
Final Restoration	Q3 2024	

4.0 PROJECT AND ROUTE ALTERNATIVES

4.1 Introduction

This section describes the alternatives to the Project that were considered to address the need for asset condition refurbishments on the L190 Line. As described in Section 2.0, the Project is needed to upgrade existing assets and provide a communications path as required per the NPCC Directory 1 Implementation Plan for bulk power supply (BPS) circuits.

An important goal in the planning and development of the proposed electric transmission system improvements was to ensure that the solutions selected to meet the electrical system needs were the most appropriate in terms of cost and reliability, and that environmental impacts are minimized to the fullest extent possible. Analyses were undertaken to evaluate the feasibility of alternatives to the Project to ensure these objectives were met. TNEC's overriding goal has been to select the alternative that best meets the Project need, with a minimum impact on the environment, at the lowest possible cost.

Section 4.2 describes the no-action alternative, Section 4.3 describes potential alternative overhead transmission line routes, Section 4.4 describes potential alternative underground transmission line routes, and Section 4.5 describes the Project.

4.2 No-Action Alternative

As detailed in Section 2.0 of this report, the proposed transmission system improvements are required to satisfy the transmission planning criteria of TNEC, the ISO-NE and New England Power Pool, and the NPCC. The NPCC Directory 1 Implementation Plan for BPS circuits requires all New England Transmission Operators (TOs) to install dual high speed schemes on their BPS circuits by September 10, 2025.

The no-action alternative would leave the L190 Line in its current condition, not meeting existing reliability and safety standards and not being able to meet the communication requirements set by the NPCC Implement Plan. In 2019, the L190 Line was noted as one of the worst performing circuits. The existing wood poles along the line are showing signs of significant asset deterioration due to pole top rot and aging. The southern portion of the line has less insulation than current standards require. For these reasons, the No Action is not an acceptable alternative for maintaining a firm and reliable electric supply for TNEC's customers as it would not address the need to bring the L190 line up to current codes and resolve the condition and reliability issues with the L190 Line. The no-action alternative is not acceptable from either an operational or reliability perspective.

4.3 New Overhead Transmission Route Alternative

The Project consists of proposed upgrades and refurbishments to existing electric utility infrastructure within an established ROW, and because of residential and commercial development in the area, TNEC concluded that establishing a new ROW was not viable. Pursuing the acquisition of new ROW would add significantly to the cost of the proposed Project and would likely result in the displacement of some residences and businesses. Developing a new ROW would not serve to minimize the environmental or social impacts of the Project, as the EFSB criteria require. Clearing and construction impacts within a new ROW corridor would result in more significant environmental impacts to wetlands, forested areas and existing land uses. Establishing a new overhead transmission route also would not address the need to bring the L190 line up to current codes and resolve the condition and reliability issues with the L190 Line. Lastly, attempting to secure a new ROW between the Old Baptist Road Tap Point and the West Kingston Substation would substantially delay the Project. For these reasons, TNEC determined that establishing a new ROW to support a new transmission line was not a feasible alternative.

Because of the development in the area and the time and expense associated with acquiring new ROW, TNEC has selected to upgrade the existing transmission line facilities within the existing ROW between the Old Baptist Road Tap Point and the West Kingston Substation to meet the identified Project need. To verify that no viable alternative overhead routes exist between the Old Baptist Road Tap Point and the West Kingston Substation, TNEC examined the general vicinity for possible alternatives to the proposed Project on the existing ROW, as described below.

4.3.1 Parallel Transmission Line

This alternative would require construction of new transmission facilities as opposed to upgrading the existing facilities. For this alternative, it would require either an increase in the width of the existing ROW, or acquisition of new ROW. In both cases, it would involve substantial time and cost and result in more impacts than would be associated with upgrades to the existing line. Additionally, acquisition of new ROW would affect existing land use and private properties. Because of time, cost, and permitting that would be associated with constructing a new transmission line, TNEC concluded that a new parallel transmission line is not a practicable alternative to the proposed action.

4.3.2 Railroad ROW

In reviewing the Project area, TNEC recognized that the Amtrak railroad ROW passes near both the Old Baptist Road Tap Point and the West Kingston Substation. As a result, TNEC assessed the viability of using the railroad ROW as an alternative route to construct a new transmission line to meet the needs of the Project. TNEC determined that the use of the railroad ROW as an alternative route was problematic for a variety of reasons. Train traffic and schedules would restrict the permissible hours of construction along the tracks, making the construction of the proposed transmission line impractical. Access restrictions due to train traffic and schedules would also make emergency or routine maintenance of the transmission line excessively difficult. High-speed train traffic would also pose a safety risk to workers constructing or maintaining the proposed transmission line.

The need to purchase the rights and easements needed to install the transmission line along Amtrak's corridor would add to the cost of the proposed transmission line, and would also significantly extend the schedule for completing the required transmission system improvements. For these reasons, TNEC determined that using the railroad ROW as an alternative route installation of a new transmission line was not viable.

4.3.3 Public Streets and Highways

Another alternative route would be the use of public streets and highways. TNEC typically requires a ROW 80 to 140 feet wide for a 115 kV transmission line (Procedure PR.06.01.012 "*Circuit and Right-of-Way Configuration"*). While transmission lines are constructed along public highways in some areas of the United States, TNEC does not generally utilize this type of construction/installation for its facilities. This alternative would cause significant disruption to existing land uses (residences and businesses), require removal of trees, and removal and relocation of existing overhead utilities. It would also create increased traffic congestion and road closures throughout the duration of construction. Additional easements outside of the public roadway ROW would likely be required in order to provide sufficient overhead clearances for the new conductors. Since there is a viable alternative, this option was rejected.

4.4 New Underground Transmission Route Alternative

TNEC also examined potential underground alternatives to the proposed Project. While an underground alternative could address the loading requirements as discussed in Section 2.0, an underground alternative would not address the maintenance and upgrades necessary to ensure safe operation of the existing transmission facilities on the L190 Line. Additionally, there would be significant cost, schedule, environmental, and operational disadvantages to an underground alternative.

The most direct route along the roadway network would extend approximately 13 miles and utilize an existing residential driveway extending from the Davisville Tap location to Route 2; follow State Route 2 south and west through East Greenwich, North Kingstown, Exeter, and South Kingstown to Route 138; follow Route 138 south and east over the Amtrack rail corridor to Liberty Lane; follow Liberty Lane west to Great Neck Road; and follow Great Neck Road to the West Kingston Substation. Due to the substantial length of underground construction, use of the roadway network for an underground alternative would add significant cost and disruption to the communities traversed by the route.

TNEC also evaluated use of the existing ROW for a potential underground alternative for the Project. There are multiple river crossings and extensive wetland areas along the ROW, there would be a state highway crossing of Route 4, and two crossings of the Amtrack rail corridor. These features can be easily spanned by overhead transmission lines, but special construction techniques, such as horizontal directional drilling or pipe-jacking, would be needed to cross these obstructions with an underground route. Environmental impacts would be substantially increased, as construction of the underground line would require development of additional access roads and excavation along the full 14 mile ROW. A new underground alternative would also take several years to design, license and build and will not be available to address the potential loading requirements discussed in Section 2.0 on a timely basis.

Underground lines also present system and operational disadvantages versus an overhead transmission line. When an overhead transmission line experiences an outage, it can typically be repaired within 24 to 48 hours. In the case of a failure of an underground transmission cable, repair times can be in the range of two weeks to a month or more. Additionally, many faults on overhead lines are temporary in nature. Often it is possible to re-energize an overhead line after a temporary fault, and return the line to service with only a brief interruption. Faults on underground transmission cables are almost never temporary, and the cable must remain out of service until the problem is diagnosed and repairs can be completed.

Due to the substantially higher costs, increased environmental impacts, and operational disadvantages discussed above, a potential underground alternative was not considered further.

4.5 L190 Asset Condition Refurbishment Alternative (Preferred)

TNEC concluded that the proposed Project is the preferred alternative to meet the identified need. The proposed Project includes structure replacements along approximately 12.5 miles of the existing L190 Line extending from the Davisville Tap to the West Kingston Substation. The existing conductor will be replaced (reconductored) with new single 795 kcmil "Drake" ACSS conductor and the existing shield wire will be replaced with OPGW from the Davisville Tap to West Kingston No. 62 Substation, along 200 feet along the Old Baptist Tap, and on the Tower Hill Tap North and South circuits (co-located in a 0.5-mile-long ROW corridor). TNEC will be maintaining and upgrading access roads, signage and grounding along the full length of Project, as applicable. This option is the only alternative that addresses the need to bring the L190 Line up to current codes and resolve the condition and reliability issues with the existing Line.

The proposed Project was determined to be the most economical solution that met the identified need.

4.6 Conclusion

TNEC evaluated several alternatives in the development of the Project as described above. Ultimately, TNEC concluded that upgrading and reconductoring the existing L190 Line is significantly preferred to the other alternatives because it will: resolve the age, condition, and reliability concerns with the L190 Line while meeting the need for the Project at the lowest possible cost; be constructed while minimizing environmental impacts; and be completed in the shortest timeframe.

5.0 DESCRIPTION OF AFFECTED NATURAL ENVIRONMENT

This section describes the specific natural features that have been evaluated for potential impacts based upon published resource information, the Rhode Island Geographic Information System (RIGIS) database, various state and local agencies, and field investigations of the Project ROW.

The Project involves work activities and structure replacements on existing 115 kV transmission lines within an established and maintained ROW. As a result, the Project is anticipated to have only limited and temporary impacts on the natural environment including, soils, vegetation, surface water, wetland and waterbodies, and wildlife. The Project is anticipated to have no impact on geology and therefore the geological characteristics are not included in the below assessment.[3]

5.1 Project Study Area

A Study Area was established to assess the existing environment both within and immediately adjacent to the existing ROW. This Study Area consists of a 5,000-foot-wide corridor, measured 2,500 feet on either side of the centerline of the ROW. The boundaries of this corridor were established to allow for a detailed desktop analysis of existing conditions within and adjacent to the Project ROW (Figure 5-1).

5.2 Soils

Because soils will be disturbed and graded for access roads, work pads and pull pads during Project construction, information concerning the physical properties, classification, agricultural suitability, and erodibility of soils near the Study Area (Figure 5-1) were obtained from the Natural Resource Conservation Service. The Soil Survey delineated map units that may consist of one or more soil series and/or miscellaneous non-soil areas that are closely and continuously associated on the landscape. In addition to the named series, map units include specific phase information that describes the texture and stoniness of the soil surface and the slope class. The soil series within the Study Area were identified. Common soil types found within the Study Area include Freetown muck, Bridgehampton silt loam, Bridgehampton-Charlton complex, Canton and Charlton very stony fine sandy loams, and Quonset gravelly sandy loam. These soil types make up approximately 30% of the Study Area soils. Approximately 0.5% of the Study Area are identified as rock outcrop, the remaining soils found within the Study Area have greater than 60 inches depth to bedrock. Study Area hydric soil status is depicted on Figure 5-2.

5.2.1 Erosive Soils

The erodibility of soils is dependent upon the slope of the land and the texture of the soil. Soils are given an erodibility factor (K), which is a measure of the susceptibility of the soil to erosion by water. Soils having the highest K values are the most erodible. K values range from 0.02 to 0.69 and vary throughout the depth of the soil profile with changes in soil texture. Very poorly drained soils and certain floodplain soils usually occupy areas with little or no slope. Therefore, these soils are not subject to erosion under normal conditions and are not given an erodibility factor. Soil map units with moderate or higher erosion hazard within in the Study Area include Broadbrook silt loams, Narragansett silt loams, Tisbury silt loam, Wapping silt loams, Agawam fine sandy loam, Aquapaug

[3] Per EFSB Rule 1.6(F)(3), which states to the extent the proposed project will have only negligible impact on any particular resource in the natural and social environment, the applicant may so state and need not provide a detailed analysis of the baseline conditions for that resource.

loamy sand, Bridgehampton silt loams, Bridgehampton-Charlton complex, Rainbow silt loams, Raypol silt loam and Scio silt loams. These soil map units have a K factor value of 0.37 to 0.43 and make up approximately 28% of the Study Area.

5.2.2 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. Farmland of statewide importance is land, in addition to prime farmland, that is of statewide importance for the production of food, feed, fiber, forage and oilseed crops. Generally, farmlands of statewide importance include those lands that do not meet the requirements to be considered prime farmland, yet they economically produce high yield of crops when treated and managed with modern farming methods. Some may produce as high a yield as prime farmland if conditions are favorable.

Prime farmland and farmland of statewide importance located within the Study Area are identified in Table 5-1. Approximately 25% of the Study Area is made up of soils classified as Prime Farmland Soils, and approximately 21% of the Study Area is made up of soils classified as Farmland of Statewide Importance.

TABLE 5-1 PRIME FARMLAND AND FARMLAND OF STATEWIDE IMPORTANCE WITHIN THE STUDY AREA

SOIL MAP UNIT SYMBOL	NAME	PRIME FARMLAND	FARMLAND OF STATEWIDE IMPORTANCE
AfA	*Agawam fine sandy loam, 0 to 3 percent slopes*	*X*	
AfB	Agawam fine sandy loam, 3 to 8 percent slopes	X	
BhA	Bridgehampton silt loam, 0 to 3 percent slopes	X	
BhB	Bridgehampton silt loam, 3 to 8 percent slopes		X
BmA	Bridgehampton silt loam, till substratum, 0 to 3 percent slopes	X	
BmB	Bridgehampton silt loam, till substratum, 3 to 8 percent slopes		X
BrA	Broadbrook silt loam, 0 to 3 percent slopes	X	
BrB	Broadbrook silt loam, 3 to 8 percent slopes	X	
CdA	Canton and Charlton fine sandy loams, 0 to 3 percent slopes	X	
CdB	Canton and Charlton fine sandy loams, 3 to 8 percent slopes	X	
Dc	Deerfield loamy fine sand		X
EfA	Enfield silt loam, 0 to 3 percent slopes	X	
EfB	Enfield silt loam, 3 to 8 percent slopes		X
HkA	Hinckley loamy sand, 0 to 3 percent slopes		X
HkC	Hinckley loamy sand, 8 to 15 percent slopes		X
HnC	Hinckley-Enfield complex, rolling		X
MmA	Merrimac fine sandy loam, 0 to 3 percent slopes	X	
MmB	Merrimac fine sandy loam, 3 to 8 percent slopes	X	
NaA	Narragansett silt loam, 0 to 3 percent slopes	X	
NaB	Narragansett silt loam, 3 to 8 percent slopes	X	

SOIL MAP UNIT SYMBOL	NAME	PRIME FARMLAND	FARMLAND OF STATEWIDE IMPORTANCE
NeB	Newport silt loam, 3 to 8 percent slopes	X	
NeC	Newport silt loam, 8 to 15 percent slopes		X
Nt	Ninigret fine sandy loam, 0 to 3 percent slopes	X	
PaA	Paxton fine sandy loam, 0 to 3 percent slopes	X	
PaB	Paxton fine sandy loam, 3 to 8 percent slopes	X	
PmA	Pittstown silt loam, 0 to 3 percent slopes	X	
QoA	Quonset gravelly sandy loam, 0 to 3 percent slopes		X
QoC	Quonset gravelly sandy loam, rolling		X
RaB	Rainbow silt loam, 3 to 8 percent slopes	X	
Rc	Raypol silt loam		X
Ru	Rippowam fine sandy loam		X
ScA	Scio silt loam, 0 to 3 percent slopes	X	
Se	Stissing silt loam		X
Ss	Sudbury sandy loam	X	
Tb	Tisbury silt loam	X	
Wa	Walpole sandy loam, 0 to 3 percent slopes		X
WbA	Wapping silt loam, 0 to 3 percent slopes	X	
WbB	Wapping silt loam, 3 to 8 percent slopes	X	
WgA	Windsor loamy sand, 0 to 3 percent slopes		X
WgB	Windsor loamy sand, 3 to 8 percent slopes		X
WhA	Woodbridge fine sandy loam, 0 to 3 percent slopes	X	

5.3 Water Resources

5.3.1 Surface Waters

The Project lies within two major drainage basins including the Narragansett Bay watershed in East Greenwich and a portion of North Kingstown, and the Upper Pawcatuck River watershed which lies south of Indian Corner Road in North Kingstown south to the West Kingston No. 62 Substation (RIGIS 2007). Watersheds within these major basins are further delineated into smaller watersheds identified by a unique level, Hydrologic Unit Code (HUC-12). The northern portion of the Project lies within the Hunt River watershed in East Greenwich and continues south into North Kingstown. Just south of Route 102 in North Kingstown, the Project lies within the Lower West Passage watershed to just south of Indian Corner Road in North Kingstown. South of Indian Corner Road in North Kingstown, the ROW enters the Chipuxet River-Pawcatuck River in North Kingstown, passing through Exeter and into South Kingstown. North of Graces Lane in South Kingstown the ROW crosses into the Usquepaug River-Pawcatuck River watershed until just south of the Amtrak railroad crossing at Great Neck Road where the watershed transitions back into the Chipuxet River-Pawcatuck River watershed which continues south to the West Kingston No. 62 Substation.

The named surface water resources and classifications within the Study Area are listed in Table 5-2. The waters of the state of Rhode Island (meaning all surface water and groundwater of the State) are assigned a Use Classification which is defined by the most sensitive uses which it is intended to protect. Waters are classified according to specific physical, chemical, and biological criteria which establish parameters of minimum water quality necessary to support the water Use Classification. The water quality classification of the major surface waters within the Study Area are identified in the descriptions of the water bodies that follow.

For waterbodies that were not listed, classification was determined by the below rules in accordance with Section 1.9(E) of the Rhode Island Water Quality Regulations:

1. All streams tributary to Class A waters shall be Class A.
2. All waters tributary to Class AA waters shall be Class AA.
3. All freshwaters hydrologically connected by surface waters and upstream of Class B, B1, SB, SB1, C, or SC waters shall be Class B unless otherwise identified in Section 1.25 of this Part.
4. All other fresh waters, including, but not limited to, ponds, kettleholes and wetlands not listed in Section 1.25 of this Part shall be considered to be Class A.
5. All seawaters not listed in Section 1.25 of this Part shall be considered to be Class SA. All saltwater and brackish wetlands contiguous to seawaters not listed in Section 1.25of this Part shall be considered Class SA.
6. All saltwater and brackish wetlands contiguous to seawaters listed in Section 1.25 of this part shall be considered the same class as their associated seawaters.

Special Resource Protection Waters (SRPWs) are high quality surface waters identified as having significant ecological or recreation uses. The following surface water resources are listed as SRPWs:

- Hunt River for ecological habitat, critical habitat (rare and endangered species) and conservation area.
- Bellville Pond for recreation, ecological habitat, and critical habitat.
- Great Swamp for ecological habitat, state park, and critical habitat.

TABLE 5-2 NAMED SURFACE WATER RESOURCES WITHIN THE STUDY AREA

WATER BODY NAME	TOWN	CLASSIFICATION/ USE	FISHERY DESIGNATION	WATER BODY CROSSED
Hunt River	East Greenwich/North Kingstown	A SRPW	Cold	Yes
Scrabbletown Brook	East Greenwich/North Kingstown	A	Cold	Yes
Sandhill Brook	North Kingstown	B	Warm	No
Rodman Mill Pond	North Kingstown	Not Listed, Determined B	Unassessed	No
Bellville Upper Pond Inlet	North Kingstown	B	Cold	Yes
Belleville Pond	North Kingstown	B SRPW	Warm	No
Jenkins Pond	North Kingstown	Not Listed, Determined B	-	No
Oak Hill Pond and Brook	North Kingstown	B	Unassessed	Yes
Secret Lake	North Kingstown	B	Warm	Yes

WATER BODY NAME	TOWN	CLASSIFICATION/ USE	FISHERY DESIGNATION	WATER BODY CROSSED
Silver Spring Lake	North Kingstown	B	Warm	No
Kettle Hole Pond	North Kingstown	B	Unassessed	Yes
Yorker Mill Pond (Yawgoo Mill Pond)	Exeter & North Kingstown	A	-	No
Chipuxet River	Exeter & South Kingstown	B	Cold	Yes
Hundred Acre Pond	South Kingstown	B	Warm	No
Barber Pond	South Kingstown	B	Warm	No
Mud Brook	South Kingstown	B	Unassessed	No
Chickasheen Brook	South Kingstown	B	Cold	Yes
Yawgoo Pond	South Kingstown	A	Warm	No
Thirty Acre Pond	South Kingstown	B	Warm	No
Larkin Pond	South Kingstown	B	Warm	No
Great Swamp	South Kingstown	Not Listed, Determined A SRPW	-	Yes

Notes:
Use Classification:
A: These waters are designated for primary and secondary contact recreational activities and for fish and wildlife habitat. They shall be suitable for compatible industrial processes and cooling, hydropower, aquacultural uses, navigation, and irrigation and other agricultural uses. These waters shall have excellent aesthetic value.
B: These waters are designated for fish and wildlife habitat and primary and secondary contact recreational activities. They shall be suitable for compatible industrial processes and cooling, hydropower, aquacultural uses, navigation, and irrigation and other agricultural uses. These waters shall have good aesthetic value.
C: These waters are designated for secondary contact recreational activities and fish and wildlife habitat. They shall be suitable for compatible industrial processes and cooling, hydropower, aquacultural uses, navigation, and irrigation and other agricultural uses. These water shall have good aesthetic value.
SRPW = Special Resource Protection Waters
Source: State of Rhode Island Water Quality Regulations 250-RICR-150-05-01. Available at https://rules.sos.ri.gov/regulations/part/250-150-05-1, accessed on January 7, 2022.

Pursuant to the requirements of Section 305(b) of the federal Clean Water Act, water bodies that are determined to be not supporting their designated uses in whole or in part are considered impaired and scheduled for restoration. The causes of impairment are those pollutants or other stressors that contribute to the actual chemical contaminants, physical parameters, and biological parameters. Sources of impairment are not determined until a total maximum daily load (TMDL) assessment is conducted on a water body. Table 5-3 lists the impaired surface water resources in the Study Area based on the State of Rhode Island 2018-2020 Impaired Waters Report (February 2021).

TABLE 5-3 IMPAIRED SURFACE WATER RESOURCES IN THE STUDY AREA

WATER BODY NAME	IMPAIRMENT	CATEGORY
Hunt River	Fecal Coliform	4A
	Enterococcus	4A
Scrabbletown Brook	Fecal Coliform	4A
Sandhill Brook	Fecal Coliform	4A
Belleville Upper Pond Inlet	Phosphorus (Total)	4A
	Enterococcus	4A
Belleville Pond	Phosphorus (Total)	4A
	Non-Native Aquatic Plants	4C

WATER BODY NAME	IMPAIRMENT	CATEGORY
	Mercury in Fish	5
Silver Spring Lake	Non-Native Aquatic Plants	4C
	Total Phosphorus, Mercury in Fish	5
Barber Pond	Dissolved Oxygen	4A
	Non-Native Aquatic Plants	4C
	Mercury in Fish	5
Chipuxet River	Non-Native Aquatic Plants	4C
	Iron, Enterococcus	5
Hundred Acre Pond	Mercury in Fish Tissue	4A
	Non-Native Aquatic Plants	4C
	Dissolved Oxygen	5
Chickasheen Brook	Enterococcus	5
Larkin Pond	Mercury in Fish Tissue	4A
	Non-Native Aquatic Plants	4C
Thirty Acre Pond	Non-Native Aquatic Plants	4C
Yawgoo Pond	Excess Algal Growth, Dissolved Oxygen, Phosphorus (Total), Mercury in Fish Tissue	4A
Secret Lake	Non-Native Aquatic Plants	4C

Notes:

- Category 4A – TMDL has already been completed. Waterbodies are listed and tracked under Category 4A when the TMDL has been completed by RIDEM and approved by United States Environmental Protection Agency.
- Category 4C – Impairment is not caused by pollutant (e.g., aquatic invasive species). Waterbodies are listed as Category 4C for tracking purposes if the waterbody is considered impaired for causes that are not pollutants and therefore a TMDL is not required nor is the appropriate approach to address the impairment.
- Category 5 – Impaired or threatened for one or more uses and requires a TMDL, development of TMDL needed.

5.3.2 Wetlands and Waterbodies

Federal- and State-regulated freshwater wetlands and/or streams were identified and delineated within the Project ROW from September 2020 to July 2021. A total of 42 freshwater wetlands were identified and delineated. Field methodology for the delineation of State-regulated resource areas within the ROW was based upon vegetative composition, presence of hydric soils, and evidence of wetland hydrology. The study methods included both on-site field investigations and off-site analysis to determine the wetland and watercourse resource areas on the Project ROW. Wetlands outside the ROW but within the Study Area were identified based on a desktop review of RIGIS wetlands data (RIGIS 1993). Figure 5-3 depicts wetland resources based on available RIGIS data within the Study Area.

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

In accordance with the provisions of the Rhode Island Fresh Water Wetlands Act and Rules, State-regulated freshwater wetlands include swamps, marshes, bogs, forested or shrub wetlands, emergent plant communities and other areas dominated by wetland vegetation and showing wetland hydrology. The Rules also regulate activities in and around streams and open water bodies which include rivers, streams, ponds, Areas Subject to Storm Flowage (ASSF), Areas Subject to Flooding (ASF) and floodplains.

Pond

The boundary of a pond is determined by the extent of water which is delineated and surveyed. A pond is an area of open standing or slow-moving water present for six or more months during the year and at least 0.25% of an acre in size. Ponds have a 50-foot perimeter wetland associated with their boundary. Ponds make up approximately 507 acres of the Study Area. Ponds located within the Study Area are listed in Table 5-2.

Swamp

Swamps are defined as areas at least three acres in size, dominated by woody vegetation, where groundwater is at or near the surface for a significant part of the growing season. A 50-foot Perimeter Wetland is applied to both forested and shrub swamps. Shrub swamps are areas dominated by broad-leaved deciduous shrubs and often have an emergent herbaceous layer. Typical species in shrub swamps include sweet pepperbush (*Clethra alnifolia*), highbush blueberry (*Vaccinium corymbosum*), winterberry (*Ilex verticillata*), swamp azalea (*Rhododendron viscosum*), and silky dogwood (*Cornus amomum*). Drier portions of shrub swamps are often densely overgrown with greenbrier (*Smilax* sp.) and blackberry (*Rubus allegheniensis*). Common species in the herbaceous layer include sensitive fern (*Onoclea sensibilis*), skunk cabbage (*Symplocarpus foetidus*), and cinnamon fern (*Osmundastrum cinnamomeum*). Shrub swamp generally occurs in areas where the wetland crosses the managed portion of the ROW.

Forested swamps mainly occur on the edges of the managed ROW where the shrub swamps are present, but where the tree cover is allowed to dominate. Vegetation in a forested swamp includes predominantly red maple, willow (*Salix* sp.), black gum (*Nyssa sylvatica*), alder (*Alnus* sp.), silky dogwood, sweet pepperbush, winterberry, swamp azalea, cinnamon fern, common reed (*Phragmites* sp.), and peat moss (*Sphagnum* spp.).

There are approximately 2,900 acres of swamp three acres or greater in size within the Study Area (RIGIS 1993). Portions of shrub swamp are traversed by the ROW in East Greenwich, North Kingstown, Exeter and South Kingstown.

Marsh/ Emergent Wetlands/ Wet Meadows

Marshes are wetlands at least one acre in size where water is generally above the surface of the substrate and where the vegetation is dominated by emergent herbaceous species. Marsh vegetation is typically dominated by broad-leaved cattail (*Typha latifolia*), tussock sedge (*Carex stricta*), and reed canary grass (*Phalaris arundinaceae*), with lesser amounts of common reed (*Phragmites australis*), sensitive fern, skunk cabbage, steeplebush (*Spiraea tomentosa*), marsh fern (*Thelypteris palustris*), and soft rush (*Juncus effusus*). Emergent wetlands and wet meadows are typically dominated by cattail, bulrush (*Scirpus pungens*), woolgrass (*Scirpus cyperinus*), soft rush, sensitive fern, and reed canary grass. Within the Study Area there are approximately 83 acres of wetlands one acre or greater that are identified as marsh/ emergent wetlands or wet meadows (RIGIS 1993).

River/ Perennial Stream

A river is typically a named body of water designated as a perennial stream by United States Geological Survey (USGS). A perennial stream maintains flow year-round and is also designated as a solid blue line on a USGS topographic map. If a stream or river is less than 10 feet wide, the area within 100 feet of each bank is regulated as a 100-foot riverbank wetland. If the stream or river is greater than 10 feet wide, the area within 200 feet of each bank is regulated as a 200-foot riverbank wetland. Seventy-eight perennial streams are located within the Study Area based on a GIS analysis of National Hydrography data. Twenty-two perennial streams were identified during wetland surveys within the ROW.

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 water runoff. Such watercourses may not have flowing water during extended dry periods but may contain isolated pools of standing water. One intermittent stream is located within the Study Area based on a GIS analysis of National Hydrography data. Fifteen intermittent streams were identified during wetland surveys on the ROW.

Shrub / Forested Wetland

Shrub / forested wetlands are characterized by the dominance of shrubs or trees. Shrub and forested wetlands have the same typical vegetation types as shrub and forested swamps. A shrub wetland is dominated by woody vegetation that is less than 20 feet tall while a forested wetland is dominated by woody vegetation greater than 20 feet tall (trees). There are approximately 3,416 acres of forested wetland and approximately 71 acres of shrub wetland within the Study Area (RIGIS 1993).

Floodplain

A floodplain is the land area adjacent to a river, stream or other body of flowing water which is, on average, likely to be covered with flood waters resulting from a 100-year frequency storm event as mapped by Federal Emergency Management Agency. Floodplain areas within the Study Area are shown on Figure 5-3. Several Federal Emergency Management Agency-mapped 100-year floodplains are present within the Project area. Most of these floodplains are associated with large low-lying wetland complexes adjacent to major drainageways such as the Hunt River, Annaquanatucket River, Secret Lake, and Chickasheen Brook.

Area Subject to Storm Flowage

ASSF are channel areas 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 other marked change in vegetative density and/or composition. Sixteen ASSFs were identified during wetland surveys on the ROW.

Area Subject to Flooding

ASFs include, but are not limited to, flood plains, depressions or low laying areas flooded by rivers, streams, intermittent streams, or areas subject to storm flowage which collect, hold, or meter out storm water and flood waters. ASFs do not connect to other freshwater or coastal wetlands as ASSFs do. There were four ASFs identified during wetland surveys on the ROW.

Special Aquatic Site – Vernal Pools

A vernal pool is a type of special aquatic site that is generally defined as a shallow body of water that fills in spring or fall with rain or snowmelt. Most vernal pools dry up by mid-summer because they lack a permanent source of water. Veral pools can be isolated depressions or found within wetlands such as red maple swamps (RIDEM 2021a). Many vernal pools are regulated by the RIDEM as special aquatic sites. A special aquatic site is defined in the RIDEM Freshwater Wetlands Rules and Regulations as a body of open standing water, either natural or artificial, which does not meet the definition of pond, but which is capable of supporting and providing habitat for aquatic life forms, as documented by the: 1) presence of standing water during most years, as documented on site or by aerial photographs; and 2) presence of habitat features necessary to support aquatic life forms of obligate wildlife species, or the presence of evidence of, or use by aquatic life forms of obligate wildlife species (excluding biting flies).

Most vernal pools contain water for a few months in the spring and early summer and are dry by mid-summer. Because they lack a permanent water source and dry periodically, vernal pools lack a permanent fish population. Vernal pools provide breeding habitat for species, particularly amphibians, which depend upon pool drying and the absence of fish for breeding success and survival (obligate vernal pool species). Some wetlands and water bodies may provide breeding habitat for amphibians, but lack the specific criteria to meet the definition of a vernal pool (e.g., provide habitat to facultative vernal pool species only, or contain evidence of breeding obligate vernal pool species occurring together with fish populations); these wetlands and water bodies have been designated as "amphibian breeding habitats."

Field investigations for potential vernal pools and amphibian breeding habitats were performed during the wetland field surveys. The wetlands on the ROW were investigated to confirm the presence/ absence of potential amphibian breeding habitats. There were 12 potential vernal pools identified during wetland surveys on the ROW.

5.3.3 Groundwater Resources

The RIDEM classifies all the state's groundwater resources and establishes groundwater quality standards for each class. The four classes are designated GAA, GA, GB, and GC. Groundwater classified as GAA and GA is to be protected to maintain drinking water quality. Groundwater classified GB are those groundwater resources which may not be suitable for public or private drinking water use without treatment due to known or presumed degradation resulting from overlying land uses. Class GC groundwater is known to be unsuitable for drinking water use due to waste disposal practices such as landfills. Class GB and GC areas are served by a public water supply (RIDEM 2019). The presence and availability of groundwater resources is a direct function of geologic deposits in the vicinity of the Project.

Groundwater resources within the Study Area are depicted on Figure 5-4. Groundwater resources within the Study Area include GA, GAA, and GB. The total acreage of groundwater resources withing the study area is approximately 17,289 acres, of this 79.24% is classified as GAA, 20.82% is classified GA, and 0.12% is classified as GB. Because GAA and GA are suitable for drinking water use without treatment, both classes are subject to the same groundwater quality standards.

The United States Environmental Protection Agency has designated Sole Source Aquifer status to aquifers that supply at least 50 percent of the drinking water for its service area and for which there are no reasonably available alternative drinking water sources should the aquifer become contaminated. There are two Sole Source Aquifers in the Study Area, totaling approximately 15,740 acres. The Hunt Annaquatucket/Pettaquamscutt Aquifer with a specific surface area of 7,275 acres and the Pawcatuck River Aquifer with a specific surface area of 8,465 acres. The purpose of sole source aquifer designation is to manage land use practices within the aquifer recharge area to protect groundwater quality.

5.4 Vegetation

A 1998 inventory of the forest resources in Rhode Island showed the major forest type in Rhode Island being oak/hickory. In the 25 years prior to the inventory, it was noted that oak/hickory had been diminishing and areas of maple/birch and oak/pine have expanded. Oak/Hickory is dominant in the northern part of the state with pine forest found in the southern part of the state. Going from north to south oak/hickory forests decrease and pine forest types increase, with the central part of the state consisting mostly of oak/pine. (USDA Forest Service 2002).

The Study Area contains a variety of vegetative cover typical of Southern New England (DeGraaf and Yamasaki 2001). These include oak/pine forest, old field, and managed lawn. This section of the report focuses on upland communities. Wetland communities are discussed in Section 5.3.2 of this report.

5.4.1 Oak/Pine Forest Community

Forested cover types within the Study Area are typically dominated by oaks (*Quercus* spp.) with or without a white pine (*Pinus strobus*) component. Although these woodlands may appear similar throughout the Study Area, differences in the structure and composition of species in these forests may occur between sites. Soil moisture holding capacity and slope aspect are important factors in determining the plant associations present at a particular site. Plant associations growing on hilltops and south facing slopes are likely to face moisture deficits during the summer. Sandy soils associated with glacial outwash deposits have lower moisture holding capacity in comparison with soils formed over deposits of glacial till. Forests established in these drier sites are often characterized by smaller and more widely spaced trees in comparison with more mesic sites.

Common associates of the hilltop oak/pine forests in the vicinity of the Project ROW include black (*Quercus velutina*), scarlet (Q. *coccinea*), and white oaks (Q. *alba*) as well as aspen (*Populus* sp.) and gray birch (*Betula populifolia*). The shrub/sapling understory includes such species as black cherry (*Prunus serotina*), lowbush blueberry (*Vaccinium angustifolium*) and greenbrier (*Smilax rotundifolia*). Sheep laurel (*Kalmia angustifolia*) and sweet fern (*Comptonia peregrina*) occasionally occur in openings between oak stands with canopy openings and on rocky slopes. Herbaceous species include bracken fern (*Pteridium aquilinum*), tree clubmoss (*Lycopodium obscurum*) and hayscented fern (*Dennstaedtia punctilobula*). These hilltop communities occur where excessively drained soils predominate, and on hilltops throughout the Study Area.

There is an increase in the diversity within plant communities on midslopes compared with dry hilltops. The increase in soil moisture produces this greater diversity in trees, shrubs and herbs. Midslope tree species in addition to oaks include black birch (*Betula lenta*), white ash (*Fraxinus americana*), American beech (*Fagus grandifolia*) and several species of hickory (*Carya* spp.). Shrubs include witch hazel (*Hamamelis virginiana*), sassafras (*Sassafras albidum*) and ironwood (*Carpinus caroliniana*). Greenbrier and poison ivy (*Toxicodendron radicans*) are also common in this community. Common groundcover species include tree clubmoss and wintergreen (*Gaultheria procumbens*). Midslope oak/pine communities occur on mesic mid-slope and lower slope positions and adjacent to forested wetlands on the uncleared portion of the Study Area.

5.4.2 Shrub/ Old Field 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. Over time, pioneer woody plant species including gray birch, black cherry, sumac (*Rhus* sp.) and eastern red cedar (*Juniperus virginiana*) have become established. Within the cleared portions of the ROW, vegetation varies considerably. On dry hilltops, little bluestem (*Schizachyrium scoparium*), round-head bushclover (*Lespedeza capitata*), staghorn sumac (*Rhus typhina*) and eastern red cedar are common. On the mid-slope, greenbrier and blackberry (*Rubus* sp.) form dense, impenetrable thickets. Numerous herbs including goldenrod (*Solidago* sp.), bracken fern (*Pteridium aquilinum*), hay scented fern (*Dennstaedtia punctilobula*), deer-tongue (*dichanthelium clandestinum*), aster (*Aster* sp.), pokeweed (*Phytolacca americana*), and mullein (*Verbascum thapsus*) are also common.

The ROW has been managed to selectively remove trees so they do not interfere with the operation of the existing transmission lines. Low shrub lands dominate portions of the ROW where succession of old field has occurred and where ROW management has resulted in tree sapling removal. Sweet fern (*Comptonia peregrina*), bayberry (*Myrica pensylvanica*), common lowbush blueberry (*Vaccinium angustifolia*), sheep laurel (*Kalmia angustifolia*), sweet pepperbush, arrowwoods (*Viburnum* sp.) are shrub species that are commonly found within the ROW.

Forest vegetation abuts the area of managed ROW in many places along the corridor. This forested edge contains species of trees and the ROW contains saplings that require more sunlight, such as black cherry (*Prunus serotina*), grey birch (*Betula populifolia*), and eastern red cedar. Mature forest containing northern red oak, red maple (*Acer rubrum*), and eastern white pine are also present along the corridor, and saplings of these species are occasionally found in the ROW.

5.4.3 Managed Lawn/Grass

Portions of the Study Area contain managed residential lawn. Typically, these areas consist of a continuous grass cover which may include Kentucky bluegrass (*Poa pratensis*), red fescue (*Festuca rubra*), clover (*Trifolium* sp.), and plantains (*Plantago* sp.). Ornamental shrubs may also occur within the residential areas of the ROW.

Within the Study Area and ROW managed sod farms are present. These areas include continuous grass species which may vary per season and include regional grass varieties mentioned above and specialty short cut grass varieties suitable for athletic and sporting venues. These sod farms are managed and kept at a short length with sections of the grass removed at times leaving exposed soil.

5.5 Wildlife

As previously described, the Study Area includes a variety of aquatic and terrestrial habitats. The wildlife assemblages present within the Study Area vary according to habitat characteristics. Typical wildlife species found commonly in the habitat types within the Study Area may include the following:

- Mammals such as white-tailed deer, foxes, raccoons, weasels and bats.
- A variety of birds such as songbirds, woodpeckers, owls, hawks and turkeys.
- Amphibians and reptiles such as salamanders, turtles, frogs, toads, and snakes.
- Many different species of invertebrates.

5.5.1 Fisheries

There are four Designated Trout Waters within the Study Area. RIDEM has listed Designated Trout Water for 2021 which include: Barber Pond and Chickasheen Brook in South Kingstown, Silver Spring Lake in North Kingstown, and Hunt River in East Greenwich in North Kingstown (RIDEM 2021b).

Refer to Table 5-1 for the warm and cold-water fishery designations associated with the surface water bodies within the Study Area.

5.5.2 Rare and Endangered Species

Correspondence regarding federally- and Rhode Island state-listed species is included in Appendix B, Agency Correspondence.

Federally-listed Species

The current United States Fish and Wildlife (USFWS) Endangered Species Consultation Procedure makes use of the online Information for Planning and Conservation (IPaC) Form (https://ecos.fws.gov/ipac/) which streamlines the USFWS environmental review process. POWER completed and submitted the IPaC Form on September 13, 2021, and results indicated that two federally-listed species, the northern long-eared bat (*Myotis septentrionalis*) and the monarch butterfly (*Danaus plexippus*), may occur in the Project ROW. No federally-designated Critical Habitat occurs in the Project ROW or Study Area. Species descriptions and habitat requirements for the northern long-eared bat and monarch butterfly are further described below.

Northern Long-eared Bat

The northern long-eared bat has suffered severe population declines across its habitat range from white-nose syndrome, a fungal disease that is often fatal. This disease can spread rampantly through winter hibernacula, disrupt hibernation, and lead to starvation and death. The northern long-eared bat was listed by the USFWS as threatened under the federal Endangered Species Act (ESA) on April 2, 2015. In the winter, northern long-eared bat hibernate in caves and mines called hibernacula. Rhode Island does not have any natural caves or abandoned mines so most bats that spend the summer in Rhode Island must leave the state and travel elsewhere to hibernate (RIDEM 2018). During the summer, northern long-eared bat prefer forests where the bats roost in colonies or singly in cavities of both live and dead trees, as well as underneath tree bark. Females give birth to a single pup each season.

According to the final 4(d) Rule for the northern long-eared bat, the Project ROW is considered exempt from ESA prohibitions for removal of “danger” trees. Danger trees are those which present the risk of falling and causing personal injury or property damage. Where possible, if danger trees are required to be removed, that work will be done outside of the time-of-year restrictions set forth by the USFWS New England Field Office (June 1 – July 31).

Additionally, since northern long-eared bats may occur throughout the Project Area and the Project involves minor tree cutting, TNEC must comply with the 4(d) rule under the ESA which became effective February 16, 2016. The 4(d) rule states that “incidental take resulting from tree removal is prohibited if it: 1) occurs within 0.25 mile radius of known northern long-eared bat hibernacula or 2) cuts or destroys known occupied maternity roost trees, or any other trees within a 150-foot radius from the known maternity tree during the pup season (June 1 through July 31).” USFWS guidance also directs Project proponents to contact state natural resources agencies to obtain additional information on the location of known northern long-eared bat hibernacula and maternity roost trees. POWER contacted RIDEM and it was confirmed that there are no known northern long-eared bat maternity roosts or hibernaculum within five miles of the Project. The Determination Key for the Northern Long-eared Bat Consultation and 4(d) Rule Consistency resulted in a “May Effect” and was submitted to the USFWS on September 13, 2021.

Monarch Butterfly

Adult monarch butterflies are large and have bright orange wings surrounded by a black border and covered with black veins. The black border includes a double row of white spots on the upper side of the wings. Adult monarchs are sexually dimorphic, with the males having narrower wing venation and scent patches. Their bright coloring warns predators that eating them can be toxic. (USFWS 2021). Due to declining populations resulting from habitat loss and degradation, continued exposure of pesticides, and climate change, the monarch butterfly was recently listed as a candidate species for listing under the federal ESA on December 17, 2020. As a candidate species, there are currently no Section 7 consultation requirements for federal agency actions (USFWS 2020).

Monarchs will use milkweed as their host plant to lay their eggs. Larvae emerge after two to five days and develop over 9 to 18 days using the milkweed to feed on. They will then pupate into a chrysalis and emerge 6 to 14 days later as an adult butterfly. During the breeding season, multiple generations of monarchs are produced with a life span of approximately two to five weeks. In some regions monarchs will breed year-round but in temperate climates such as eastern and western North America, monarchs will migrate and live for an extended period of time, six to nine months. In the fall, these monarchs will migrate to overwintering sites which can be over 3,000 kilometers. In early spring, February and March, any surviving monarchs will breed at the overwintering sites. These monarchs which originally flew south will fly back through breeding grounds and their offspring will start the generational migration cycle over again.

State-Listed Species

Based on correspondence and follow up communication with the RIDEM, the following state-listed species have been documented on or near the Project ROW (Table 5-4):

TABLE 5-4 STATE LISTED SPECIES DOCUMENTED ON OR WITHIN 500 FEET OF THE PROJECT ROW

COMMON NAME	SCIENTIFIC NAME	REFERENCES FOR IDENTIFICATION
Humped Bladderwort	*Utricularia gibba*	Native Plant Trust, Go Botany. *Utricularia gibba*. https://gobotany.nativeplanttrust.org/species/utricularia/gibba/. Accessed November 21,2021.
Foxtail Clubmoss	*Lycopodiella alopecuroides*	Native Plant Trust, Go Botany. Lycopodiella alopecuroides. https://gobotany.nativeplanttrust.org/species/lycopodiella/alopecuroides/. Accessed November 21, 2021.

6.0 DESCRIPTION OF AFFECTED SOCIAL ENVIRONMENT

This section provides a detailed description of the physical and social environment on and off site. TNEC is providing information on the land uses within and proximate to the ROW, visual resources in the vicinity of the Project, and the public roadway systems in the area. The Project involves work activities on an existing 115 kV transmission line within an established and maintained ROW, therefore the Project is anticipated to have no impacts on population trends or employment conditions of the Study Area. Therefore, in accordance with EFSB Rule 1.6(F)(3), TNEC will not provide a detailed analysis of the baseline conditions for those resources.

6.1 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.

Predominant land uses making up over 90% of the Study Area include deciduous, mixed, and softwood forest; medium, medium-low, and medium-high density residential; cropland; water; wetland; commercial; transportation; pasture; and mines, quarries and gravel pits as shown in Figure 6-1 (RIGIS 2021a).

6.1.1 Land Use Along the Transmission Line Corridor

The northern terminus of the Project is located at the Davisville Tap, approximately 0.4 mile north of South Road in East Greenwich. Approximately 0.6 mile of the Project is located in East Greenwich and runs south from the Davisville Tap to the North Kingstown municipal boundary, generally parallel and to the east of Route 2 (South County Trail). The ROW continues into North Kingstown and after crossing Old Baptist Road, continues south crossing forested areas, wetland, vacant and commercial areas before reaching Route 102. South of Route 102 the ROW continues in a southerly direction through forested and commercial areas and reaching an Amtrak railway crossing. From the railroad, the ROW crosses Lafayette Road and continues in a south easterly direction toward the southwest portion of Secret Lake. This portion of the route passes through shrubland, forested upland areas, developed recreation, residential areas, commercial, pasture, gravel pits, wetland and crosses surface water resources.

The Tower Hill Tap extends approximately 3,000 feet east from the vicinity of L190 Structure 121 north of Allenton Road to the western side of Tower Hill Road passing through residential, forested and wetlands areas.

The ROW continues south through forested areas from the Tower Hill Tap point approximately 500 feet then turns southwest and crosses Route 4. From Route 4 the ROW continues southwest through forested, residential, and wetland areas along the southern edge of Kettle Hole Pond before turning south.

From Kettle Hole Pond, the ROW passes areas of forest and developed recreation before crossing Indian Corner Road. Then it continues south approximately 2,800 feet through forested and cropland areas. The ROW then turns westward and continues approximately 6,000 feet where it crosses Slocum Road, the division between North Kingstown and Exeter. This portion of the route crosses forested, transitional and residential areas.

Continuing west in Exeter, the ROW passes through residential, cropland, and forested areas and crosses Yawgoo Valley Road. It then continues west through forested and cropland areas where it crosses the Amtrak Railroad at a second location. From the railroad, the ROW continues in a south westerly direction through cropland and forested areas to Wolf Rocks Road.

South of Wolf Rocks Road, the ROW crosses into South Kingstown, and continues west to Waites Corner Road and on to Kingstown Road (Route 138). This portion of the ROW passes through forested, cropland, vacant land, commercial, surface water, and residential areas. From Route 138, the ROW continues south through forested, residential, commercial, and cropland areas to Liberty Lane. After crossing Liberty Lane, the ROW continues south across the Chickasheen Brook and through forested areas to the third Amtrak railroad crossing associated with the Project. The ROW then continues south to its terminus at the West Kingston Substation passing through forested, and brushland areas.

6.1.2 Open Space and Recreation

Several areas of public open space, including recreational areas, are present within the Project Study Area. These include the Audubon Hunt River Preserve and the Davisville Memorial Refuge off Davisville Road, Belleville Pond area (Ryan Park) between Lafayette Road and Oak Hill Road, the Great Swamp Wildlife Management Area off Liberty Lane and Great Neck Road. These open space resources provide year-round opportunities for hiking, canoeing and nature study, as well as seasonal opportunity for fishing and hunting.

Established recreational areas within the Study Area include Feurer Park located off of Lafayette Road, Ryan Park in the vicinity of Belleville Pond, Lischio Field located in Donald Downs Park in North Kingstown, and West Kingston Park in South Kingstown. These facilities include athletic fields, tennis courts, and playgrounds. The Kings Crossing Golf Club (Woodland Greens) is located between South Road and Old Baptist Road in North Kingstown and the southeastern portion of East Greenwich. In Exeter, the Yawgoo Valley Ski Area provides skiing opportunities in winter and water slides in the summer.

6.1.3 Future Land Use

In order to assess future land use, an analysis of current zoning was undertaken. Typically, towns and cities mange future growth through zoning regulations which provide a degree of control over a community. The majority of the Study Area is zoned farming, open space, planned business development, industrial or residential in varying densities. Agricultural land within the Study Area consists of turf farms in the vicinity of Indian Corner Road and Slocum Road in North Kingstown, and Yawgoo Valley Road, Waites Corner Road and Route 138 in South Kingstown which are being commercially farmed. Portions of the Study Area are located within the Hunt River Preserve in North Kingstown, and the Great Swamp in South Kingstown.

The Comprehensive Plan of East Greenwich was affirmed in March 2014, but does not specifically address transmission lines. The Town of North Kingstown Comprehensive Plan (2019) does not mention utility transmission line construction and only mentions the transmission line easement in the vicinity of Post Road which is not a portion of this Project. The Comprehensive Plan for the Town of Exeter approved March 3, 2004 does not mention utility transmission line construction. The Town of South Kingstown Comprehensive Plan adopted May 24, 2021 identifies Natural Hazards & Climate Change goals including being "resilient to the impacts of natural hazards and climate change." One action identified in the Comprehensive Plan is to coordinate with utility company "to identify the location of critical electrical lines and substations to develop appropriate protection measures and opportunities for burying critical utility lines."

6.2 Visual Resources

The Project crosses one area, West Allentown Road Turf Farm, included on the Rhode Island Scenic Landscape Inventory list (RIGIS 2021b). This area is crossed by the Project in Exeter in the vicinity of Slocum Road, Gladys Kenyon Road and Old Yawgoo School Road. No other areas included in the Scenic Landscape Inventory are located immediately adjacent to the Project ROW.

6.3 Cultural and Historic Resources

TNEC contracted POWER to conduct a cultural resources due diligence literature review for the Project in August 2020. POWER coordinated with the Rhode Island Historical Preservation & Heritage Commission (RIHPHC) to identify previously recorded archaeological resources and completed a review of publicly-available records to identify historic above-ground resources within the Project study area. These reviews included both above-ground historic resources and archaeological resources that are listed or evaluated as eligible for listing in the State or National Register of Historic Places as well as surveyed properties that have not been evaluated or listed, within one kilometer of the Project. POWER also reviewed the results of a pedestrian survey conducted in the Project corridor during a previous cultural resources review and completed an archaeological sensitivity assessment of the Project ROW to provide information about cultural resources that could be affected by the proposed Project.

6.3.1 Architectural Resources

The due diligence review identified eight above-ground historic resources listed on the National Register of Historic Places within one kilometer of the Project: one village area at Lafayette, the Scrabbletown Historic and Archaeological District, Kingston Railroad Station, the Six Principle Baptist Church, and four historic houses. The closest of the above-ground historic resources is the Benoni Rose house North Kingstown, located approximately 0.10 kilometer (328 feet) from the Project ROW.

6.3.2 Archaeological Resources

The due diligence review identified 47 previously recorded archaeological sites within the study area: 35 Pre-Contact Native American sites and 19 Post-Contact period archaeological sites (seven sites contained both Pre- and Post-Contact components). POWER completed a Phase I Subsurface archaeological survey within the Project corridor in the fall of 2021 and has identified upwards of 21 locations that yielded cultural material. None of these locations have yet been formally assessed by RIHPHC and so no site designations have been applied. A large number of these locations are likely to be designated as isolated finds as they have yielded extremely low-density materials. POWER submitted an end-of-field memorandum to the RIHPHC in March 2022 with preliminary results and recommended Phase II Site Examination at 13 of these 21 locations. POWER also submitted a request to modify the existing permit to conduct these Phase II surveys. All of the locations at which POWER proposed Phase II testing yielded Pre-Contact Native American resources during the Phase I Survey. Two areas of dense Post-Contact materials were observed but impacts to those locations appear avoidable and so no additional testing was proposed. RIHPHC concurred with POWER’s recommendation and modified the existing permit; Phase II survey is currently underway.

6.4 Transportation

The transportation needs of the Project are served by a network of federal, state, and local roads and highways. The Project crosses 17 town roads, and two state routes (Table 6-1).

TABLE 6-1 ROAD CROSSINGS

ROAD NAME	TYPE
South Road	Town
Stony Lane	Town
Old Baptist Road	Town
Route 102	State
Lafayette Road	Town
Oak Hill Road	Town
Route 4	State
Indian Corner Road	Town
Sylvan Court	Town
Glen Hill Drive	Town
Slocum Road	Town
Yawgoo Valley Road	Town
Brown Place	Town
Wolf Rock Road	Town
Graces Lane	Town
Waites Corner Road	Town
Route 138*	State
Liberty Lane	Town
Great Neck Road	Town

*The Project crosses Route 138 twice.

6.5 Electric and Magnetic Fields

Electric fields are created by the voltage on electric conductors, whereas magnetic fields are created by the current on electric conductors. TNEC, like all North American electric utilities, supplies electricity at 60 Hertz (Hz). Therefore, the electric utility system and the equipment and conductors connected to it produce 60 Hz (power-frequency) electric and magnetic fields (EMF). These fields can be either measured using instruments or calculated using an electromagnetic model.

EMFs are present wherever electricity is used. This includes not only utility transmission lines, distribution lines, and substations, but also electrical wiring in homes, offices, and schools and electrical appliances and machinery.

Electric fields exist whenever voltages are present on transmission conductors; they are not dependent on the magnitude of current flow. The magnitude of the electric field is primarily a function of the configuration and operating voltage of the line and decreases with the distance from the source. The electric field may be shielded (i.e., the strength may be reduced) by any conducting surface, such as trees, fences, walls, buildings, and most types of structures. The strength of an electric field is measured in volts per meter (V/m) or kilovolts per meter (kV/m), where 1 kV/m = 1,000 V/m.

Magnetic fields are present whenever current flows in a conductor; they are not dependent on the voltage present on the conductor. The magnetic field strength is a function of both the current flow on the conductor and the configuration of the transmission line. The strength of magnetic fields also decreases with distance from the source. Since the flow of electricity or load on a transmission line varies with time of day based on the need for electric power in the region, the magnetic field associated with electric transmission lines also varies throughout the day and with seasonal changes in electric demand. Unlike electric fields, however, most common materials have little shielding effect on magnetic fields.

Magnetic fields are measured in units called Gauss. For the low levels normally encountered during daily activities, the field strength is expressed in a much smaller unit, the milliGauss (mG), which is one thousandth of a Gauss. Table 6-2 lists common household devices and typical magnetic field levels measured at the distances indicated from the source.

TABLE 6-2 COMMON SOURCES OF MAGNETIC FIELDS

SOURCES*	DISTANCE FROM SOURCE	
	6 inches (mG)	24 inches (mG)
Microwave Ovens	100-300	1-30
Dishwashers	10-100	2-7
Refrigerators	Ambient - 40	Ambient – 10
Fluorescent Lights	20-100	Ambient – 8
Copy Machines	4-200	1-13
Drills	100-200	3-6
Power Saws	50-1,000	1-40

Note: * Different makes and models of appliances, tools, or fixtures will produce different levels of magnetic fields. These are generally-accepted ranges.
Source: Public Service Commission of Wisconsin 2017.

Table 6-3 is provided to illustrate guidelines suggested by various national and international health organizations for exposure to both electric and magnetic fields.

TABLE 6-3 60 HZ EMF GUIDELINES ESTABLISHED BY HEALTH AND SAFETY ORGANIZATIONS

ORGANIZATION	MAGNETIC FIELD	ELECTRIC FIELD
American Conference of Governmental and Industrial Hygienists (ACGIH) (occupational)	10,000 mG[a] 1,000 mG[b]	25 kV/m[a] 1.0 kV/m[b]
International Commission on Non-Ionizing Radiation Protection (ICNIRP) (general public, continuous exposure)	2,000 mG	4.2 kV/m
Non-Ionizing Radiation Committee of the American Industrial Hygiene Assoc. endorsed (in 2003) ICNIRP's occupational EMF levels for workers	4,170 mG	8.3 kV/m
International Committee on Electromagnetic Safety	9,040 mG	5.0 kV/m
U.K., National Radiological Protection Board [now Health Protection Agency]	2,000 mG	4.2 kV/m
Australian Radiation Protection and Nuclear Safety Agency, Draft Standard, Dec. 2006[c]	3,000 mG	4.2 kV/m

Notes:
[a] ACGIH guidelines for the general worker.
[b] ACGIH guideline for workers with cardiac pacemakers.
[c] https://www.arpansa.gov.au/regulation-and-licensing/regulatory-publications/radiation-protection-series/codes-and-standards/rpss-1.

6.6 Noise

Ambient sound levels are influenced by diverse factors such as vehicular traffic, commercial and industrial activities, and outdoor activities typical of both rural and developed environments. Noise receptors include businesses, residences, schools and designated recreational areas.

7.0 IMPACT ANALYSIS

This section analyzes potential impacts of the Project on the existing natural and social environments within the Study Area and the Area of Potential Effect. As with any construction Project, potential adverse impacts can be associated with the construction, operation, or maintenance of an electric transmission line. These impacts have been minimized to the greatest extent feasible through thoughtful design, construction, operation, and maintenance practices.

Potential impacts to the natural and social environments associated with the Project can be categorized based on construction-related (temporary) impacts and operation-related (permanent) impacts. Examples of potential temporary construction-related impacts include wetlands impacts due to construction mats, traffic impacts, and construction noise associated with the operation of heavy equipment. The Project will be constructed in a manner that minimizes the potential for adverse environmental impacts. A monitoring program will be conducted by TNEC to verify that the Project is constructed in compliance with all relevant licenses and permits and all applicable federal, state, and local laws and regulations along with Best Management Practices (BMPs). Design and construction mitigation measures will be implemented so that construction-related environmental impacts are minimized.

Impacts to environmental resources and the social environment are expected to be minimal and are addressed in the following sections.

7.1 Summary of Environmental Effects and Mitigation

The Project will occur within an existing ROW and will use existing access roads, thereby largely avoiding and minimizing adverse environmental impacts. No long-term impacts to soil, bedrock, vegetation, surface water, groundwater, or air quality will occur. Any potential sedimentation impacts, and other short-term construction impacts to wetlands and surface waters will be mitigated using soil erosion and sediment control BMPs and construction mats to protect wetland soils, vegetation root stock, and streams. Minor, temporary disturbances of wildlife may result from equipment travel and construction crews working in the Project corridor. Any wildlife displacement will be negligible and temporary since no permanent alteration of the existing habitat is proposed. An environmental monitor will be part of the Project team to ensure compliance with all regulatory programs and permit conditions, and to oversee the proper installation and maintenance of the soil erosion and sediment control BMPs.

7.2 Summary of Social Effects and Mitigation

The Project involves existing transmission lines within existing ROWs. No long-term impacts to residential, commercial or industrial land uses will occur as a result of the Project. Any construction noise impacts are expected to be brief and localized. No visual impacts will result from the Project. Traffic control plans will be employed as necessary at the ROW access points off local and state roads, and for the installation of conductors across roadways. The Project will not adversely impact the social and economic conditions in the Project area. To the contrary, the Project will ensure the continued reliability of the electric system.

7.3 Soils

Construction activities which expose unprotected soils have the potential to increase natural soil erosion and sedimentation rates. Soil compaction and decreased infiltration rates may result from equipment operations. Standard construction techniques and BMPs will be employed to minimize any short-term impacts due to construction activity. These include the installation of straw bales, siltation fencing, compost filter sock, water bars, diversion channels, the reestablishment of vegetation and dust control measures as appropriate. These devices will be inspected by TNEC's environmental monitor frequently during construction and repaired or replaced if necessary. TNEC will develop and implement a Soil Erosion and Sediment Control Plan, which will detail BMPs and inspection protocols.

Soil erosion and sediment control measures will be selected to minimize the potential for soil erosion and sedimentation in areas where soils are impacted. TNEC will adhere to its ROW Access, Maintenance, and Construction Best Management Practices document (EG-303). The Company will pay particular attention to the highly erodible soils that are encountered within the Study Area. On all slopes greater than eight percent which are above sensitive areas, impacted soils will be stabilized with straw or chipped brush mulch to prevent the migration of sediments.

Temporary soil erosion controls may be placed in the following types of areas, in accordance with site-specific field determinations:

- Across or along portions of cleared ROW, at intervals dictated by slope, soil erodibility, amount of vegetative cover remaining, and down-slope environmental resources.
- Along access ways within the transmission line ROW.
- Across areas of impacted soils on slopes leading to streams and wetlands.
- Around portions of construction work sites that must unavoidably be located in wetlands.

The temporary soil erosion controls will be maintained, as necessary, throughout the period of active construction until restoration has been deemed successful, as determined by standard criteria for storm water pollution control/prevention and soil erosion control. In addition to silt fence or straw bales, temporary soil erosion controls may include the use of mulch, jute netting (or equivalent), soil erosion control blankets, reseeding to establish a temporary vegetative cover, temporary or permanent diversion berms (if warranted), and/or other equivalent structural or vegetative measures. After the completion of construction activities in any area, permanent stabilization measures (e.g., seeding and/or mulching) will be performed as necessary.

During the periodic post-construction inspections, TNEC will determine the appropriate time frame for removing these temporary soil erosion controls. This determination will be made based on the effectiveness of restoration measures, such as percent re-vegetative cover achieved, in accordance with applicable permit and certificate requirements.

7.4 Water Resources

7.4.1 Major Surface Waters

Potential impacts to surface waters if sediment transport is not controlled include temporary increased turbidity and 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. For this Project, however, any impact of the Project upon major surface waters will be minor and temporary.

Construction activities temporarily increase risks for soil erosion and sedimentation that may temporarily degrade existing water quality; however, appropriate BMPs will be implemented and maintained to effectively control sediment. Temporary construction mats will be used to access structure locations within or adjacent to surface water features as conditions warrant. Sedimentation and turbidity within these watercourses will be minimized through the implementation and installation of BMPs prior to construction activities.

7.4.2 Wetlands and Waterbodies

TNEC has planned and designed the Project to minimize potential impacts to wetlands. However, due to site constraints, construction logistics, and engineering constraints, minor impacts to wetlands are unavoidable. To minimize these potential impacts, wetland crossings were chosen to cross at previously impacted locations or at narrow points of the wetland. Construction mats will be used at all unavoidable wetland crossings. Where structures are located in or near wetland areas, erosion control measures in addition to construction mats, will be employed as needed to reduce sedimentation impacts on the wetland. Five of the existing structures in wetland will be replaced with structures on larger concrete foundations resulting in approximately 904 square feet of total permanent impact to wetland.

The Project will require installation of temporary construction mat spans over two intermittent and four perennial streams. All stream crossings will be bridged with construction mats installed in accordance with EG-303NE.

Table 7-1 summarizes the wetlands impacts based on preliminary design data.

TABLE 7-1 SUMMARY OF POTENTIAL IMPACTS ON WETLANDS

WETLAND ID (TYPE)[1]	TEMPORARY IMPACT (SQUARE FEET)	PERMANENT IMPACT (SQUARE FEET)
L57 (PSS)	52,058	456 (3 structures with concrete foundations)
L120 (PSS)	336	-
L122 (PEM/PSS)	98,806	224 (1 structure with concrete foundation)
L130 (PSS)	24,506	-
L136 (PSS)	9,307	-
L138 (PSS)	3,521	-
L154 (PEM/PSS)	5,545	-
L160 (PEM/PSS)	174	-
L163 (PSS)	877	-
L166 (PSS)	1,082	-
L171 (PEM/PSS)	115,451	-
L7N (PSS)	19,093	-
L176 (PSS)	813	-
L181 (PSS)	2,641	-
L193 (PSS)	1,439	-
L203 (PSS/PEM)	5,123	-
L211 (PSS)	84	-

WETLAND ID (TYPE)[1]	TEMPORARY IMPACT (SQUARE FEET)	PERMANENT IMPACT (SQUARE FEET)
L223 (PEM/PSS)	14,558	-
L243 (PSS)	7,385	-
L244 (PSS/PEM)	1,864	-
L255 (PSS)	33,735	224 (1 structure with two 12-foot caissons)
L257 (PSS)	8,886	-
L259 (PSS/PEM)	9,296	-
AR219 (PFO)[2]	87	-
AR219A (PFO)[2]	128	-

7.4.3 Groundwater Resources

The only potential impact to groundwater resources would result from inadvertent spillage or release of petroleum, hydraulic fluid, or other products. Potential impacts to groundwater resources within the Project ROW as a result of construction activity on the transmission line facilities will be negligible. Equipment used for construction will be properly inspected, maintained and operated to reduce the chances of spill occurrences of petroleum products. Within primary groundwater recharge areas, special safeguards will be implemented to assure the protection of groundwater resources. Construction equipment will be required to carry spill containment and prevention devices (i.e., absorbent pads, clean up rags, five-gallon containers, and absorbent material) and fueling of equipment will occur in upland areas where practicable. 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 must be utilized and TNEC's Environmental representatives must be consulted prior to initiating the refueling. Following construction, the normal operation and maintenance of the transmission line facilities will have no impact on groundwater resources.

7.5 Vegetation

Along most of the ROW and at structure sites, vegetation mowing will be required prior to construction of the Project. These activities will be limited to those areas necessary to provide access to existing and proposed Project structure locations, to facilitate safe equipment passage, to provide safe work sites for personnel within the ROW, and to maintain safe clearances between vegetation and transmission line conductors for reliable operation of the transmission facilities. Pruning and individual tree removal may be required in certain locations along the ROW to ensure adequate safety and operational clearances for the new transmission line. During and following construction, danger trees that have been determined to present a potential hazard to the integrity of the line will be marked and pruned or removed. No long-term change in the vegetation on the ROW will be required for the Project since all the work will be within existing and maintained transmission line ROW.

After completion of work on the transmission facilities, TNEC will stabilize, seed and mulch impacted areas with appropriate grass-type mixes and straw mulch. Vegetative species compatible with the use of the ROW for transmission line purposes are expected to regenerate naturally, over time. TNEC will promote the re-growth of desirable species by implementing vegetative maintenance practices to control tall-growing trees and undesirable invasive species that conflict with line clearances, thereby enabling native plants to dominate.

7.6 Wildlife

Minor, temporary disturbances of wildlife may result from equipment travel and construction crews working in the Project corridor. During construction, displacement of wildlife may occur 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 temporarily 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 the transmission line construction. The species impacted during the refurbishment 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. Only minor tree cutting or trimming is required for the Project; therefore, no impacts to northern long-eared bats are anticipated. TNEC will take steps necessary to minimize disturbance to preferred pollinator habitat throughout the construction period, such as selecting non-milkweed dominated areas for on-site foundation spoils management. In-situ restoration of disturbed soils will allow natural revegetation, including recolonization of milkweed and other important nectar sources used by monarchs. No long-term impacts to general wildlife are expected to result from the Project.

7.7 Air Quality

There are two potential sources of air quality impacts associated with the Project – dust and vehicle emissions – neither of which are expected to be significant. Due to the transitory nature of the construction, air quality in the Project ROW will not be significantly affected by construction along the ROW. Emissions produced by the operation of construction machinery (nitrogen oxides, sulfur oxides, carbon monoxide, and particulate matter) are short-term and not generally considered significant.

7.8 Social and Economic

The Project will not adversely impact the overall social and economic condition of the Project area. The Project does not require, nor will it lead to long-term residential or business disruption. Temporary construction impacts, primarily related to construction traffic and equipment operation, are expected to be minor. As described in Section 6.0, the proposed work will be located entirely within an existing 115 kV transmission line ROW. By providing continued reliable supply of electricity, the Project will support economic growth and development.

7.8.1 Land Use

Since the Project involves refurbishment of existing facilities within an existing cleared ROW, there will be no permanent, long-term impacts to the existing residential, commercial or recreational land uses in the Project area.

The Project will continue to be compatible with the various land uses along the route. Because the Project occurs within an area dedicated for use for electrical facilities, it will not displace any existing land uses, nor will it affect any future development proposals. Short-term land use impacts may occur during the construction phase of the Project. TNEC will provide notification of the intended construction plan and schedule to affected landowners and abutters so that the effect of any temporary disruptions may be minimized.

7.8.2 Consistency with Local Planning

The Towns of East Greenwich, North Kingstown, Exeter, and South Kingstown have Comprehensive Plans which describe the local direction regarding future development and growth in each community. Each municipality's Comprehensive Plan was evaluated with regard to expressed town-wide goals. Because the Project consists of refurbishment and upgrades that will occur entirely within an existing cleared transmission line ROW, it will not alter existing land use patterns and will not adversely impact future planned development. The Project will provide a continued reliable supply of electricity for the growth and development envisioned by the Comprehensive Plans of the host communities.

7.9 Visual Resources

The Project involves refurbishment and upgrades to existing electric transmission facilities including structure replacements, replacement of existing shield wire, and reconductoring. Structures will generally be replaced with structures of the same type (i.e., wood H-frame structures will be replaced with steel H-frame structures) and along the same alignment in roughly the same location as the existing structure. Structure heights along the line will change as a result of the replacement structures; however, the majority of the proposed L190 structures will be shorter in height than the existing and adjacent G185S transmission line structure. Overall, the potential for visual impact has been minimized through use of an existing and cleared transmission line ROW and because the Project will not materially change the existing appearance of the ROW, no significant impacts to visual resources are anticipated as a result of the Project.

7.10 Cultural and Historic Resources

No architectural above-ground resources were identified within the Project ROW. Accordingly, the Project will not affect architectural above-ground resources. Historical period stone walls have been observed at several locations, have been recorded with submeter accuracy, and will be included in an avoidance and protection plan in order to prevent inadvertent impacts during Project construction.

POWER began Phase I archaeological survey in June 2020 for the Project and have to date identified at least 21 archaeological resources, though none of the resources have been reviewed by RIHPHC and thus have not received formal site designations. Many of the resources are of extremely low density and likely represent isolated finds. Laboratory processing and analysis is pending and POWER plans to submit an end-of-field memorandum to the RIHPHC in February 2022, which will present the results and recommendations of the Phase I survey.

7.11 Noise

Noise impacts are expected to be negligible. Temporary construction noise may be generated by the Project that will occur during normal daytime working hours. Proper mufflers will be required to control noise levels generated by construction equipment. 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. 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 on Sundays and holidays. Prior to and during construction, TNEC will notify landowners, abutting property owners, municipal officials, and local police and fire chiefs of the details of planned construction including the normal work hours and any extended work hours.

7.12 Transportation

The construction related traffic increase will be small relative to total traffic volume on public roads in the area. In addition, it will be intermittent and temporary, and construction related traffic will cease once the Project is completed. The addition of this traffic for the limited periods of time is not expected to result in any additional congestion or change in operating conditions along any of the roadways along the ROW. Where access to the ROW intersects a public way, the construction team will follow a pre-approved work zone traffic control plan. Although traffic entering and exiting the ROW at these locations is expected to be small, vehicles entering and exiting the site will do so safely and with minimal disruption to traffic along the public way. Following construction, traffic activity will be minimal and will occur only when the ROW or transmission lines must be maintained. As a result, no long-term impacts to traffic flow or roadways are expected.

TNEC will coordinate construction in the vicinity of the Amtrak Northeast Corridor with Amtrak operation and safety personnel.

7.13 Safety and Public Health

Following construction of the facilities, all transmission line structures will be clearly marked with warning signs to alert the public to potential hazards if climbed. Trespassing on the ROW will be discouraged by using existing gates and/or barriers at entrances from public roads. Because the proposed facilities will be designed, built and maintained in accordance with the standards and codes as described in Section 3.4.5, the public health and safety will be protected.

7.13.1 Electric and Magnetic Fields

The Project is upgrading a 115 kV line section of the L190 that supports an interface between two large areas in ISO-NE. Equipment outages (both Generation and Transmission) as well as the Economic Generation Market regularly impact the amount and directions of transfers on this interface. The fluctuation and large variance of the power flows along this interface, and particularly this transmission corridor, inhibits predicting the transfers along this portion of the L190 Line with any degree of certainty.

The conservative approach for the EMF analysis of the Project is to assume maximum current flow across this line section, as allowed by the thermal ratings of the conductor (Pre-Project versus Post-Project). This assumption will provide the worst-case scenario for the EMF analysis as all other levels of current will result in lower EMF values. The EMF levels were analyzed at a minimum conductor height, at a location of one meter above the ground and reported as the maximum resultant field. Tables 7-2 and 7-3 provide the maximum values at the edge of the ROW for electric and magnetic fields, respectively. The EMF modeling cross-sections are shown in Figure 7-1 (Siting Report - Page 43).

A discussion of the status of the health research relevant to exposure to EMF was prepared by Exponent, Inc. and is attached as Appendix A.

TABLE 7-2 MAXIMUM ELECTRIC FIELD STRENGTHS PRE AND POST PROJECT CONDITIONS

LINE SECTIONS	CONDITION	CALCULATED ELECTRIC FIELD (kV/m)	
		-ROW EDGE*	+ROW EDGE**
West Kingston Substation to Tower Hill Tap (XS-1)	Pre- Project	0.2	0.4
	Post-Project	0.2	0.6
Tower Hill Tap (Line L190) (XS-2)	Pre-Project	0.1	0.1
	Post-Project	0.1	0.1
Tower Hill Tap to Wickford Substation (XS-3)	Pre-Project	0.1	0.8
	Post-Project	0.1	0.7
Wickford Substation to North End of the Project Corridor (XS-4)	Pre-Project	0.1	0.7
	Post-Project	0.1	0.7

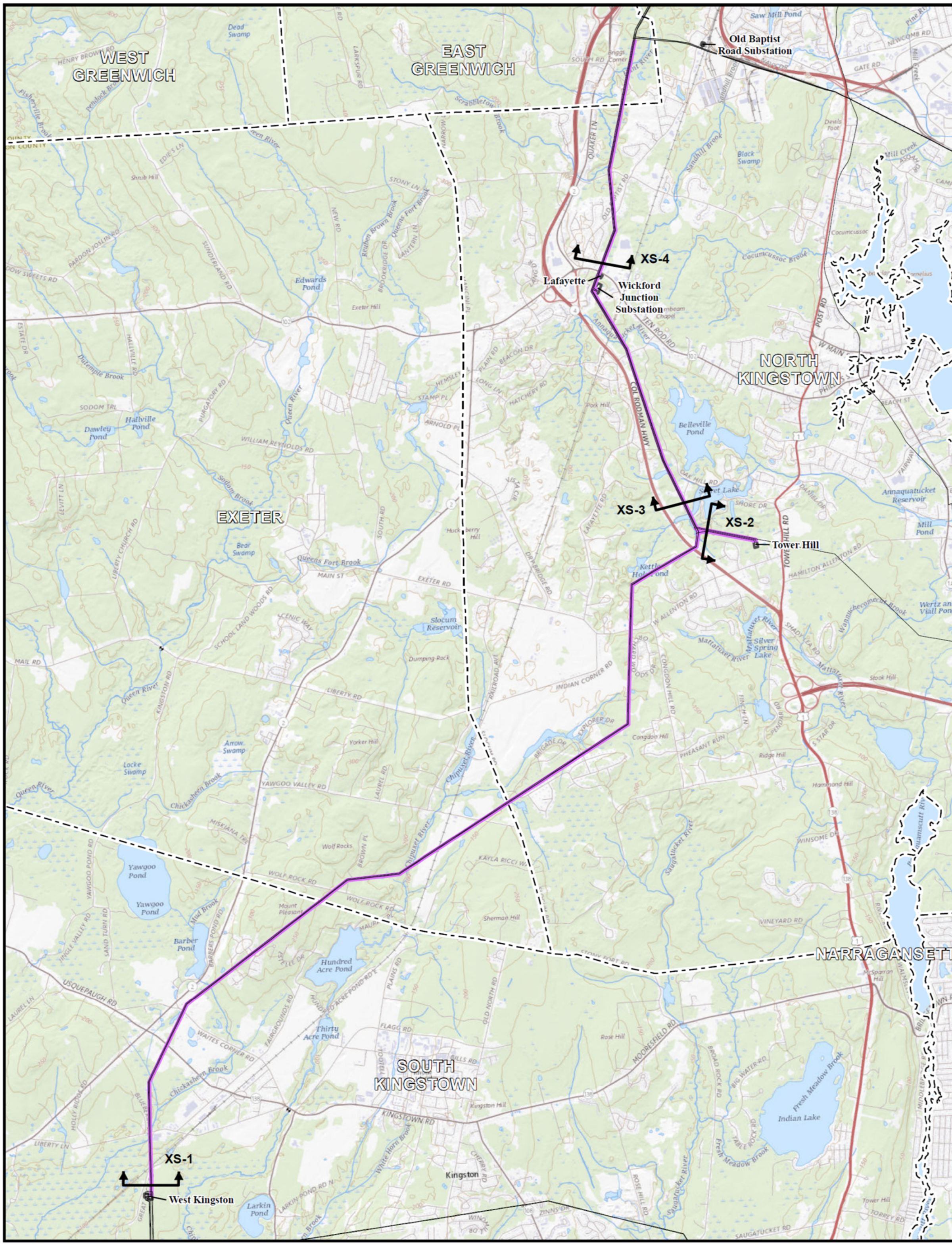
* West of Line G185S or South of Line L190
** East or North of Line L190

TABLE 7-3 MAXIMUM MAGNETIC FIELD STRENGTHS PRE AND POST PROJECT CONDITIONS, MAXIMUM CONDUCTOR RATING LOADING CONDITIONS

LINE SECTIONS	CONDITION	CALCULATED MAGNETIC FIELD (milliGauss)	
		-ROW EDGE*	+ROW EDGE**
West Kingston Substation to Tower Hill Tap (XS-1)	Pre- Project	69.2	104.7
	Post-Project	67.4	100.6
Tower Hill Tap (Line L190) (XS-2)	Pre-Project	15.8	19.0
	Post-Project	18.4	23.6
Tower Hill Tap to Wickford Substation (XS-3)	Pre-Project	39.2	119.1
	Post-Project	39.2	145.1
Wickford Substation to North End of the Project Corridor (XS-4)	Pre-Project	48.4	139.1
	Post-Project	48.0	142.4

* West of Line G185S or South of Line L190
** East or North of Line L190

FIGURE 7-1 EMF MODELING CROSS-SECTIONS



8.0 MITIGATION MEASURES

Mitigation measures for this Project will be used to reduce the impacts of the work on the natural and social environment. The Project consists of the refurbishment and upgrades of an existing transmission line within an existing ROW. As described in Section 7.0, there are no long-term impacts to mitigate as a result of this Project. Therefore, mitigation efforts are focused on the short-term temporary construction phase of the Project.

8.1 Construction Phase

The construction phase of the Project will include the replacement of poles and conductors on the L190 Line. This work will require only minor disturbances to the surrounding natural environment.

8.1.1 Mitigation of Natural Resource Impacts

TNEC will implement several measures during construction which will minimize impacts to the environment. These include the use of existing access roads and structure pads where possible, installation of erosion and sedimentation controls, supervision and inspection of construction activities within resource areas by an environmental monitor and minimization of disturbed areas. Stabilization of soil will occur when areas are disturbed. The following section details various mitigation measures which will be implemented to minimize construction related impacts.

When the existing transmission lines were originally constructed, and as the lines have been maintained over the years, access roads were established within most portions of the ROW. During construction of the Project, vehicles will utilize these existing access roads where practical to minimize disturbance within the ROW. Access through wetlands will be provided by using construction mats from the existing maintained portion of the ROW. Excavated soils will be stockpiled and spread in approved upland areas outside all biological wetland areas in such a manner that general drainage patterns will not be affected. Construction access will be limited to the existing structure locations, work pads, and proposed access routes, and will be lined with erosion and sedimentation control BMPs where needed. Each area will be restored following erection of the structures and installation of the new wires and conductors.

Vegetation management will be necessary along access routes and work pad locations. These activities may require minor vegetation maintenance including brush removal up to a width of 20 feet centered on the access road and pruning limbs to a height of 20 feet to maintain clearances and allow safe passage of construction equipment and vehicles. To maintain a visual buffer into the ROW, existing vegetation will be retained at all road crossings and areas subject to public view, where possible. TNEC will adhere to a site-specific invasive species control plan which will require that all equipment and temporary matting brought on site will be certified as clean. Temporary matting will be removed upon completion of the Project and the area will be restored back to pre-existing conditions and contours to the extent practicable.

8.1.2 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.

As part of Rhode Island Pollution Discharge Elimination System permitting, a site-specific Soil Erosion and Sediment Control Plan will be developed and implemented during the construction phase of the Project. The Soil Erosion and Sediment Control Plan will be maintained on-site and updated throughout the Project to reflect environmental inspection reporting and BMPs. Construction crews will be responsible for conducting daily inspections and identifying erosion controls that must be maintained or replaced as necessary.

8.1.3 Supervision and Monitoring

Throughout the entire construction process, TNEC will retain the services of an environmental monitor. The primary responsibility of the monitor will be to oversee construction activities, including the installation and maintenance of erosion and sedimentation controls, on a routine basis to ensure compliance with all federal and state permit requirements, TNEC company policies, and other commitments. The environmental monitor will be a trained environmental scientist responsible for supervising construction activities relative to environmental issues. The environmental monitor will be experienced in the erosion control techniques described in this report and will have an understanding of 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 to retaining the services of an environmental monitor, TNEC will require the construction team 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 of wetland access and appropriate work methods. Additionally, all 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 construction team's awareness of these issues.

8.1.4 Air Quality

During earth disturbing activities, the construction team will deploy dust mitigation measures as described in National Grid's EG-303. Exposed soils will be wetted and stabilized as necessary to suppress dust generation, and crushed stone aprons will be used at all access road entrances to public roadways. Consequently, fugitive dust emissions are anticipated to be low.

TNEC requires the use of ultra-low sulfur diesel fuel exclusively in the construction team's diesel-powered construction equipment. Vehicle idling is to be minimized during the construction phase of the Project, in compliance with the Rhode Island Diesel Engine Anti-Idling Program, Air Pollution Control Regulation No. 45, authorized pursuant to Rhode Island General Laws § 31-16.1 and § 23-23-29. Vehicle idling for diesel and non-diesel-powered vehicles is limited to five minutes except for powering auxiliary equipment, for heating/defrosting purposes in cold weather, and for cooling purposes in hot weather. The construction team is responsible for complying with the state regulatory requirements along with the National Grid Environmental Guidance (EG-802RI) Vehicle Idling – Rhode Island.

8.1.5 Mitigation of Social Resource Impacts

TNEC will minimize social resource impacts during construction by incorporating several standard mitigation measures. By use of an established transmission line ROW rather than creating a new ROW, the potential for disruption due to construction activities will be limited to an area already dedicated to transmission line uses. Construction generated noise will be limited by the use of mufflers on all construction equipment and 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. TNEC will minimize the potential for disturbance from the construction by notifying abutters of planned construction activities before and during construction of the line. Some short-term impacts are unavoidable, even though they have been minimized. By carrying out the reconductoring of the transmission lines in a timely fashion, TNEC will keep these impacts to a minimum. TNEC's contractors will prepare traffic management plans, as necessary, which will minimize impacts associated with increased construction traffic on local roadways.

Regarding historic and archaeological resources, POWER has prepared an avoidance and protection plan outlining protective measures to be carried out during construction at the locations of any observed cultural resources, including archaeological sites and historic stone features. TNEC will comply with the protective measures identified in the plan including contractor training, on-site monitoring by a qualified professional archaeologist, installation of avoidance fencing and signage, and use of compression control measures. Protective measures will be removed during final restoration.

8.2 Post-Construction Phase

Following the completion of construction, TNEC uses standard mitigation measures on all transmission line construction projects to minimize the impacts of projects on 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. Other measures are used on a site-specific basis. TNEC will implement the following standard and site-specific mitigation measures for the Project.

8.2.1 Restoration of Natural Resource Impacts

Restoration efforts, including final grading and installation of permanent erosion control devices, and seeding of disturbed areas, will be completed following construction. Construction debris will be removed from the Project site and disposed of at an appropriate landfill. Pre-existing drainage patterns, ditches, roads, fences, and stone walls will be restored to their former condition, where appropriate. Permanent slope breakers and erosion control devices will be installed in areas where the disturbed soil has the potential to impact wetland resource areas.

Vegetation maintenance of the ROW will be accomplished with methods identical to those currently used in maintaining the existing ROW. TNEC's ROW vegetation maintenance practices encourage the growth of low-growing shrubs and other vegetation which provides a degree of natural vegetation control. In addition to reducing the need to remove tall growing tree species from the ROW, the vegetation maintained on the ROW inhibits erosion.

8.2.2 Mitigation of Social Resource Impacts

Upon completion of the Project, electric and magnetic field levels will not significantly change at the edges of the ROW from the existing condition. Because all EMFs will be well below established exposure guidelines, no mitigation is proposed. Where possible, TNEC will limit access to the ROW by installing permanent gates and barriers where not already installed along access roads entering the ROW from public ways.

9.0 BIBLIOGRAPHY

DeGraaf, R.M. and M. Yamasaki. 2001. New England Wildlife: Habitat, Natural History, and Distribution. 2nd Edition. Hanover, NH: University Press of New England. 482 p.

Public Service Commission of Wisconsin. 2017. EMF Electric & Magnetic Fields. Retrieved February 3, 2022 from https://psc.wi.gov/Documents/Brochures/EMF.pdf.

Rhode Island Department of Environmental Management (RIDEM). 2018. Bats of Rhode Island. Retrieved December 3, 2021 from http://www.dem.ri.gov/programs/bnatres/fishwild/pdf/bat.pdf.

_____. 2019. Groundwater Quality Rules (250-RICR-150-05-3). January 9, 2019. Retrieved November 29, 2021 from https://rules.sos.ri.gov/regulations/part/250-150-05-3.

_____. 2021a. Vernal Pools. Retrieved December 2, 2021 from http://www.dem.ri.gov/programs/water/wetlands/vernal-pools.php .

_____. 2021b. Designated Trout Waters. Retrieved November 27, 2021 from http://www.dem.ri.gov/programs/fish-wildlife/freshwater-fisheries/troutwaters.php

Rhode Island Geographic Information System (RIGIS). 1993. Wetlands 93; wetlands93.zip. Rhode Island Geographic Information System Data Distribution System, URL: https://www.rigis.org/datasets/ed960ffd342d42e9b3167d9c9116e99c_0/explore?location=41.582270%2C-71.513943%2C9.43 (last date accessed 21 December 2021).

_____. 2007. Watershed Boundary Dataset: HUC 12. Available at: https://www.rigis.org/datasets/watershed-boundary-dataset-huc-12. Accessed March 16, 2021.

_____. 2021a. Land Use and Land Cover (2011). Retrieved November 23, 2021 from https://www.rigis.org/datasets/2ca25218976b4fe690427e5c0e17e54d/explore?location=41.585983%2C-71.505878%2C9.44.

_____. 2021b. Scenic Landscape Inventory. Retrieved November 23, 2021 from https://www.arcgis.com/home/item.html?id=47335178326a4ca0b5a23185731c24d7.

State of Rhode Island. 2021. 2018-2020 Impaired Waters Report. Retrieved November 29, 2021 from http://dem.ri.gov/programs/benviron/water/quality/pdf/iwr1820.pdf.

_____. 2022. State of Rhode Island Water Quality Regulations 250-RICR-150-05-01. Available at https://rules.sos.ri.gov/regulations/part/250-150-05-1, accessed on January 7, 2022.

United States Department of Agriculture, Forest Service. 2002. The Forests of Rhode Island. Retrieved November 29, 2021 from http://www.dem.ri.gov/programs/bnatres/forest/pdf/riforest.pdf.

United State Fish and Wildlife Service. 2021. Monarch Butterfly (Danaus plexippus). Retrieved September 30, 2021 from https://ecos.fws.gov/ecp/species/9743#lifeHistory.

_____. 2020. Monarch Butterfly – Questions and Answers: Designation of the Monarch as a Candidate Species -ESA Section 7. December 16, 2020. Retrieved September 30, 2021 from https://www.fws.gov/savethemonarch/FAQ-Section7.html.

APPENDIX A CURRENT STATUS OF RESEARCH ON EXTREMELY LOW FREQUENCY ELECTRIC AND MAGNETIC FIELDS AND HEALTH, 2018 THROUGH 2021 (JUNE 3, 2022)

Health Sciences Practice

Exponent®

Current Status of Research on Extremely Low Frequency Electric and Magnetic Fields and Health, 2018 through 2021

Current Status of Research on Extremely Low Frequency Electric and Magnetic Fields and Health, 2018 through 2021

Prepared for:

The Narragansett Electric Company

Prepared by:

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

June 3, 2022

Table of Contents

List of Figures

List of Tables

Acronyms and Abbreviations

μT	Microtesla
AC	Alternating current
ADHD	Attention-deficit/hyperactivity disorder
ALL	Acute lymphoblastic leukemia
ALS	Amyotrophic lateral sclerosis
AMI	Acute myocardial infarction
B-ALL	B-lineage acute lymphoblastic leukemia
CgA	Chromogranin
CHD	Congenital heart disease
CI	Confidence interval
CNS	Central nervous system
DMBA	7,12-dimethylbenz[a]anthracene
DNA	Deoxyribonucleic acid
DOX	Doxorubicin
EFSB	Energy Facilities Siting Board
EHC	Environmental Health Criteria
ELF	Extremely low frequency
EMF	Electric and magnetic fields
Exponent	Exponent, Inc.
FITR	Fourier transform infrared
G	Gauss
GSH	Glutathione
Hz	Hertz
IARC	International Agency for Research on Cancer
ICES	International Committee on Electromagnetic Safety
ICNIRP	International Commission on Non-Ionizing Radiation Protection
JEM	Job exposure matrix
kV	Kilovolt
kV/m	Kilovolts per meter
MDA	Malondialdehyde

mG	Milligauss
mg	Milligram
ml	milliliter
MND	Motor neuron disease
NTP	National Toxicology Program
OR	Odds ratio
RR	Relative risk
SCENIHR	Scientific Committee on Emerging and Newly Identified Health Risks
SOD	Superoxide dismutase
TBARS	Thiobarbituric acid reactive substances
TUNEL	Terminal deoxynucleotidyl transferase (TdT) dUTP Nick-End Labeling
TWA	Time weighted average
V/m	Volts per meter
WHO	World Health Organization

Limitations

At the request of the Narragansett Electric Company, Exponent, Inc., 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.

Executive Summary

This report was prepared to address the topic of extremely low frequency (ELF) electric and magnetic fields (EMF) and health at the request of the Narragansett Electric Company.

Section 1 of this report discusses the nature, sources, and typical environmental exposure levels of ELF EMF. 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 a fundamental part of technologically-advanced societies. Sources of man-made ELF EMF include appliances, wiring, and motors, as well as distribution and transmission lines.

Research on ELF EMF and health began with the goal of finding therapeutic applications 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 50 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. This research considered many aspects of physiology and diseases, including cancers in children and adults, neurodegenerative diseases, reproductive effects, and cardiovascular disease.

Scientists use systematic methods to conduct and evaluate scientific research and assess the potential impact of a specific agent on human health; these methods are discussed in Section 2. 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 and government organizations. Policy makers and the public should look to the conclusions of these reviews, since they are conducted using established scientific standards by scientists representing the various disciplines required to assess the topic at hand. In a health risk assessment of any exposure, it is essential that scientists evaluate the type and strength of relevant research studies available. Human health studies vary in methodological rigor; therefore they vary in their capacity to extrapolate findings to the population at large. Furthermore, three types of studies—

epidemiology, *in vivo*, and *in vitro*—relevant to the particular research topic must be evaluated concurrently to understand possible health risks.

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, which accounted for the strength and quality of the individual research studies they evaluated. Section 3 provides a summary of the WHO's conclusions with regard to the major outcomes they evaluated. 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).

Section 4 of this report provides a systematic literature review and a critical evaluation of relevant epidemiologic and *in vivo* studies published from December 2018 through December 2021. These recent studies did not provide sufficient evidence to alter the basic conclusion of the WHO—the research does not confirm that electric fields or magnetic fields are a cause of cancer or any other disease at the levels we encounter in our everyday environment. The current guidance from the WHO on its website states that "… the WHO concluded that current evidence does not confirm the existence of any health consequences from exposure to low level electromagnetic fields."[1]

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, which are listed in Section 5. The conclusions of these documents are generally consistent with the WHO review published in 2007 and with the scientific consensus articulated in Section 4.

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 exposure limits established by the International Commission on Non-Ionizing Radiation Protection or the International Committee for Electromagnetic Safety for the prevention of acute health effects at high exposure levels, which are summarized in Section 6. In light of their assessments of the scientific research, some scientific organizations recommend low-cost interventions to reduce ELF EMF exposure. While the large body of existing research does not confirm any likely harm associated with ELF EMF exposure at low levels, research on this topic will continue to reduce remaining uncertainty.

Section 7 of this report provides an overall summary of the epidemiologic and *in vivo* research published since the WHO 2007 report was released. When these recent studies are considered in the context of previous research, they do not provide evidence to alter the conclusion that ELF EMF exposure at the levels we encounter in our everyday environment is not a cause of cancer or any other disease process.

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 is the controlling document.

---

[1] https://www.who.int/news-room/questions-and-answers/item/radiation-electromagnetic-fields. Accessed March 24, 2022.

1 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 review 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, which accounted for the strength and quality of the individual research studies they evaluated.

The Narragansett Electric Company, formerly a subsidiary of National Grid, requested that Exponent, Inc. (Exponent) provide an easily-referenced document that updates a report previously prepared for the Rhode Island Energy Facility Siting Board as part of its Applications for the 2019 Rhode Island Transmission Projects (Exponent, 2019). Exponent (2019) systematically evaluated peer-reviewed research and reviews by scientific panels published through December 2018. This current report updates this earlier report with a systematic evaluation of peer-reviewed research and reviews by scientific panels published from December 2018 through December 2021, and describes if and how these recent results affect conclusions reached by the WHO in 2007.

Nature of extremely low frequency electric and magnetic fields

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 (*see* 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 voltage 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); 1 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 of gauss (G) or milligauss (mG), where 1 G=1,000 mG.[2] The strength of the magnetic field at any point depends on characteristics of the source. In the case of power lines, magnetic-field strength is dependent on the arrangement of conductors, the amount of current flow, and distance from the conductors.

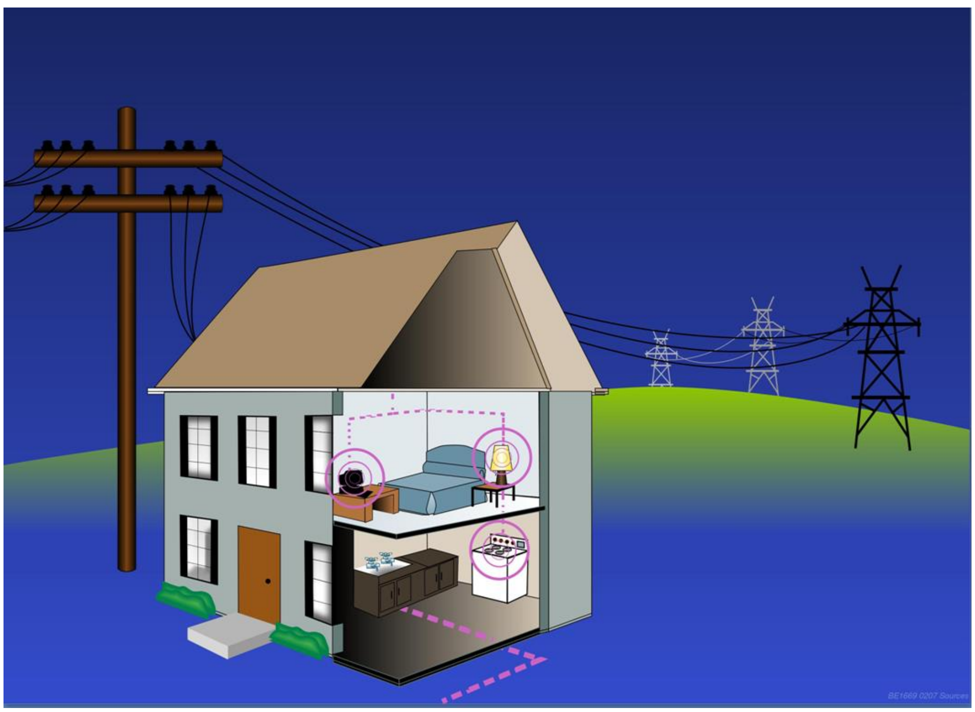


Figure 1. Numerous sources of ELF EMF in our homes (appliances, wiring, currents running on water pipes, and nearby distribution and transmission lines).

[2] 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).

Sources and exposure

The intensity of both electric fields and magnetic fields diminishes with increasing distance from the source. Electric fields 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 and everyday life (e.g., in transportation systems and in homes and businesses), people living in modern communities 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 V/m to 20 V/m, while appliances produce levels up to several tens of V/m (WHO, 2007).

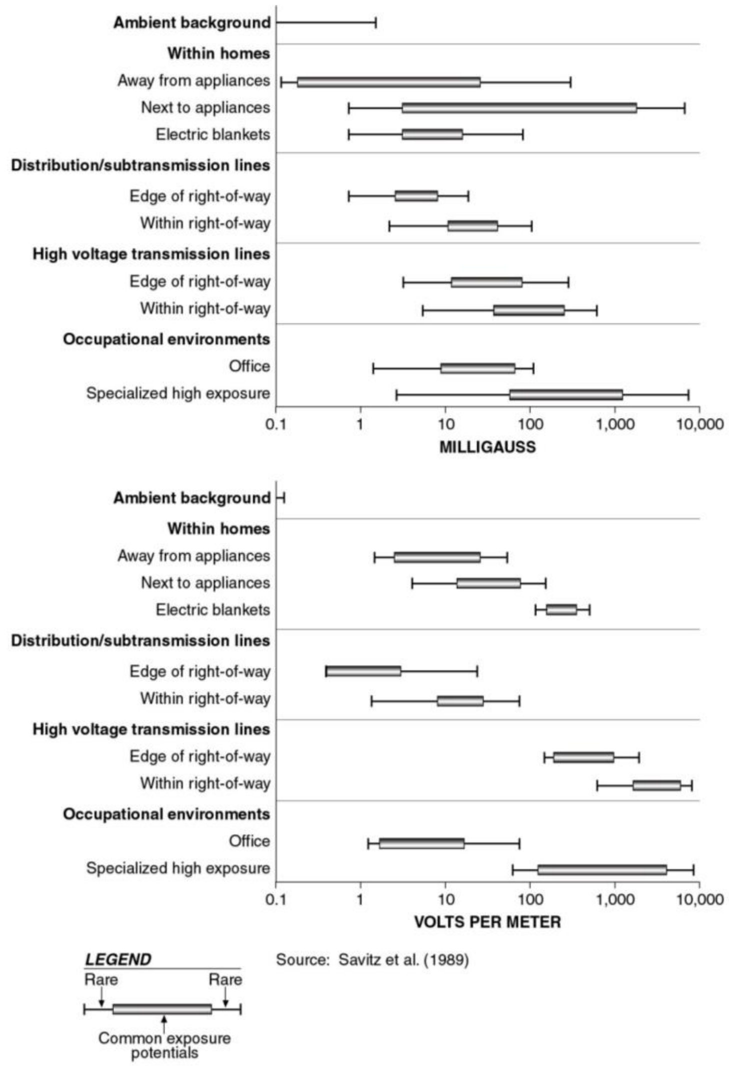


Figure 2. Electric- and magnetic-field strengths in the environment.

Experiments have yet to show which aspect of ELF EMF exposure, if any, may be relevant to biological systems. The current standard to evaluate 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).[3]
  - 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 (electric oven); and 0.7 mG (refrigerator).
  - Several 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 metal piping, and homes close to three-phase electric power distribution and transmission lines tend 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, telecommunications workers) have higher exposures due to work near equipment with high magnetic-field levels (NIEHS, 2002).

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

- *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, as illustrated in Figure 2 above, and as discussed in a National Institute of Environmental Health Sciences booklet on EMF (NIEHS, 2002).

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 (ICNIRP, 2010). Also, strong electric fields can induce charges on the surface of the body that can lead to small shocks (i.e., micro shocks). These acute, shock-like effects cause no long-term damage or health consequences. Limits for the general public and workplace have been set to prevent these effects, but there are no real-life situations where these levels are exceeded on a regular basis. Standards and guidelines are discussed in more detail in Section 6.

2 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 to ensure that studies with a given result are not selectively chosen from available studies 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 present 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 typically are conducted within the larger framework of health risk assessments or evaluations of particular exposures or exposure circumstances that qualitatively and quantitatively define health risks. Several agencies have described weight-of-evidence and health risk assessment methods, 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; the U.S. Environmental Protection Agency (US EPA), which sets guidance for public exposures; the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) for the European Union; and the U.S. National Toxicology Program (NTP) (USEPA, 1993, 1996; WHO, 1994; SCENIHR, 2012; NTP, 2015). Two steps precede a weight-of-evidence evaluation: 1) a systematic review to identify the relevant literature, and 2) 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 ELF EMF in a weight-of-evidence review, including exposure considerations, study design, and 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

Methods to evaluate exposure range widely in studies of ELF EMF include:

- Classifying residences based on the relative capacity of nearby power lines to produce magnetic fields (i.e., wire code categories).
- Assessing exposure based on occupational titles.
- Calculating magnetic-field levels based on job histories (i.e., a job-exposure matrix [JEM]).
- Determining residential distance from nearby power lines.
- Taking spot measurements of magnetic-field levels inside or outside residences.
- Taking 24-hour and 48-hour measurements of magnetic fields in a particular location in a house (e.g., a child’s bedroom).
- Calculating magnetic-field levels based on the characteristics of nearby power installations.
- Taking personal measurements of magnetic fields for a 24-hour or 48-hour period using a dosimeter.

Each of these methods has strengths and limitations (Kheifets and Oksuzyan, 2008). Magnetic-field exposure is ubiquitous, but it varies for each individual over a lifetime because the locations one frequents change and the ELF EMF sources in those locations also change. This lack of consistency makes 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 account for 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 (e.g., using a JEM). 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, any differences in the job tasks performed by each machine operator, or any potential variability in magnetic fields produced by the machines over time (Kheifets et al., 2009;[4] Gobba et al., 2011). In addition, such occupational measurements do not account for the worker's residential magnetic-field exposures.

Types of health research studies

Research studies can be broadly classified into three groups: 1) epidemiologic observations of people, 2) experimental laboratory studies of humans and animals (*in vivo*), and 3) experimental laboratory studies of cells and tissues (*in vitro*). Epidemiologic studies investigate how disease is distributed in populations and what factors influence or determine this disease distribution (Gordis, 2000), and attempt to identify potential causes for disease while observing people as they go about their 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 epidemiologic 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

[4] 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.

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 assess cause-and-effect relationships. An example of a human experimental studies relevant to this area of research would be ones 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* studies of animals and *in vitro* experimental studies also are 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 that relate to the same exposure in whole body humans and animals. The responses of cells and tissues outside the body, however, 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 to assess whether a particular agent could cause adverse health effects using both epidemiologic and experimental studies, and both approaches have been used to evaluate whether exposure to ELF EMF has any adverse effects on human health. Epidemiologic studies are valuable because they are conducted in human populations, but they are limited by their non-experimental design and typical retrospective nature. In epidemiologic studies of magnetic fields, for example, researchers cannot control the amount of individual exposure, how exposure occurs over time, the contribution of different sources, or individual behavior other than exposure that may affect disease risk, such as diet. In valid risk assessments of ELF EMF, epidemiologic studies are considered alongside experimental studies of laboratory animals, while studies of isolated cells and tissues are generally considered supplementary.

Estimating risk

Epidemiologists measure the statistical association between exposures and disease in order to estimate risk. This brief summary is included to provide a foundation for understanding and interpreting statistical associations in epidemiologic 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. For example, the absolute risk of invasive childhood cancer in children 0 to 19 years of age for 2004 was 14.8 per 100,000 children (Ries et al., 2007). An RR evaluates whether a particular exposure or inherent quality (e.g., EMF, diet, genetics, race) is associated with a disease outcome and is calculated by looking at the absolute risk in one group relative to a comparison group. For example, white children 0 to 19 years of age had an estimated absolute risk of childhood cancer of 15.4 per 100,000 in 2004, and African American children in the same age range 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 an 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 epidemiologic 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 versus 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 epidemiologic 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%) of including 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 was conducted a very large number of times, 95% of the measured estimates would be within the upper and lower confidence limits.

The CI range 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 the true RR estimate. If the 95% CI does not include 1.0, the probability that an association is due to chance alone is 5% or lower, and the result is considered statistically significant, as discussed above.

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 to 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 important tools 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 (Linet, 2003). Therefore, meta- and pooled analyses are used not only to synthesize or combine data, but also to understand which 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 epidemiologic studies

One key reason that the results of epidemiologic 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 epidemiologic 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 epidemiologic 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 epidemiologic 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 also tend to 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 versus association and evaluating evidence regarding causal associations

Epidemiologic 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 their studies are exposed, and diseases can be caused by a complex interaction of many factors, the results of epidemiologic studies must be interpreted with caution. A single epidemiologic 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 U.S. Surgeon General published a landmark report on smoking-related diseases (HEW, 1964). As part of this report, the Surgeon General outlined nine criteria for evaluating epidemiologic studies (along with experimental data) for causality. In a more recent edition of this report, these criteria have been reorganized into seven criteria. In the earlier report, 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 list and brief description of each criterion.

Table 1. Criteria for evaluating whether an association is causal (HHS, 2004)

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 between exposure and disease, the less likely such an effect is the result of chance or unmeasured confounding.
Specificity	The exposure is the single cause or one of a few causes 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	The observation that the stronger or greater the exposure, the stronger or greater the effect, also known as a dose-response relationship.
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 populations.

The criteria were meant to be applied to statistically significant associations observed in the cumulative epidemiologic literature (i.e., if no statistically significant association is 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, except for temporality, rule out causation.

In summary, the judicious consideration of these criteria is useful in evaluating epidemiologic 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, epidemiologic 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 that report consistent results across many different populations and study designs and are supported by experimental data collected from *in vivo* and *in vitro* studies.

Biological response versus 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 the cause of disease. For example, as a person 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 a biological response to the change in light conditions. Pupil constriction, however, is neither a disease itself, nor is it known to cause disease.

3 The WHO 2007 Report: Methods and Conclusions

The WHO is a scientific organization within the United Nations system with the mandate to provide leadership on global health matters, shape health research agendas, and set 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 conducted their review using standard scientific procedures, as outlined in its Preamble and described above in Section 2. 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,[5] 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

[5] 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.

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. As identified in Figure 3, categories include (from highest to lowest risk): *carcinogenic to humans*; *probably carcinogenic to humans*; *possibly carcinogenic to humans*; *not classifiable as to its carcinogenicity to humans*; 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 epidemiologic studies and less than sufficient evidence of carcinogenicity in studies of experimental animals. *In vitro* research is not described in Figure 3 because it provides ancillary information; it is used to a lesser degree in evaluating carcinogenicity and is classified simply as strong, moderate, or weak.

	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. Note that in 2019, IARC removed the category *Probably not a Carcinogen* (Group 4), as only one chemical had ever been assigned to that category. https://monographs.iarc.who.int/wp-content/uploads/2019/07/2019-SR-001-Revised_Preamble.pdf. Accessed March 18, 2022

The IARC has reviewed over 1,000 substances and exposure circumstances to evaluate their potential carcinogenicity. Eighty percent of exposures fall in the categories *possibly carcinogenic* (31 percent) or *not classifiable* (48 percent).[6] This occurs because 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 carcinogenic*, 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 (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).

The WHO concluded the following regarding specific diseases:

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 to 4 mG (Ahlbom et al., 2000; Greenland et al., 2000). These data, categorized as limited epidemiologic evidence, resulted in the classification of magnetic fields as possibly carcinogenic by the IARC in 2002.

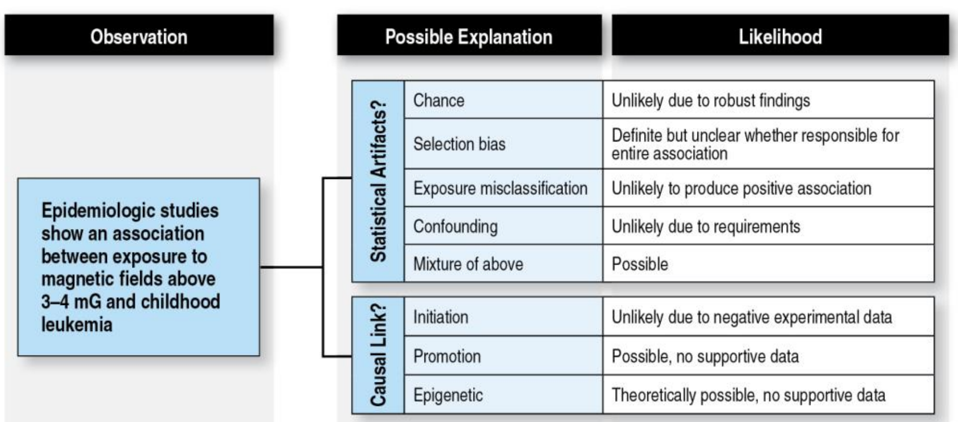
---

[6] https://monographs.iarc.fr/agents-classified-by-the-iarc/. Accessed March 18, 2022.

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 (*see* Figure 4). The authors concluded the following:

- Chance is an unlikely explanation since the pooled analyses had a large 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.
- Exposure misclassification would likely result in an underestimate of the true association, although it is not entirely clear.

The WHO concluded that reconciling the epidemiologic data on childhood leukemia and the negative experimental findings (i.e., no hazard or risk observed) through innovative research is currently the highest priority in the field of ELF EMF research. The WHO stated, however, that the public health impact of magnetic fields on childhood leukemia would likely be minimal if the association was determined to be causal given that few children are expected to have long-term *average* magnetic-field exposures greater than 3 to 4 mG.



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, "[i]n 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 epidemiologic 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 epidemiologic 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.

4 Current Scientific Consensus

The following sections identify and describe epidemiologic and *in vivo* studies related to ELF EMF and health published between December 2018 and December 2021. 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 3. A previous Exponent report summarized the literature through December 2018 (Exponent, 2019) and concluded that those 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 33 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 English language literature indexed between December 2018 and December 2021.[7] All fields (e.g., title, abstract, keywords) were searched with various search strings that referenced the exposure and disease of interest.[8] A researcher with experience in this area reviewed the titles and abstracts of these publications for inclusion in this evaluation. The following specific inclusion criteria were applied:

1. **Outcome**. Epidemiologic studies evaluated cancer; reproductive or developmental effects; neurodegenerative diseases; or cardiovascular disease; *in vivo* studies evaluated carcinogenicity. Research on other outcomes was not included (e.g., psychological effects, behavioral effects, hypersensitivity).
2. **Exposure**. Studies evaluated ELF EMF at a frequency of 50 or 60-Hz.
3. **Exposure assessment methods**. Studies evaluated exposure beyond self-report of an activity or occupation, and estimated exposure through various methods including calculated

---

7 Since the literature search was performed at the end of December 2021, and 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 published prior to December 2021 are not included in this update.

8 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).

EMF levels using distance from power lines, measured TWA exposure, and average exposure estimated from JEMs.

4. **Study design**. Study design included epidemiologic studies, meta-analyses, pooled analyses, human experimental studies, and *in vivo* studies of carcinogenicity. 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 3) regarding 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 non-peer reviewed on-line materials were included.

Epidemiologic 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 2 through 9 list the relevant studies that were published from December 2018 through December 2021 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 (Ahlbom et al., 2000; Greenland et al., 2000), a statistically significant two-fold association was observed between childhood leukemia and estimated average exposure to high levels of magnetic fields (i.e., greater than 3 to 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*, which, as noted previously, is 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 their 2007 review.

Since the WHO conducted their review, childhood leukemia continues to be a main focus of ELF EMF epidemiologic research. Kheifets et al. (2010a) provided an update to the analyses conducted by Ahlbom et al. (2000) and Greenland et al. (2000) by reporting the results of a pooled analysis of seven case-control studies of childhood leukemia and ELF EMF published between 2000 and 2010. Although the authors included a large number of cases (n=10,865) in this analysis, only 23 cases had measured fields and 3 cases had calculated fields in the highest exposure category (≥3 mG). A moderate and statistically not significant association was reported for the highest exposure category (OR 1.44, 95% CI 0.88-2.36), which was weaker than the association reported in the previous pooled analyses (Ahlbom et al., 2000; Greenland et al., 2000).

More recently, several case-control studies from the United States (Crespi et al., 2016), France (Sermage-Faure et al., 2013), Denmark (Pedersen et al., 2014a, 2014b, 2015), and the United Kingdom (Bunch et al., 2014, 2015; Swanson and Bunch, 2018) assessed the risk of childhood leukemia in relation to residential proximity to high-voltage power lines. None of these studies reported consistent overall associations between childhood leukemia development and residential distance to high-voltage power lines. The largest of these studies (Bunch et al., 2014) was an update of an earlier study in the United Kingdom (Draper et al., 2005) and included over 53,000 childhood cancer cases diagnosed between 1962 and 2008 and over 66,000 healthy children as controls. Overall, the authors reported no association between childhood leukemia development and residential proximity to power lines with any of the voltage categories. The statistical association reported in the earlier study (Draper et al., 2005) was no longer apparent in the updated analysis (Bunch et al., 2014).

These case-control studies had large sample sizes and were population-based studies requiring no subject participation, which minimizes the potential for selection bias. The main limitation of these studies was the reliance on distance to power lines as the main exposure metric, which is known to be a poor predictor of actual residential magnetic-field exposure. Several observers in the scientific literature discussed the limitations of distance as an exposure proxy in the context of the French study by Sermage-Faure et al. (Bonnet-Belfais et al., 2013; Clavel et al., 2013). In addition, Chang et al. (2014) provided a detailed discussion of the limitations of exposure assessment methods based on geographical information systems. Swanson et al. (2014) also concluded, based on their analysis of data from the British study (Bunch et al., 2014), that geocoding information not based on exact address, but only on post code information, is "probably not acceptable for assessing magnetic-field effects" (Swanson et al., 2014, p. N81).

Additional research reviewed in Exponent (2019) also has not provided consistent or compelling evidence of an association (e.g., Magnani et al., 2014; Salvan et al., 2015; Tabrizi and Bigdoli, 2015; Tabrizi and Hossein, 2015; Su et al., 2016; Kheifets et al. 2017, Amoon et al., 2018a, 2018b; Kyriakopoulou et al., 2018). In their 2015 report, SCENIHR concluded that the epidemiologic data on childhood leukemia and EMF exposure reviewed for the report "are consistent with earlier findings of an increased risk of childhood leukaemia with estimated daily average exposures above 0.3 to 0.4 μT [microtesla] [i.e., 3 to 4 mG]" and noted that "no mechanisms have been identified and no support is existing [*sic*] from experimental studies that could explain these findings, which, together with shortcomings of the epidemiological studies prevent a causal interpretation" (SCENIHR, 2015, p. 164).

Recent studies (December 2018 through December 2021)

Crespi et al. (2019) examined the same California study population as Crespi et al. (2016) to investigate the separate and combined relationship between distance from high-voltage power lines and calculated magnetic-field exposure and childhood leukemia risk. The authors reported that neither residential proximity to high-voltage power lines (<50 meters, ≥200 kilovolts [kV]) nor calculated magnetic fields (≥0.4 μT [≥4 mG]) alone were associated with childhood leukemia; however, an association was observed for study subjects with both residential proximity to high-voltage power lines and high calculated magnetic-field levels (Crespi et al., 2019). No associations were observed with low-voltage power lines. The authors considered their study as "hypothesis generating" and noted that the observed associations could be spurious findings due to small sample sizes or confounding. The authors concluded that their findings "argue against magnetic fields as a sole explanation" for an association between distance and childhood leukemia and "in favor of some other explanation" linked to the power lines (Crespi et al., 2019, p. 535).

In further analyses of data from the same California childhood cancer epidemiologic study, Amoon et al. (2019, 2020) assessed the role of residential mobility and dwelling type in estimating the potential effect of magnetic-field exposure on childhood leukemia risk. Amoon et al. (2019) reported that residential mobility had some impact on the association between magnetic-field exposure and childhood leukemia but concluded that confounding by residential mobility is “unlikely to be the primary driving force behind previously observed largely consistent, but unexplained associations” (Amoon et al., 2019, p. 7). Amoon et al. (2020) reported that while race, ethnicity, and socioeconomic status were associated with dwelling type (e.g., single-family home, apartment, duplex, mobile home), dwelling type was not associated with childhood leukemia, and thus did not appear to be a confounder in the relationship between magnetic-field exposure and childhood leukemia risk in this study. The authors reported potential differences in the strength of the association between childhood leukemia and magnetic-field exposure by dwelling type and recommended additional research in this area.

Auger et al. (2019a) examined the relationship between residential proximity to high-voltage transmission lines and transformer stations during pregnancy of the mother and risk of childhood cancer in the offspring in a cohort of 784,000 children born in Québec and followed for one decade after birth. No statistically significant associations were reported between distance to high-voltage power lines or transformer stations and any cancer outcomes, including hematopoietic cancer, and solid tumors (Auger et al., 2019a). The authors concluded that their results “suggest an absence of a causal link between [EMF] from high voltage power sources and the risk of cancer in children” (Auger et al., 2019a, p. 6).

Núñez-Enríquez et al. (2021) conducted a case-control study to assess the relationship between residential magnetic-field exposure and B-lineage acute lymphoblastic leukemia (B-ALL) in Mexico City, Mexico. The study included children less than 16 years of age (290 cases and 407 controls). Exposure to magnetic-field exposure was assessed using 24-hour measurements in the participants’ bedrooms. The authors reported statistically significant associations between B-ALL and 24-hour magnetic-field exposures ≥ 0.4 μT [4 mG] and ≥ 0.6 μT [6 mG]; however, non-statistically significant associations were reported for 24-hour magnetic field exposures ≥ 0.2 μT [2 mG], ≥ 0.3 μT [3 mG], and ≥ 0.5 μT [5 mG]. The authors concluded that “to date, a clear mechanism through which exposure to ELF- MFs [magnetic fields] may be associated with leukemia has not been established. Therefore, it is possible that other factors related to ELF- MF exposure, which we could not identify in the present study, may be relatively more relevant as risk factors for childhood leukemia development” (Núñez-Enríquez et al., 2021, p. 9). Reliance on 24-hour measurements, the large proportion of participants with higher magnetic-field exposures (14% of cases and 11% of controls had 24-hour exposures ≥ 0.3 μT [3 mG]), and the ability to analyze the most common childhood leukemia subtype (B-ALL) separately are among the study's strengths. The statistically significantly higher frequency of infections during the first year of life among cases, compared the controls, may be indicative of potential confounding. The hospital-based selection of controls may be a source of selection bias, if the catchment areas of the hospitals used to recruit controls were different than those of the hospitals where the leukemia cases were treated and recruited. Participation rate was also lower among cases than among controls, representing another potential source of selection bias.

Recent pooled analyses of epidemiologic studies of childhood leukemia and magnetic-field exposure indicated weak and statistically non-significant associations. Swanson et al. (2019) examined 41 studies to assess the trends in childhood leukemia risk over time. The authors reported a statistically non-significant decline in risk from the mid-1990s until the present, which they stated was "unlikely to be solely explained by improving study quality but may be due to chance" (Swanson et al., 2019, p. 470). The authors concluded, however, that the current body of literature on EMF "argue against health effects of MFs [magnetic fields] at these exposure levels" (Swanson et al., 2019, p. 485). Talibov et al. (2019) conducted a pooled analysis of 11 case-control studies examining the relationship between parental occupational exposure to ELF magnetic fields and childhood leukemia. No statistically significant association was found for paternal or maternal exposure by leukemia sub-type or overall, and no association was observed when additional exposure categories were used. The authors concluded that their study "suggests that parental ELF-EMF exposure plays no relevant role in the aetiology of childhood leukemia" (Talibov et al., 2019, p. 752).

Amoon et al. (2022) conducted a pooled analysis of and included original data from epidemiologic studies of residential exposure to magnetic fields and childhood leukemia published after the 2010 pooled analysis (Kheifets et al., 2010a). The study compared the exposures of 24,994 children with leukemia to those of 30,769 controls without leukemia to measured or calculated magnetic fields at their residences in California, Denmark, Italy, and the United Kingdom (Amoon et al., 2022). The exposures of these two groups to magnetic fields were found to not significantly differ, so the authors reported "[u]nlike previous pooled analyses, we found no increased risk of leukemia [above 0.4 μT]" and "[i]n conclusion, our results do not show the risk increase observed in previous pooled analysis and, over time, show a decrease in effect to no association between MF and childhood leukemia."

Investigators from Korea conducted a systematic review and meta-analysis of exposure to ELF-MF and childhood cancer (Seomun et al., 2021). The authors included 30 studies in their meta-analyses and reported that "[c]hildren exposed to 0.2-, 0.3-, and 0.4-μT ELF-MFs [magnetic fields] had a 1.26 (95% CI 1.06-1.49), 1.22 (95% CI 0.93-1.61), and 1.72 (95% CI 1.25-2.35) times higher odds of childhood leukemia." The authors did not specifically evaluate the change in association between ELF magnetic fields and childhood leukemia over time, and the overall results were likely influenced by the larger number of earlier studies.

Assessment

In summary, while most of the large and methodologically advanced studies published within the last decade (e.g., Bunch et al., 2014, Pedersen et al., 2014a, 2014b, 2015; Crespi et al., 2016; Kheifets et al., 2017, Crespi et al., 2019) showed no statistically significant associations between estimates of exposures from power lines, and recent pooled analyses indicated weaker and statistically non-significant associations, the association between childhood leukemia and magnetic fields observed in some earlier studies remains unexplained. Thus, the results of recent studies do not change the classification of the epidemiologic data as limited. In their most recent review of the research, SSM concluded that,

> Regarding the exposure to ELF magnetic fields and the development of childhood leukaemia, associations have been observed, but a causal relationship has not been established (SSM, 2021, p. 6).

In 2020, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) published a review of the research related to potential health effects of EMF exposure; the Commission's objective was to identify any data gaps in the body of literature on which they based their exposure guidelines (see Section 6) (ICNIRP, 2020). Regarding the research on childhood leukemia, ICNIRP did not recommend further epidemiologic studies on this topic, noting that any additional studies would be "unlikely to advance the knowledge, as they will potentially be affected by the same types of biases as existing studies" (ICNIRP, 2020, p. 535). ICNIRP (2020) did recommend "[f]urther studies on mechanisms and biological data from childhood leukemia experimental models" while also stating, "there is no support from animal experiments and there are no mechanistic data that can provide an explanation for any effect on biological structures at the exposure levels that have been identified in epidemiological studies"

(ICNIRP, 2020, p. 536). The lack of evidence of a plausible biological mechanism between magnetic-field exposure and childhood leukemia development has been noted in other recent publications (e.g., Habash et al., 2019) and is discussed in the sub-section on *in vivo* studies related to carcinogenesis.

Table 2. Relevant studies of childhood leukemia (December 2018 - December 2021)

Author	Year	Study Title
Amoon et al.	2019	The sensitivity of reported effects of EMF on childhood leukemia to uncontrolled confounding by residential mobility: a hybrid simulation study and an empirical analysis using CAPS data.
Amoon et al.	2020	The role of dwelling type when estimating the effect of magnetic fields on childhood leukemia in the California Power Line Study (CAPS).
Amoon et al.	2022	Pooled analysis of recent studies on magnetic fields and childhood leukaemia.
Auger et al.	2019a	Residential exposure to electromagnetic fields during pregnancy and risk of child cancer: a longitudinal cohort study.
Crespi et al.	2019	Childhood leukemia risk in the California Power Line Study: magnetic fields versus distance from power lines.
Núñez-Enríquez et al.	2021	Extremely low-frequency magnetic fields and the risk of childhood B-lineage acute lymphoblastic leukemia in a city with high incidence of leukemia and elevated exposure to ELF magnetic fields.
Seomun et al.	2021	Exposure to extremely low-frequency magnetic fields and childhood cancer: a systematic review and meta-analysis.
Swanson et al.	2019	Changes over time in the reported risk for childhood leukemia and magnetic fields.
Talibov et al.	2019	Parental occupational exposure to low-frequency magnetic fields and risk of leukaemia in the offspring: findings from the Childhood Leukaemia International Consortium (CLIC).

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).

Addressing these recommendations, researchers conducted both a meta-analysis (Mezei et al., 2008) and a pooled analysis (Kheifets et al., 2010b) of available studies. The meta-analysis by Mezei et al. (2008) reported no overall association, but reported a statistically non-significant weak association with calculated or measured magnetic fields above 3 to 4 mG based on a sub-analysis of five studies. The pooled analysis by Kheifets et al. (2010b) included data from 10 studies of childhood brain cancer or central nervous system (CNS) cancer with long-term measurements, calculated fields, or spot measurements of residential magnetic-field exposure published from 1979 to 2010. Similar to childhood leukemia, few cases of childhood brain cancer had estimated magnetic-field exposures greater than 3 to 4 mG. None of the analyses showed statistically significant increases, and while some categories of high exposure had an OR >1.0, the overall patterns were not consistent with an association and no dose-response trends were apparent. The authors concluded that their results provide little evidence for an association between magnetic fields and childhood brain tumors.

Several of the same epidemiologic studies discussed in the childhood leukemia section investigated the potential relationship between residential proximity to overhead and underground transmission lines and childhood brain cancer (Bunch et al., 2014, 2015, 2016; Pedersen et al., 2015; Crespi et al., 2016). None of these studies reported any consistent association between distance to power lines and childhood brain cancer risk. Su et al. (2018) published a meta-analysis of epidemiologic studies that investigated the association between parental exposure to ELF magnetic fields and nervous system tumors in their offspring. The authors reported no consistent associations between maternal or paternal exposure to ELF magnetic fields and neuroblastoma or CNS tumors.

Recent studies (December 2018 through December 2021)

The previously discussed study on childhood leukemia by Auger et al. (2019a) also investigated the association between exposure to EMF during pregnancy and the occurrence of CNS tumors in the offspring. The authors reported a statistically non-significant association between a residential distance of 80 meters from a transformer station and CNS tumors. When the analysis was stratified by gender, the authors reported an association for males only. No associations were observed with distance to transmission lines. The authors concluded that "[r]esidential proximity to transformer stations is associated with a borderline risk of childhood cancer, but the absence of an association with transmission lines suggests no causal link" (Auger et al., 2019a).

The meta-analysis of Seomun et al. (2021) described above also included studies of childhood brain cancer. No statistically significant associations were reported; the OR was 0.95 (95% CI 0.59-1.56) for magnetic-field exposure >0.2 μT, and 1.25 (95% CI 0.45-3.45) for magnetic-field exposure >0.4 μT.

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 the two recent studies do not alter the classification of the epidemiologic data in this field as inadequate, as they did not report any consistent and convincing evidence for an association. This is in line with the 2015 SCENIHR review, which concluded that "no association has been observed for the risk of childhood brain tumours" (SCENIHR, 2015, p. 158).

Table 3. Relevant studies of childhood brain cancer (December 2018 - December 2021)

Authors	Year	Study
Auger et al.	2019a	Residential exposure to electromagnetic fields during pregnancy and risk of child cancer: a longitudinal cohort study.
Seomun et al.	2021	Exposure to extremely low-frequency magnetic fields and childhood cancer: a systematic review and meta-analysis.

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. Research in this area provided additional support for the WHO's conclusion that there is no association between exposure to ELF EMF and breast cancer development. A large case-control study that investigated the risk of several types of adult cancers and residential distance to high-voltage power lines reported no association between female breast cancer and residential distance to power lines or estimated exposure to magnetic fields (Elliott et al., 2013). Several occupational epidemiologic studies of female and male breast cancers also provided no support for an association between ELF EMF exposure and breast cancer development (Sorahan, 2012; Li et al., 2013; Koeman et al., 2014; Grundy et al., 2016).

Recent studies (December 2018 through December 2021)

No published epidemiologic studies examining the potential relationship between ELF EMF and breast cancer development were identified within the time period of this report.

Assessment

As no new published studies were identified during the time period of this report, the conclusion that there is no association between ELF EMF and breast cancer, as expressed by the WHO and other reviewing agencies, continues to be valid. The review by SCENIHR (2015) concluded that overall studies on "adult cancers show no consistent associations" (p. 158). The SSM concluded in two recent annual reports that, with respect to female breast cancer, "now it is fairly certain that there is no causal relation with exposure to ELF magnetic fields" (SSM, 2016, p. 7), and with respect to male breast cancer, "[t]o date, there is no established link between ELF-MF [magnetic field] exposure and breast cancer in men" (SSM, 2018, p. 49).

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).

Overall, the epidemiologic studies of ELF EMF and adult brain cancer that were reviewed in our previous reports predominantly support no association with brain cancer in adults but remain limited due to the exposure assessment methods and insufficient data available on specific brain cancer subtypes. Two Swedish case-control studies discussed in Exponent (2019) investigated the relationship between occupational exposure to ELF EMF and glioma (Carlberg et al., 2017) and meningioma (Carlberg et al., 2018). In Carlberg et al. (2017), the authors reported no overall association between glioma and cumulative exposure to ELF EMF and a marginally significant association with the highest average exposure category. Sub-analyses examining the association by tumor grade and exposure period did not show consistent associations. In Carlberg et al. (2018), no trend or association was reported between meningioma development and exposure to ELF EMF using any of the exposure metrics or exposure periods.

Recent studies (December 2018 through December 2021)

Carlberg et al. (2020) evaluated a potential link between occupational exposure to magnetic fields and acoustic neuroma. Similar to previous papers (Carlberg et al., 2017, 2018), the authors in Carlberg et al. (2020) relied on data from previously published case-control studies in Sweden (Hardell et al., 2006, 2013). Carlberg et al. (2020) included 310 cases and 3,485 controls during the time periods of 1997 to 2003 and 2007 to 2009 and assessed average and cumulative magnetic-field exposure using the participants' questionnaire responses and a previously developed JEM (Turner et al., 2014). The authors reported no statistically significant associations between acoustic neuroma and either average or cumulative magnetic-field exposure, regardless of the exposure period examined (1 to 14 years or 15+ years). The authors concluded that "occupational ELF-EMF was not associated with an increased risk for acoustic neuroma" (Carlberg et al., 2020, p. 1).

Carles et al. (2020) conducted a case-control epidemiologic study to investigate the association between residential proximity to power lines and brain tumor development from 1965 to 2006 among adults in France. The authors included 490 cases (gliomas and meningiomas combined) and 980 controls in their study. Exposure was assessed using the distance from the residence to the nearest power line and the voltage of the power lines as surrogate indicators of magnetic-field exposure. Several statistically significant associations were reported, although the associations were not consistent across brain tumor types or exposure metrics, and no clear exposure-response trend was observed. Statistically significant associations were reported between living <50 meters from power lines of any voltage for more than 15 years and all brain tumors, as well as meningiomas; between ever living <50 meters from a power line of any voltage and glioma; and between ever living <50 meters from a high-voltage power line (<200 kV) and both glioma and all brain tumors. No statistically significant associations were observed between any tumor type and living <50 meters from very high voltage power lines (≥200 kV) or living near power lines of any voltage for more than 5 years and more than 10 years. In addition, no statistically significant associations were observed for assessed magnetic-field exposure ≥0.3 μT [3 mG]). Souques et al. (2020) highlighted several methodological limitations in the Carles et al. (2020) study, including the potential for exposure misclassification due to inaccuracies of the geolocation method used to ascertain residential distance to power lines and the study's failure to account for underground lines, which would result in lower exposure levels, and concluded that due to these limitations, the results of the Carles et al. (2020) study were "meaningless and unusable" (Souques et al. 2020, p. 2).

Khan et al. (2021) reported results on newly diagnosed brain cancer cases in a cohort study of 256,372 individuals who lived in residential buildings with indoor transformer stations in Finland. Exposure to magnetic fields was assessed based on the location of the participants' apartment in relation to the location of the transformer station in the building; those participants who lived for at least 1 month in an apartment located directly above a transformer room or that shared a wall with a transformer room were considered exposed (n=9,636 exposed individuals). The authors reported no association between magnetic-field exposure and meningioma based on residential location and a non-statistically significant association with glioma. No association was reported between brain tumors and duration of residence near transformers. Limitations of the study include the low number of cases and the exposure assessment method, which did not account for personal behavior and time spent in the apartment that may influence personal exposure, or potential confounding exposures. Its prospective design, the minimized potential for selection bias (no contact was required with the study subject), and the previously validated exposure classification system (Okokon et al., 2014) are among the strengths of the study.

Assessment

Recent studies do not provide support for an association between exposure to magnetic fields and brain cancer development. As mentioned above, the most recent SCENIHR report states that, overall, studies on "adult cancers show no consistent associations" (SCENIHR, 2015, p. 158).

Table 4. Relevant studies of adult brain cancer (December 2018 - December 2021)

Authors	Year	Study
Carlberg et al.	2020	Case-control study on occupational exposure to extremely low-frequency electromagnetic fields and the association with acoustic neuroma.
Carles et al.	2020	Residential proximity to power lines and risk of brain tumor in the general population.
Khan et al.	2021	A cohort study on adult hematological malignancies and brain tumors in relation to magnetic fields from indoor transformer stations.
Souques et al.	2020	Letter to editor regarding "residential proximity to power lines and risk of brain tumor in the general population" by Carles C. and coll.

Adult leukemia and lymphoma

There is a vast literature on adult leukemia and ELF EMF, most of which is related to occupational exposure. Overall, the findings of these studies are inconsistent—some studies report a positive association between measures of ELF EMF and leukemia and other studies show 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 occupational cohorts and updating a meta-analysis on occupational magnetic-field exposure. Subsequently, Kheifets et al. (2008) provided an update to two meta-analyses they published in the 1990s. Their updated meta-analysis indicated that pooled risk estimates from more recent studies were lower than in past meta-analyses and that no consistent pattern was observed by leukemia subtypes. Thus, the combined results were not in support of a causal association between occupational EMF exposure and adult leukemia.

Studies reviewed in Exponent (2019) did not provide evidence to change the WHO conclusion (Talibov et al., 2015; Huss et al. 2018a). In the same study as their retrospective cohort analysis of the Swiss National Cohort, Huss et al. (2018a) conducted a meta-analysis of epidemiologic studies of occupational exposure to ELF magnetic fields and acute myeloid leukemia, in which the authors reported a weak overall association.

Recent studies (December 2018 through December 2021)

The Finnish cohort study by Khan et al. (2021), described above, also reported results on the potential association between magnetic-field exposures from indoor transformer stations in residential buildings and development of hematological neoplasms, including lymphoma and leukemia. Based on very small number of cases (n=4), a statistically significant association was reported for ALL; this association was observed to increase with duration of exposure. No associations were reported for other leukemia subtypes or for lymphoma or multiple myeloma, and the risk level for these diseases decreased with increasing duration of exposure. As discussed above, the study's limitations include the low number of cases and the lack of personal exposure data or information on potential confounding exposures.

Researchers from Australia (Odutola et al., 2021) conducted a systematic review and meta-analysis of various occupational exposures and follicular lymphoma, a common non-Hodgkin lymphoma subtype; only two studies were identified that specifically investigated occupational ELF magnetic-field exposure (Koeman et al., 2014; Huss et al., 2018a). No consistent pattern was observed in these studies.

Assessment

Recent studies did not provide substantial evidence for an association between EMF and leukemia overall, leukemia sub-types, or lymphoma in adults. Thus, the previous conclusion that the evidence is inadequate for adult leukemia remains appropriate. While some scientific uncertainty remains on a potential relationship between adult lymphohematopoietic malignancies and magnetic-field exposure because of continued deficiencies in study methods, the current database of studies provides inadequate evidence for an association (EFHRAN, 2012; SCENIHR, 2015).

Table 5. Relevant studies of adult leukemia (December 2018 - December 2021)

Authors	Year	Study
Khan et al.	2021	A cohort study on adult hematological malignancies and brain tumors in relation to magnetic fields from indoor transformer stations.
Odutola et al.	2021	A systematic review and meta-analysis of occupational exposures and risk of follicular lymphoma.

Reproductive and developmental effects

In 2002, two studies 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 (earlier studies on miscarriage were limited because they used surrogate measures of exposure, including visual display terminal use, electric blanket use, or wire code data). The Li et al. (2002) study, however, was criticized by the National Radiological Protection Board *inter alia* because of the potential for selection bias, a low compliance rate, measurement of exposure after miscarriages, and apparent selection of exposure categories after inspection of the data (NRPB, 2002). The scientific panels that 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, "[t]here is some evidence for increased risk of miscarriage associated with measured maternal magnetic-field exposure, but this evidence is inadequate" and recommended further epidemiologic research (WHO, 2007, p. 254).

Following the publication of these two studies, 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 (i.e., less physically active) and women who miscarried (i.e., more physically active after miscarriage) (Savitz, 2002). It was proposed that physical activity is associated with an increased opportunity for peak magnetic-field exposure, 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 environmental exposure to peak magnetic fields while doing activities in one's community. This hypothesis received empirical support from studies that reported consistent associations between activity (mobility during the day) and various metrics of peak magnetic-field exposure measurements (Mezei et al., 2006; Savitz et al., 2006; Lewis et al., 2015). These findings suggest that the association between maximum magnetic-field exposure and miscarriage was due to differing activity patterns of the cases and controls, not to a magnetic-field effect on embryonic development and viability.

Studies on ELF EMF exposure and reproductive or developmental effects published subsequent to the WHO 2007 report included ones focusing on miscarriage or stillbirth (Auger et al., 2012; Shamsi Mahmoudabadi et al., 2013; Wang et al., 2013; Li et al., 2017) and birth outcomes (Mahram and Ghazavi, 2013; de Vocht and Lee, 2014; de Vocht et al., 2014; Eskelinen et al., 2016; Sadeghi et al., 2017; Sudan et al., 2017; Migault et al., 2018). These additional publications provided little new insight on pregnancy and reproductive outcomes and did not change the classification of the data from earlier assessments as inadequate. Recommendations for future studies included, among others, the selection of appropriate study populations, the assessment and control for potential confounding by the mothers' physical activity, the careful characterization of exposure, and the analysis of various exposure metrics in the study (Lewis et al., 2016).

Recent studies (December 2018 through December 2021)

Exponent (2019) included a summary of Li et al. (2017), in which the authors examined the association between magnetic-field exposure and miscarriage in a cohort of 913 pregnant women in California. Exposure was assessed using 24-hour personal magnetic-field measurements collected on a single day during pregnancy, and the 99th percentile value observed during the 24-hour measurement period was used as the exposure of interest by the authors. The authors reported an increased risk of miscarriage in women with higher magnetic-field exposure (i.e., the 99th percentile value during the 24-hour measurement of ≥2.5 mG) compared to women with lower magnetic-field exposure (<2.5 mG) when measurements were collected on a typical day (defined as a day reflecting the participants' typical pattern of work and leisure activities during pregnancy). They reported no association, however, among those women whose magnetic-field exposure was measured on a non-typical day, and no trend was observed for miscarriage risk with increasing magnetic-field exposures >2.5 mG. The authors did not report the overall TWA for the 24-hours of exposure that could be compared to previous studies. As discussed in Exponent (2019), there are several notable limitations of this study, including the collection of only one measurement over a single 24-hour period during pregnancy, a lack of information on the exact timing of the measurement (i.e., whether the measurement day preceded or followed the occurrence of miscarriage among cases), and a lack of measured mobility during the measurement day, a potential major source of confounding in the study (e.g., Savitz, 2002; Mezei et al., 2006; Savitz et al., 2006). Recently, Grimes and Heathers (2021) published an evaluation of the Li et al. (2017) paper and concluded that "this work exemplifies a number of deeply unsound methodological choices that nullify its strong conclusion." The limitations discussed by Grimes and Heathers (2021) include the exclusion of over half of the study population resulting in a disproportional selection of subjects by exposure status, and the inappropriate dichotomization of the data.

Canadian researchers analyzed a population-based sample of 2,164,246 infants born in Quebec, Canada, between 1989 and 2016, to assess the relationship between residential proximity to ELF EMF and risk of birth defects (Auger et al., 2019b). The authors calculated distance to the nearest high-voltage transmission line or transformer station using geocoded postal codes of the mother's residence at birth and used hospital records to identify defects present at the time of birth. No strong or consistent associations were reported. Weak, positive associations were observed between a residential address within 50 meters from transmission lines and genital, clubfoot, or sense organ defects; however, reduced risks were observed for noncritical heart defects and congenital hip dislocation. The study's limitations include the lack of information on exposure to other agents and on risk factors that are known to potentially cause birth defects (e.g., mothers' smoking habits).

Researchers in Iran conducted a cross-sectional study to evaluate the relationship between residential proximity to high-voltage power lines and female infertility (Esmailzadeh et al., 2019). The authors included 462 cases and 471 controls with no history of infertility in their study. Exposure was assessed by measuring the distance to the nearest high-voltage power lines using geographic information systems and aerial evaluations. The authors reported an association between infertility and living within 500 meters of the power lines compared to living more than 1,000 meters away. One of the main limitations of the study was the cross-sectional design, which does not allow to determine whether exposure to the magnetic fields occurred before or after the outcome of interest (i.e., infertility). Another severe limitation of the paper was the use of residential address within 500 meters of power lines as a surrogate for EMF exposure; beyond approximately 100 meters, no elevation of ELF EMF levels can be expected. Therefore, no valid conclusions can be drawn from the study with respect to exposure to EMF and infertility.

Researchers in China evaluated the association between magnetic-field exposure and fetal growth in a cohort study of 128 pregnant women using 24-hour personal magnetic-field measurements taken during the third trimester of pregnancy (Ren et al., 2019). The authors reported associations between prenatal magnetic-field exposure and fetal growth indicators (lower birth weight, thinner skinfold, and smaller head, arm, and abdominal circumference) for newborn girls, but not for newborn boys. While the use of personal exposure measurements is an improvement in exposure assessment methods compared to many earlier studies, the collection of only one measurement over a single 24-hour period during pregnancy may result in exposure misclassification, as day-to-day changes in exposure cannot be captured in one 24-hour measurement period.

A cohort study conducted among female patients of a Massachusetts fertility clinic examined the relationship between personal magnetic-field exposure levels and pregnancy outcomes (Ingle et al., 2020). The study included 119 women (age 18 to 46 years), recruited from 2012 to 2018 while undergoing fertility treatment. Exposure assessment was based on personal exposure measurements taken in three 24-hour time periods separated by several weeks; the study participants also completed a time-activity diary documenting their daily activities. The authors reported no statistically significant associations between magnetic-field exposure levels and the included main outcomes measures (e.g., implantation, clinical pregnancy, live birth, and pregnancy loss). The study's strengths include the prospective design, the use of personal exposure monitors, and the collection of repeated measurements; its limitations include the relatively small sample size.

Data from previously conducted cohort studies in California were analyzed to assess whether maternal exposure to magnetic fields is associated with the development of attention-deficit/hyperactivity disorder (ADHD) in their offspring (Li et al., 2020). The study included 1,482 mother-child pairs from 1996 to 1998 and 2006 to 2012. Exposure assessment was based on 24-hour personal magnetic-field measurements collected on a single day during the first or second trimester of pregnancy and the authors used the 90th percentile value observed during the 24-hour measurement period as the exposure metric of interest. Cohort members with ADHD diagnoses were identified through medical records. The authors reported a statistically significant association between exposure to magnetic fields ≥ 1.3 mG and ADHD diagnosis in their offspring; a stronger association was observed for children with a diagnosis persisting into adolescence. As noted above, measurements taken over a single 24-hour period during pregnancy represents a limitation of the study. Further, the specific exposure metric (90th percentile) and cut-point (1.3 mG) used in the study are unconventional and have not typically been used in previous epidemiologic studies of potential health effects of EMF. The authors' use of an unusual cut-point was recently called into question by others in the research community; as a result, in February 2021, the primary author of Li et al. (2020) issued a notice of retraction and replacement for the study, based on "errors in the statistical analyses" (Li, 2021). The author reported that the journal editors requested that the researchers re-analyze the study data using continuous and categorical exposure levels, rather than the 1.3 mG cut-point, which was poorly defined and explained by the authors. In the notice of retraction, Li (2021) stated that based on the updated analyses, "the associations were inconsistent and nonlinear, [therefore] limiting interpretations" and that the findings "should be interpreted with caution."

Researchers in Iran conducted a cross-sectional study to evaluate the relationship between exposure to magnetic fields and levels of reproductive hormones in 122 male power plant workers aged 20 to 50 years (Suri et al., 2020). Each worker completed a general health questionnaire and provided a blood sample used to determine serum levels of free testosterone, luteinizing hormone, and follicle stimulating hormone. TWA exposure of each employee was calculated based on measurements taken at the workstations and rest areas of the employees and categorized into tertiles. The authors reported no statistically significant differences in the serum levels of any of the three hormones examined when compared across the three exposure groups. The study's cross-sectional design precludes any causal interpretation.

Another Iranian cross-sectional study examined the relationship between maternal exposure to electromagnetic fields, including power lines and various radiofrequency field sources (e.g., mobile phones, Wi-Fi, cordless phones), and speech problems in offspring (Zarei et al., 2019). The study included 110 mothers of children 3 to 7 years of age with speech problems who had been referred to a speech treatment center and 75 mothers of children defined as "healthy" by the authors (no additional details provided). Questionnaire based information was used for exposure assessment to determine "whether they [study subjects] had been exposed to different sources of electromagnetic fields" (Zarei et al., 2019, p. 62); no additional details were provided on exposure assessment. Statistically significant associations were reported between offspring with speech problems and maternal "history of exposure to high tension power lines" before and during pregnancy (Zarei et al., 2019, p. 63). The study's limitations include the small overall sample size and the small number of exposed subjects; the lack of information on control selection; the use of self-reported and poorly described questionnaire-based information for exposure assessment; and the potential for selection bias, as mothers were enrolled in the study using "convenience sampling."

Chinese researchers conducted a case-control study to evaluate the relationship between exposure to electrical appliances and electronic equipment in early pregnancy and congenital heart disease (CHD) in the offspring (Zhao et al., 2021). The study included 585 cases and 1,754 controls born without birth defects. Occupational and residential exposure to selected electrical appliances and electronic equipment (mobile phone, television, computer, induction cooker, microwave oven) 3 months before pregnancy and during the first trimester of pregnancy was determined based on personal interviews with the mothers during their hospital stay for childbirth. The authors reported statistically significant associations between offspring with CHD and maternal exposure to computers, induction cookers, and microwave ovens before and during pregnancy; a decrease in offspring with CHD was observed for mothers who reported wearing a radiation protection suit during the time periods under study, which might block radiofrequency fields not ELF magnetic fields. The study's limitations include a high potential for recall bias because mothers who have given birth to infants with CHD may be more likely to recall the events leading up the diagnosis compared to mothers who gave birth to healthy children and thus have less reason to recall such memories. In addition, statistically significant differences between the cases and controls were reported for several potentially confounding variables (e.g., drinking, passive smoking, and folic acid supplement). Most important, the appliances that were assessed in this study are known sources of radiofrequency fields and exposures to ELF-EMF would be relatively minor.

Migault et al. (2020) conducted a pooled analysis of two previously published French cohort studies (Vandentorren et al., 2009; Ancel et al., 2014) to examine the relationship between maternal exposure to magnetic fields during pregnancy and the risk of adverse birth outcomes. A JEM was used to assess occupational maternal exposure to magnetic fields during three separate periods of gestational age. The authors reported no association between cumulative magnetic-field exposure and prematurity among the two highest exposure categories; conversely, an increased risk of prematurity was observed for the lower exposure category. No consistent associations were observed between cumulative magnetic-field exposure and being small for gestational age. The authors concluded that "due to the heterogeneity of the results regarding exposure levels, the associations observed cannot be definitely explained by ELF-EMF exposure" (Migault et al., 2020, p. 27). The study's limitations include the heterogeneity in study populations between the two included studies, low portion of mothers with high magnetic-field exposure (3% to 4%), and missing information on other occupational exposures that could explain the observed associations (e.g., chemical agents).

Assessment

The recent epidemiologic studies evaluated do not provide substantial new evidence in support of an association between EMF and reproductive or developmental outcomes and thus the classification of the data as inadequate remains appropriate. Studies in this research area still suffer from limitations in study design, sample size, and exposure assessment method. The most recent review by SCENIHR concluded that "recent results do not show an effect of ELF MF [magnetic field] exposure on reproductive function in humans." (SCENIHR, 2015). Regarding research on reproductive or developmental outcomes, ICNIRP concluded in their 2020 review of potential research gaps that "[s]ubsequent [epidemiologic] studies [after 2010] do not support the hypothesis that ELF-MFs [magnetic fields] are related to adverse pregnancy outcomes, and the older laboratory studies did not find an association between ELF-MFs and reproduction and/or development … Overall, the evidence gathered so far does not indicate any data gaps that require research for guideline development" (ICNIRP, 2020, p. 534).

Table 6. Relevant studies of reproductive and developmental effects (December 2018 - December 2021)

Authors	Year	Study
Auger et al.	2019b	Maternal proximity to extremely low frequency electromagnetic fields and risk of birth defects.
Esmailzadeh et al.	2019	Exposure to electromagnetic fields of high voltage overhead power lines and female infertility.
Grimes and Heathers	2021	Association between magnetic field exposure and miscarriage risk is not supported by the data.
Ingle et al.	2020	Association of personal exposure to power-frequency magnetic fields with pregnancy outcomes among women seeking fertility treatment in a longitudinal cohort study.
Li et al.	2017	Exposure to magnetic field non-ionizing radiation and the risk of miscarriage: a prospective cohort study.
Li et al.	2020	Association between maternal exposure to magnetic field nonionizing radiation during pregnancy and risk of attention-deficit/hyperactivity disorder in offspring in a longitudinal birth cohort.
Li et al.	2021	Notice of retraction and replacement. Li et al. Association between maternal exposure to magnetic field nonionizing radiation during pregnancy and risk of attention-deficit/hyperactivity disorder in offspring in a longitudinal birth cohort. JAMA Netw Open. 2020;3(3):e201417.
Migault et al.	2020	Maternal cumulative exposure to extremely low frequency electromagnetic fields, prematurity and small for gestational age: a pooled analysis of two birth cohorts.
Ren et al.	2019	Prenatal exposure to extremely low frequency magnetic field and its impact on fetal growth.
Suri et al.	2020	Relationship between exposure to extremely low-frequency (ELF) magnetic field and the level of some reproductive hormones among power plant workers.
Zarei et al.	2019	Mother's exposure to electromagnetic fields before and during pregnancy is associated with risk of speech problems in offspring.
Zhao et al.	2021	Risk of congenital heart disease due to exposure to common

Authors	Year	Study
		electrical appliances during early pregnancy: a case-control study.

Neurodegenerative diseases

Research into the possible effect of magnetic fields on the development of neurodegenerative diseases began in 1995; the majority of research since then has focused on Alzheimer's disease and a specific type of motor neuron disease called 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 scientific 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 studies reviewed 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 are 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 improved methods; in particular they recommended studies that enrolled incident Alzheimer's disease cases (rather than ascertaining cases from death certificates), as well as studies that estimated electrical shock history in ALS cases.

Following the research recommendations of the WHO, scientists conducted epidemiologic research that studied exposure to ELF EMF and development of neurodegenerative diseases. Overall, these studies, including those reviewed in Exponent (2019) (e.g., Yu et al., 2014; Fischer et al., 2015; Koeman et al., 2015, 2017; Vergara et al., 2015; Pedersen et al., 2017; Vinceti et al., 2017; Checkoway et al., 2018), did not provide consistent and convincing support for an association. Several meta-analyses of these studies reported weak to no evidence of an association between occupational exposure to ELF magnetic fields and neurodegenerative disease (Zhou et al., 2012; Vergara et al., 2013; Capozella et al., 2014; Huss et al., 2018b;

Jalilian et al., 2018; Röösli and Jalilian, 2018). The authors of several of these meta-analyses concluded that potential within-study biases, evidence of publication bias, and uncertainties in the various exposure assessments greatly limit the ability to infer an association, if any, between occupational exposure to magnetic fields and neurodegenerative disease.

Several studies have examined the potential role of electric shocks in occupational environments as a possible explanation for the weak and inconsistent association between ELF EMF and ALS. The studies that addressed the issue of electric shocks in the development of neurodegenerative and neurological diseases presented no convincing evidence for an association (Das et al., 2012; Grell et al., 2012; van der Mark et al., 2014; Brouwer et al., 2015; Ingre et al., 2015; Bozzoni et al., 2016).

Recent studies (December 2018 through December 2021)

Gervasi et al. (2019) conducted a case-control epidemiologic study to evaluate the relationship between residential proximity to overhead power lines and risk of Alzheimer's disease and Parkinson's disease in Italy. The study included 9,835 cases of Alzheimer's dementia and 6,810 cases of Parkinson's disease, and four controls matched to each case on sex, year of birth, and municipality of residence. Exposure assessment was based on residential distance from the nearest overhead power line (>30 kV). The authors reported a weak, statistically not significant association between residences within 50 meters of overhead power lines and both Alzheimer's disease and Parkinson's disease. The study's strengths include the large study population and the inclusion of potential confounders. The characterization of exposure using residential distance to power lines, however, is a primary limitation of the study.

Peters et al. (2019) assessed the potential relationship between occupational exposure to both ELF magnetic fields and electric shock with ALS in a multi-country European case-control study that included 2,704 cases and 1,323 controls. Occupational exposure was assessed using a JEM. Statistically significant associations were observed between ALS and ever having been exposed above background levels to either magnetic fields or electric shocks. No clear exposure-response trend was observed, however, with exposure duration or cumulative exposure.

Filippinni et al. (2020) conducted a case-control study in Italy, including 95 cases and 1,235 controls, to evaluate the association between ALS and various environmental and occupational factors, including electromagnetic fields. Questionnaire-based information was used to assess occupational and residential exposures to electric and magnetic fields. The authors reported a statistically significant association between ALS and proximity to overhead power lines. The association between ALS and occupational exposure to EMF was not statistically significant; occupational use of electric and electronic equipment was associated with a statistically non-significant decreased risk of ALS development. The study's limitations include the possibility of selection bias due to the low overall response rate (<20%) and the potential for exposure misclassification as a result of reliance on a self-reported information to assess exposures.

Researchers in New Zealand conducted a case-control study, including 319 cases and 604 controls, to assess the association between occupational exposure to electric shocks, magnetic fields, and motor neuron disease [MND], including ALS (Chen et al., 2021). Exposure was assessed based on the participants' occupational history obtained using questionnaires and previously developed JEMs for electric shocks and magnetic fields. The authors reported no association between MND and exposure to magnetic fields when examining any of the exposure metrics (e.g., ever/never exposed, duration of exposure, cumulative exposure level). Positive associations were reported between MND and a job with the potential for electric shock exposure.

Gunnarsson and Bodin (2018) conducted a meta-analysis of occupational risk factors for development of ALS and reported statistically significant associations between occupational exposure to EMF and ALS and between jobs that involve working with electricity and ALS. The authors noted a "slight" publication bias and some study heterogeneity (Gunnarsson and Bodin, 2018, p. 10). Significant associations were also reported between ALS and heavy physical work, exposure to metals (including lead) and chemicals (including pesticides), and working as a nurse or physician. Gunnarsson and Bodin (2019) updated their previous meta-analysis (Gunnarsson and Bodin, 2018) to also include Parkinson's disease and Alzheimer's disease. A weak statistically significant, association was reported between exposure to EMF and Alzheimer's disease; no association was observed for Parkinson's disease. When the authors combined the studies of ALS and Alzheimer's disease, a stronger association with EMF was observed in those studies published prior to 2005 compared to studies published more recently. The authors opined that there is "an evident publication bias" in the studies published before 2005.

Huang et al. (2020) conducted a meta-analysis of 43 epidemiologic studies to investigate potential occupational risk factors for dementia or mild cognitive impairment. The authors included five cohort studies and seven case-control studies related to magnetic-field exposure. Positive associations were reported between dementia and work-related magnetic-field exposures in both types of studies. The authors, however, provided no information on the occupations held by the study participants, their magnetic-field exposure levels, or how magnetic-field levels were assessed. The authors also reported a high level of heterogeneity among studies. This analysis adds little to the weight of the evidence for an association between dementia and magnetic fields due to its limitations.

Filippini et al. (2021) conducted a meta-analysis to assess the dose-response relationship between residential exposure to magnetic fields and ALS. The authors identified six ALS epidemiologic studies that assessed exposure to residential magnetic fields by either distance from overhead power lines or magnetic-field modelling. They reported a decrease in risk of ALS in the highest exposure categories for both distance-based and modeling-based exposure estimates. The data were also used to conduct dose-response analyses for modelled magnetic field estimates; the authors reported that their dose-response analyses "showed little association between distance from power lines and ALS." The authors noted that their study was limited by small sample size, the potential for residual confounding, and by "some publication bias."

Jalilian et al. (2021) conducted a meta-analysis of occupational exposure to ELF magnetic fields and electric shocks and development of ALS including 27 studies from Europe, the United States, and New Zealand. A weak statistically significant association was reported between magnetic-field exposure and ALS; no association was observed between electric shocks and ALS. "Moderate to high" heterogeneity and indications of publication bias was identified for the study's magnetic-field exposure and ALS and the authors noted that "the results should be interpreted with caution" (Jalilian et al., 2021, p. 1).

Grebeneva et al. (2021) evaluated morbidity among electric power company workers in Kazakhstan. The authors included three groups of "exposed" workers who worked at electric substations (a total of 161 workers) and controls "who were not associated with exposure to electromagnetic fields (114 people)." Morbidity was assessed "based on analyzing the sick leaves of employees" from 2010 to 2014 and expressed as "incidence rate per 100 employees."

The authors reported higher "incidence rate" of "diseases of the nervous system" in two of the exposed categories compared to the non-exposed group. No meaningful conclusions from the study could be drawn, however, because no specific diagnoses within "diseases of the nervous system" were presented in the paper. The study also had a small sample size and short follow up period. In addition, no measured or calculated magnetic-field levels were presented by the authors.

Assessment

In recent years, multiple studies examined the potential relationship between EMF, electric shocks, and neurodegenerative diseases. Many of these studies represented methodological improvements (e.g., increased sample size, improved exposure assessment, inclusion of incidence cases) compared to previous studies. In spite of these methodological improvements, the overall evidence from these studies provided no consistent or convincing support for a causal association. The most recent SCENIHR report (2015) concluded that newly published studies "do not provide convincing evidence of an increased risk of neurodegenerative diseases, including dementia, related to ELF MF [magnetic field] exposure" (SCENIHR, 2015, p. 186). In their 2020 review of research data gaps, ICNIRP concluded, "[f]urther epidemiological and experimental studies on Alzheimer's disease and ALS would be useful" (ICNIRP, 2020, p. 535).

Table 7. Relevant studies of neurodegenerative disease (December 2018 - December 2021)

Authors	Year	Study
Chen et al.	2021	Associations of occupational exposures to electric shocks and extremely low-frequency magnetic fields with motor neurone disease.
Filippini et al.	2020	Environmental and occupational risk factors of amyotrophic lateral sclerosis: a population-based case-control study.
Filippini et al.	2021	Residential exposure to electromagnetic fields and risk of amyotrophic lateral sclerosis: a dose-response meta-analysis.
Gervasi et al.	2019	Residential distance from high-voltage overhead power lines and risk of Alzheimer's dementia and Parkinson's disease: a population-based case-control study in a metropolitan area of Northern Italy.
Grebeneva et al.	2021	Evaluating occupational morbidity among energy enterprise employees in industrial region of Kazahstan.
Gunnarsson and Bodin	2018	Amyotrophic lateral sclerosis and occupational exposures: a systematic literature review and meta-analysis.
Gunnarsson and	2019	Occupational exposures and neurodegenerative diseases – a

Authors	Year	Study
Bodin		systematic literature review and meta-analysis.
Huang et al.	2020	Association of occupational factors and dementia or cognitive impairment: a systematic review and meta-analysis.
Jalilian et al.	2021	Amyotrophic lateral sclerosis, occupational exposure to extremely low frequency magnetic fields and electric shocks: a systematic review and meta-analysis.
Peters et al.	2019	Associations of electric shock and extremely low-frequency magnetic field exposure with the risk of amyotrophic lateral sclerosis.

Cardiovascular disease

A hypothesis asserts 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)

As discussed in Exponent (2019), Elmas (2016) summarized some of the literature examining the effects of EMF exposure on the heart. The review included studies that assessed the relationship between long-term occupational exposure and heart rate, as well as several studies examining short-term exposure and various health impacts. The author concluded that "despite these studies, the effects of EMFs on the heart remain unclear" and that there is "not yet any consensus in these works about possible mechanisms by which effects of EMF exposure may occur" (Elmas, 2016, p. 80).

Recent studies (December 2018 through December 2021)

The study by Grebeneva et al. (2021), described above, also evaluated the occurrence of "diseases of the circulatory system" among other diseases and reported higher "incidence rate" of these conditions in two of the exposed categories compared to the non-exposed group. No meaningful conclusions from the study can be drawn due to the same limitations discussed above.

Assessment

The conclusion that there is no association between magnetic fields and cardiovascular diseases has not changed. Regarding research on cardiovascular outcomes, ICNIRP concluded in their 2020 review of potential research gaps that "the research available at the time the ICNIRP 2010 Guidelines were drafted provided convincing null findings, which suggest there are no data gaps in this area that require research" (ICNIRP, 2020, p. 534).

Table 8. Relevant studies of cardiovascular disease (December 2018 - December 2021)

Authors	Year	Study
Grebeneva et al.	2021	Evaluating occupational morbidity among energy enterprise employees in industrial region of Kazahstan.

In vivo studies related to carcinogenesis

In the field of ELF EMF research, a number of research laboratories have conducted studies that 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 tumors in many organs. These studies are known as chronic bioassays.

In addition to these studies, magnetic-field exposure was administered alone (to test for the ability of magnetic fields to act as a complete carcinogen). Other studies exposed animals to a known carcinogen at the same time they were exposed to magnetic fields to assess their cancer-promoting capability.

Another type of study exposed animals to magnetic fields and examined biological processes of only indirect relevance to the development of cancer but are nonetheless of interest to scientists. These studies investigated biomarkers of damage to deoxyribonucleic acid (DNA) and factors affecting the oxidation of DNA and other molecules. Recently, the scope of these studies was expanded to investigate the potential therapeutic benefits of EMF exposure on the development of tumors implanted in animals.

The overall conclusion of the WHO regarding animal studies was that "[o]verall there is no evidence that ELF exposure alone causes tumours. The evidence that ELF field exposure can enhance tumour development in combination with carcinogens is inadequate" (WHO, 2007, p. 322).

The state of this research as reviewed by the WHO and more recent publications reviewed in the Exponent (2019) report are summarized.

Chronic bioassays

The WHO review (2007) 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 review. Some animals, however, develop a type of lymphoma similar to childhood ALL and studies exposing these 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 Lerchl, 2004). Following the release of the WHO review, Bernard et al. (2008) reported that magnetic-field exposure did not affect development of the most common form of childhood leukemia induced in a rat model by a chemical carcinogen.

As evaluated in Exponent (2019), subsequent chronic bioassays from the Ramazzini Institute were entirely consistent with prior studies (Soffritti et al., 2016a, 2016b), but a small study of shorter duration reported some differences between exposed and control groups among female mice, but not males (Qi et al., 2015). Serious limitations in the design, conduct, and reporting of these more recent studies, however, undercut the weight given to the results of these studies.

Carcinogenic agents plus magnetic fields (combined)

Studies investigated whether exposure to magnetic fields can promote cancer or act as a co-carcinogen in treated animals in combination with known cancer-causing agents, such as ionizing radiation, ultraviolet radiation, or other chemicals. While no effects were observed in these studies on chemically-induced, pre-neoplastic liver lesions, leukemia or lymphoma, skin tumors, or brain tumors (WHO, 2007, Tables 78-79), the WHO noted that 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 tumors initiated by this chemical carcinogen. 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 protocols and the species strain. In Fedrowitz et al. (2004) and Fedrowitz and Löscher (2008), 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.[9]

Exponent (2019) evaluated studies reported by the Ramazzini Institute that reported weak evidence for interactions between magnetic fields and exposure to ionizing radiation (Soffritti et al., 2015; 2016a) and formaldehyde (Soffritti et al., 2016b) but the methods and limitations of these studies are similar to other reports from the Ramazzini Institute that reported no effects of magnetic field alone and merit little weight.

Magnetic-field effects on cellular processes potentially relevant to cancer

Some studies reviewed by the WHO 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. More recent studies in which animals were exposed to higher

[9] The WHO concluded with respect to the German studies of mammary carcinogenesis, "[i]nconsistent 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).

levels of magnetic fields for longer exposure periods reported no increase in damage to DNA (Saha et al., 2014; Korr et al., 2014). Indicators of biological processes that might lead to DNA damage are constantly investigated, but while short-term effects on indicators of oxidation in tissues show some effects at very high levels (100,000 mG), effects at lower (but still high) levels (1,000 mG) are inconsistent and longer exposures do not result in greater responses (Akdag et al., 2013; Glinka et al., 2013; Hassan and Abdelkawai, 2014; Manikonda et al., 2014).

Studies reviewed in Exponent (2019) had scattered results in this category. Alcaraz et al. (2014) reported an increase in micronuclei in erythrocytes of mice following exposure to a 2,000 mG, 50-Hz, magnetic field, which had not been reported by others at lower levels of magnetic fields and was unaffected by concomitant antioxidant treatment. Wilson et al (2015) reported that magnetic field up to 3,000 mG did not increase mutations in blood cells of mice or a dose-related increase in testes. A follow up study reported no increase the amount of DNA breaks produced by X-rays or affect the repair of DNA damage caused by X-rays (Woodbine et al., 2015).

Exponent (2019) also evaluated studies that reported effects of magnetic field on oxidative indicators in the blood of rats and mice at field levels of 80,000 to 200,000 mG (Li et al., 2015; Luo et al., 2016).

In summary, the WHO concluded the following with respect to *in vivo* research related to cancer: "[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. 322). Subsequent research, as reviewed in Exponent (2019) and below, has not provided any clear support for the idea that magnetic fields promote the development of tumors initiated by carcinogenic chemicals or that magnetic fields have any confirmed effect on oxidative processes that might damage DNA or other cellular components linked to cancer.

Recent *in vivo* studies of carcinogenesis (December 2018 through December 2021)

Cancer bioassays

As noted above, past large-scale, long-term bioassays of magnetic-field exposures reported that lifetime exposure to magnetic fields do not initiate or promote tumor development in rodents. No new studies of this type have been published in the most recent evaluation period.

Carcinogenic treatments plus magnetic fields (combined)

The Ramazzini Institute republished some data from its previous research (Soffritti and Giuliani, 2019), which was reviewed in Exponent (2019).

Other investigators developed a new model for childhood leukemia by inserting the gene ETV6-RUNX1 into fertilized mouse embryos (Rodriquez-Hernandez et al., 2017). This gene is found in about 25% of children with ALL. They observed that about 11% of the mice born with this gene developed leukemia if raised under ordinary laboratory conditions in which bacterial and viral infections were common. In a subsequent pilot study by Campos-Sanchez et al. (2019), these genetically-modified mice were exposed to a 50-Hz magnetic fields at 15,000 mG. The authors were unable to assess an effect because of the small number of mice studied, the low frequency of disease development, and the lack of sham controls. No further research on this animal model has been published.

EMF effects on cellular processes potentially relevant to cancer

While the case could be made that almost any biochemical process might be related to cancer, historically, processes relating to damage to DNA and chromosomes have been given the most attention and weight (IARC, 1999).

Aslankoc et al. (2018) assessed epididymal sperm count, motility, and DNA damage in male Wistar rats (8 rats randomly assigned per group) exposed to a 50-Hz electric field at 10 kV/m or sham control exposure for 23 hours per day and 0.1 milliliters (ml) of physiological serum via oral gavage for 30 days. There were no significant differences between the control group and electric-field treated animals on overall body temperature, testicular temperature, testicular weight, testosterone, follicle-stimulating hormone, luteinizing hormone, and catalase. Relative to control animals, rats exposed to electric fields had increased body weight and body weight gain, higher comet scores for epididymal spermatozoa, increased malondialdehyde (MDA) levels, and more apoptotic cells in terminal deoxynucleotidyl transferase (TdT) dUTP Nick-End Labeling (TUNEL) analysis. In addition, rats exposed to electric fields had reduced epididymal sperm count and sperm motility, superoxide dismutase (SOD), and glutathione peroxidase.

The explanation for these results would seem to be the “vacuolisation, germ cell decrease in the seminiferous epithelium … oedema and vascular congestion in the interstitial tissue.” Based on these findings, the authors concluded that exposure to 50-Hz electric fields for 23 hours per day for 30 days resulted in DNA damage and oxidative stress that may have adversely affected male fertility. The histological results, however, support an alternative explanation. That is, the intermittent contact of the testes (with lower resistance than the feet) with the metal floor electrode led to current flow, and perhaps even spark discharges, which were the primary source of damage to the testes. In addition, the investigators did not consider that such a very strong electric field from high-voltage electrodes would be stressful to the rats because of the physical stimulation of the body fur and vibrissae and the generation of ozone (e.g., Goheen et al., 2004). The study also included two other groups: electric-field exposed plus the antioxidant resveratrol, and only resveratrol. In general, resveratrol treatment partially ameliorated the effects of electric fields. This study is limited by the use of a single electric-field dose, poor exposure assessment, absence of experimenter blinding, and no functional confirmation of infertility (i.e., breeding), which contrast to the otherwise thorough and well-done assessment of male reproductive tissues and physiology.

Magnetic- and electric-field treatments on tumor growth

In recent years, multiple studies have investigated the therapeutic potential of magnetic-field and electric-field exposures in the treatment of experimentally-induced tumors.

Yadamani et al. (2018) injected TUBO breast cancer cells in mice (8 per group) and 14 days later compared the morphology of cells from a single tissue section from the tumor of one control mouse with a single tissue section from the tumor of another mouse exposed to a 40,000 mG, 50-Hz magnetic field for 90 minutes per day for 14 days. The study stated that compared to control mice, treated mice showed decreases in the number of core cells, blood vessels, and cell structural appearance, which was accompanied by apoptosis. This study is limited by the use of a single magnetic-field level, the incomplete reporting of results, and an analysis of just one mouse each from the control and treatment group. In addition, the authors did not specify whether animals were randomly assigned to exposure or control groups or were handled similar to the exposed group (sham controls), and they provided little detail on experimental methods, including the coding of the samples to prevent bias in the analysis of the samples and data. No weight can be given to this study given the multiple limitations of the methods and analyses.

Rageh et al. (2020) tested whether magnetic fields would enhance the anti-tumor action of cisplatin, a drug used to treat solid tumors of the breast, lung, and neck. Ehrlich carcinoma tumor cells were subcutaneously injected into the right flank of female BALB/c mice and 14 days later randomly assigned to groups of 10 mice in: 1) a control group; 2) groups of mice treated with doses of cisplatin (3 or 6 milligrams per kilogram [mg/kg] intraperitoneal); 3) a group exposed to 3 mg/kg cisplatin and a 50,000 mG, 500-Hz magnetic field for 30 minutes, and 4) a group treated just with the magnetic field. Mice were administered cisplatin on experimental days 1, 4, and 8, while magnetic-field exposure occurred daily for 2 weeks. The growth of tumors was assessed by tumor volume and tumor and kidney tissues were analyzed by histologic and biochemical tests.

Cisplatin at low and high doses, and the combination of low dose cisplatin and magnetic-field exposure, significantly decreased tumor volumes. Perhaps contrary to expectation, the high dose of cisplatin was significantly less effective than the low dose of cisplatin in reducing tumor volume; the addition of the magnetic field to the low dose had little effect. Four interrelated metrics used to evaluate DNA damage as measured in comet assays of tumors and kidneys were similar in both tissues. There were no differences between the DNA damage metrics of mice exposed to magnetic fields alone and the DNA damage metrics of control mice in tumor tissue. In kidney tissue, mice exposed to magnetic fields alone had a significantly higher percent of DNA in tail than control mice, with no other significant differences observed in other comet parameters for kidney tissue. The concurrent administration of cisplatin and magnetic fields, however, significantly increased the DNA damage to the tumors, but had little effect on the damage to the kidney compared to low dose cisplatin. The authors report that damage to the kidney (nephrotoxicity) is a common effect of cisplatin administration.

Contrary to the author's global summary of the study results "the magnetic field … reduce[s] the nephrotoxicity [of cisplatin]," the DNA damage as indicated by all metrics showed that the low dose cisplatin + magnetic-field treatment was marginally greater, not lower, than the damage from low dose cisplatin alone. The study also measured a positive correlation between indices of DNA damage and MDA and negative correlations with antioxidant enzyme SOD, glutathione (GSH) level, and tumor volume, but no analysis of magnetic-field data was included in the paper. This study is limited by the use of a single magnetic-field dose, inadequate description of methods, including magnetic-field exposure, the lack of sham-exposed controls, the lack of randomization of mice to groups or blind analysis of data, no specification of counts of Ehrlich carcinoma tumor cells transplanted into animals, incomplete presentation of data, and unclear summaries and analyses of most results. No weight can be given to the results of this study regarding magnetic fields.

Orel et al. (2021) exposed Walker-256 carcinosarcoma-bearing rats (n=10 per group) to 50-Hz EMF plus doxorubicin (DOX) (a drug used to treat hematologic and solid tumors) or DOX alone, to assess the therapeutic potential of these combined treatments. The rats were not randomly allocated to control and treatment groups. Rats were implanted with carcinosarcoma cells (2 x 10^6 microliters medium 199) in the right hind dorsum. Two days following implantation, animals were administered 1.5 mg/kg DOX intravenously. Rats in the EMF condition were anesthetized and exposed to a 2 kV/m, 50-Hz electric field and a magnetic field of 164 mG [2,040 Amperes/meter], for 80 minutes every 2 days for a total of five exposures, but the control animals to which they were compared were not handled similarly or anesthetized, which would have qualified as a sham control.

Although not discussed by the authors, EMF treatment alone produced a dramatic reduction in tumor growth (volume) over the 14 days of the study compared to untreated rats, and treatment with DOX and DOX + EMF produced further reductions in tumor growth. Tumor-bearing animals with no treatment, DOX, or EMF alone had significantly reduced body weight gain relative to DOX + EMF treated animals. Survival rates of tumor-bearing rats did not differ; however, all intervention groups showed improved survival relative to controls. The authors also examined the histological structure of the liver and blood components indicative of hepatic redox processes. All treatments reduced the activity of antioxidant enzymes SOD, CAT, and GSH activity of the liver and increased liver enzymes (alanine aminotransferase and aspartate aminotransferase) in the blood. Another indicator of liver damage, thiobarbituric acid reactive substances (TBARS), was increased in control rats with tumors and those treated with DOX; however, EMF alone or EMF+ DOX reduced this measure of toxicity by about 60%. Although the description of the methods and clarity of the analysis was better in this study than the Rageh et al. (2020) study, it shared limitations (single dose of EMF, no randomization, no blinded analysis, and no sham-exposed control group). The latter omission is serious because the repeated handling and anesthesia of the EMF-treated groups produced stress not experienced by rats in the control group and the DOX alone group, and the isoflurane anesthesia administered with EMF could have affected the metabolism and toxicity of DOX as well as measures of redox status. Thus, it is impossible to separate the effects attributed to EMF from those of the co-administered anesthetic.

Occupational biomarker studies

Bagheri Hosseinabadi et al. (2019) performed a cross-sectional study[10] of 102 thermal power plant workers and 136 office workers in Shahroud, Iran, that measured aspects of DNA damage in blood lymphocytes in these groups by the comet assay as well as indicators of programmed cell destruction (apoptosis) by flow cytometry. Measured electric fields and magnetic fields and self-estimated time spent at workstations were used to compute TWA exposures. The analyses ranked the power plant workers by exposure into three groups and 50 cells from each subject were classified for DNA characteristics for five inter-related indices from the alkaline comet assay. The EMF measurements and comet assays were performed by separate persons and the comet assays were analyzed in a blinded fashion.

Differences between power plant workers for four of five of these indices from the comet assay by level of magnetic-field exposure were reported, but not on the most commonly reported measure of damage—length of the comet tail. Data from flow cytometry also indicated significant differences between the plant worker groups on cellular apoptosis but not measured DNA damage. Comparisons of power plant and office workers on these comet assay measures showed small numerical differences between these groups with great variability. Statistical differences between these exposed groups were reported for three of the five indices. No explanation was given for the authors' failure to report the results of flow cytometry analyses of the comparison group of office workers.

Zendehdel et al. (2019) performed a cross-sectional study of workers at an electric generating plant. They reported a statistically significant difference in DNA strand breaks measured by the comet assay in blood cells between 29 power plant workers and a support group of 28 members. Although the two groups of workers were similar with respect to age, length of work experience, and smoking status, the investigators made no effort to compare the workers with regard to exposure to the many chemical exposures within in a coal-fired power plant that have been

[10] In a cross-sectional study, the investigators determine the study subjects' exposure and outcome status at the same time; thus, these types of studies are not suitable to draw any conclusion on a potential causal association.

associated with indicators of DNA damage (Celik et al., 2007) or social or economic factors. In addition, Zendehdel et al. (2019) reported no attempt to prevent bias in the collection and analysis of the samples by investigators by standard procedures for blinding. The authors did not report the time separating the measurement of the magnetic field and blood drawing.

Zendehdel et al. (2020) reported further cross-sectional analyses of data collected in their previous study (Zendehdel et al., 2019). In this latest study they compared measurements of the Fourier transform infrared (FITR) absorption spectra of DNA and hemoglobin extracted from the blood of workers in the powerhouse. The population consisted of controller workers with a mean exposure to magnetic fields of about 100 mG [10 µT] for 70% of their work time (n=29) and administrators in the powerhouse with somewhat lower mean magnetic-field exposure (60 mG [6 µT]) (n=29). Measurements of ELF magnetic fields were obtained from 78 stations in the power production site. Median exposure to magnetic fields of controllers was 8.5 mG [0.85 µT] (range of 40 to 500 mG [4 to 50 µT]) while median exposure to magnetic field of administrators was 5 mG [0.5 µT]. Participants in both groups were males employed at the powerhouse for 5 to 12 years, were between the ages of 30 and 46, and had similar smoking histories. No data on workplace use, exposure to solvents, or airborne emissions from the power generating plant were provided. The total hemoglobin concentration was reported only for controller subjects and was stated to be significantly lower than the levels of administrative subjects. Wave numbers associated with COO glutamic acid in the FITR spectra were reported to be marginally (14%) lower in controllers compared to administrators. Differences between the two groups in six molecular characteristics of DNA also were statistically significant, but neither the direction of the difference nor the data were shown.

Since this paper is among the first to apply the FITR spectroscopy to the study of these biomolecules from the environment, it should have confirmed that these changes were related to or indicative of functional changes and had overcome known problems of this method (Han, 2018). For example, the authors could have compared molecular changes in DNA measured in this study to the measures of DNA damage obtained from the comet assays of the same subjects in the earlier study. Or, they could have confirmed that exposure of DNA and hemoglobin *in vitro* to magnetic fields produced the same specific changes to the molecules as reported in human subjects. This study is limited by its retrospective cross-sectional design and other major failures in the design and analysis, including no substantiated relevance to biological endpoints of interest, and no clear support that the reported changes had any relationship to magnetic-field levels experienced by these groups (e.g., correlation between measurements on individual subjects with long-term measurements).

Another cross-sectional study examined 15 male workers who maintain 225-kV and 400-kV transmission lines, who also live near these lines and substations, and 25 male controls (Touitou et al., 2020). No details on the controls were provided. The exposed workers had 1 to 20 years of experience in this type of work. The workers' magnetic-field exposures were measured at 30 second intervals for 1 week; the average magnetic-field levels of the exposed workers was 9 mG and the exposure of controls averaged 0.9 mG. From 10 PM to 8 AM, 13 blood samples were drawn from each participant, and chromogranin A (CgA), a general, non-specific marker that is elevated by neuroendocrine tumors and by stimulation of the adrenal gland by stress, was measured in each sample. The CgA levels were observed to decrease steadily at the same rate from a nighttime peak in both the exposed and control groups. The results did not indicate that elevated exposure to magnetic fields had any significant effect on this indicator.

In weighing the findings of the studies that measured DNA damage and related parameters, it is important to note that the measurement of DNA characteristics of single cells in the comet assay is a specialized and highly technical process that requires considerable experience. None of the laboratories that performed the sample analyses appeared to have demonstrated expertise, nor the historical database necessary, to carry out these complex tests, and none of the data reported in these studies met the criteria required to confirm a clear positive response (OECD, 2015).

Oxidative indicator studies

Normal cellular processes produce reactive oxygen and other oxidant species, and while they are effectively managed by other cellular functions, when they are produced in great excess, they can be damaging to DNA and other cell components and may support some carcinogenic processes. Several studies investigated a variety of indicators of oxidative stress in blood samples. It is important, however, not to simply assume that substances that increase oxidative stress are harmful, and antioxidants, including some vitamins, are beneficial. For example, there are clinical trials and other studies that report antioxidants may damage DNA (Fox et al., 2012), may not protect against cancer in humans (Goodman et al., 2011), and may increase cancer risk and tumor progression (Sayin et al., 2014).

Bagheri Hosseinabadi et al. (2020) conducted a double-blind randomized control trial to assessing whether administration of vitamin E (400 units), vitamin C (1,000 milligrams [mg]), or a combination in cocoa milk, attenuated DNA fragmentation below that of a randomly selected control group. The subjects were recruited from a thermal power plant in Semnan, Iran, and. Participants (n=91; 21 to 24/group) were employed at the thermal power plant for at least 2 years (technicians, engineers, operators, and office workers). In this study, the average magnetic-field exposure was 16.5 µT (165 mG) and electric-field exposure was 22.5 V/m, but these exposures did not differ between the employees who were allocated to the control group or groups that were treated with vitamins. EMF measurements and sample collection were similar to those used in the previous study (Bagheri Hosseinabadi et al., 2019). The study did not report when the EMF measurements were taken or the times when blood sample collections were made before and after the treatment period. Employees working more than 10 years at the plant had significantly more tail DNA on the comet assay than workers employed for shorter durations, and there were no differences in pre-treatment levels of any DNA measure reported for the groups. After the treatment period, post-measurements of apoptosis did not differ from pre-treatment levels following any treatments. In contrast, several post-treatment comet assay indicators in the vitamin C, vitamin E, and vitamins C+E groups were significantly lower than in the post-treatment control group. Administration of 400 units of vitamin E predicted a greater decreased DNA damage on comet assay better than other intervention groups; however, there was a significant decrease in comet indices for all groups, except control. Because of the short duration of this study and absence of follow-up with participants, it cannot be determined if these findings have any relevance to a long-term benefit of these supplements or the cocoa milk to workers, or any relationship to EMF, chemical, or other conditions in this population, or to past or future risks of cancer. While Bagheri Hosseinabadi et al. (2020) provides information on vitamin supplements, it provided no insight on the role magnetic fields may have in cell DNA attributes. Data from the same study subjects were later analyzed for measures of antioxidant vitamins on oxidative stress and proinflammatory cytokines (Bagheri Hosseinabadi et al., 2021a), and also were not related to measurements of magnetic fields. The results also appear inconsistent with a lack of effect of antioxidants on mutation frequencies of mice exposed to magnetic fields (Alcaraz et al., 2014).

Bagheri Hosseinabadi et al. (2021b) analyzed the same samples (or workers) as evaluated for DNA damage in the earlier Bagheri Hosseinabadi et al. (2019) cross-sectional study of power plant workers. In this study, they report that MDA, SOD, and catalase indicators of oxidative stress increased with the mean level of magnetic-field exposure of three groups within the plant. The results were quite similar for the three groups segregated by level of electric-field exposure. In contrast, the overall total antioxidant capacity measure did not differ between the three groups of workers. The study did not provide sufficient data and analyses to assess whether the differences in the indicators resulted from just the magnetic field, just the electric field, or both fields. The similarity in the results also could occur because work locations closer to equipment would tend to increase both electric-field and magnetic-field exposure, as well temperate and airborne exposures. The authors acknowledged the limitations of the cross-sectional design of the study and discussed similarities and differences in the outcomes of earlier studies.

Assessmen

No new long-term cancer bioassay studies, the gold standard for identifying carcinogens in animals, were reported in this period. No other studies that combined exposure to carcinogens + magnetic fields were reported. One study reported a spectrum of effects in the testes of male rats exposed to a 10 kV/m electric field, including DNA damage, for which conducted currents and discharges from contact with one of the exposure electrodes is a plausible explanation, not the induction of an electric field in tissue through the air (Aslankoc et al., 2018).

The idea that magnetic fields might enhance the effect of drugs used to treat cancer was explored in three studies in which animals were injected with tumor cells and then given chemical chemotherapy alone, magnetic field alone, or both. Two studies reported that the magnetic field alone at levels of 40,000 mG (Yadamani et al., 2018) or 50,000 magnetic + 2 kV/m electric fields (Orel et al., 2021) reduced the growth of tumors. The third study reported that magnetic fields exposure enhanced the effect of an anti-tumor drug on tumor volume (Rageh et al., 2020).

Recent studies also investigated two potential mechanisms related to carcinogenesis: genotoxicity and oxidative stress. Three investigators performed cross-sectional studies of workers in a substation, arc welding, electrical power plant, and high-voltage transmission line workers to compare markers of damage to DNA damage or neuroendocrine tumors in blood samples from workers with varying EMF exposures. Two studies reported small differences in comet assay measures of DNA damage between groups of workers that were not fully consistent within the studies (Bagheri Hosseinabadi et al., 2019; Zendehdel et al., 2019, 2020). A much smaller study (Touitou et al., 2020), reported no differences between exposed and unexposed workers with a history of 1 to 20 years of work at a utility on a biomarker for stress and neuroendocrine tumors despite a 10-fold difference in their measured exposures to magnetic fields.

A cross-sectional study of workers in a thermal power plant reported lower levels, of DNA damage measured by the comet assay when taking vitamins than a control group but included no analyses of EMF exposure (Bagheri Hosseinabadi et al., 2020). A second cross-sectional study by this group reported measures of oxidative stress were elevated in thermal power plant workers categorized by higher magnetic- and electric-field exposures, but the analysis was insufficient to isolate EMF from other likely exposures (Bagheri Hosseinabadi et al., 2021b). A third study of power plant workers tested whether antioxidant vitamins had an effect on blood levels of proinflammatory cytokines. Reductions were reported but these results were not related to levels of magnetic-field exposure and so were not informative (Bagheri Hosseinabadi et al., 2021a).

Overall, the *in vivo* studies of EMF published since the last update do not alter the WHO's conclusion that the overall evidence from *in vivo* studies does not support the role of EMF exposure in genotoxic effects and continues to show that there is inadequate evidence of carcinogenicity due to EMF exposure. The quality of most studies, however, leaves much to be improved, so the recommendation that "further studies on mechanisms and biological data from childhood leukemia experimental models are recommended" is appropriate (ICNIRP, 2020, p. 535).

Table 9. Relevant *in vivo* studies related to carcinogenesis (December 2018 - December 2021)

Authors	Year	Study
Campos-Sanchez et al.	2017	Novel ETV6-RUNX1 mouse model to study the role of ELF-MF in childhood B-acute lymphoblastic leukemia: a pilot study.
Aslankoc et al.	2018	The impact of electric fields on testis physiopathology, sperm parameters and DNA integrity-The role of resveratrol.
Bagheri Hosseinabadi et al.	2019	DNA damage from long-term occupational exposure to extremely low frequency electromagnetic fields among power plant workers.
Zendehdel et al.	2019	DNA effects of low level occupational exposure to extremely low frequency electromagnetic fields (50/60 Hz).

Authors	Year	Study
Bagheri Hosseinabadi et al.	2020	The effect of vitamin E and C on comet assay indices and apoptosis in power plant workers: A double blind randomized controlled clinical trial
Orel et al.	2020	Effects induced by a 50 Hz electromagnetic field and doxorubicin on Walker-256 carcinosarcoma growth and hepatic redox state in rats.
Rageh et al	2020	Magnetic fields enhance the anti-tumor efficacy of low dose cisplatin and reduce the nephrotoxicity.
Touitou et al.	2020	Evaluation in humans of ELF-EMF exposure on chromogranin A, a marker of neuroendocrine tumors and stress.
Zendehdel et al.	2020	Quality assessment of DNA and hemoglobin by Fourier transform infrared spectroscopy in occupational exposure to extremely low-frequency magnetic field.
Bagheri Hosseinabadi et al.	2021a	The effects of antioxidant vitamins on proinflammatory cytokines and some biochemical parameters of power plant workers: A double-blind randomized controlled clinical trial.
Bagheri Hosseinabadi et al.	2021b	Oxidative stress associated with long term occupational exposure to extremely low frequency electric and magnetic fields.

5 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 4.

The following list indicates the scientific organization and a link to the online reports or statements. Although not listed below, the recent *Report on Carcinogens* from the NTP did not list either ELF EMF as "Known To Be Human Carcinogens" or "Reasonably Anticipated To Be Human Carcinogens" (NTP, 2021).

- **The European Health Risk Assessment Network on Electromagnetic Fields Exposure**
    - http://efhran.polimi.it/docs/IMS-EFHRAN_09072010.pdf (EFHRAN, 2010 [*in vitro* and *in vivo* studies])
    - http://efhran.polimi.it/docs/D2_Finalversion_oct2012.pdf (EFHRAN, 2012 [human exposure])
- **The Health Council of Netherlands**
    - http://www.gezondheidsraad.nl/en/publications/bioinitiative-report-0 (HCN, 2008a)
    - http://www.gezondheidsraad.nl/en/publications/high-voltage-power-lines-0 (HCN, 2008b)
    - 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)

- **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)
  - https://www.icnirp.org/cms/upload/publications/ICNIRPlfgaps2020.pdf (ICNIRP, 2020)
- **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 (SSI)

  - https://www.stralsakerhetsmyndigheten.se/contentassets/d5e931cff47b498099d7bcddae5ec6a7/200501--reports-from-ssis-international-independent-expert-group-on-electromagnetic-fields-2003-and-2004 (SSI, 2005)
  - https://www.stralsakerhetsmyndigheten.se/contentassets/54f003dfe0ec4a24a9b212963841983f/200704-recent-research-on-emf-and-health-risks.-fourth-annual-report-from-ssis-independent-expert-group-on-electromagnetic-fields-2006 (SSI, 2006)
  - https://www.stralsakerhetsmyndigheten.se/contentassets/119df5b843164b93be8f7143321af021/200812-recent-research-on-emf-and-health-risks.-fifth-annual-

report-from-ssis-independent-expert-group-on-electromagnetic-fields-2007 (SSI, 2007)

- https://www.stralsakerhetsmyndigheten.se/contentassets/119df5b843164b93be8f7143321af021/200812-recent-research-on-emf-and-health-risks.-fifth-annual-report-from-ssis-independent-expert-group-on-electromagnetic-fields-2007 (SSI, 2008)

- **The Swedish Radiation Safety Authority (SSM)**
    - https://www.stralsakerhetsmyndigheten.se/contentassets/921664c245584802811f517dbba81e7d/200936-recent-research-on-emf-and-health-risks.-sixth-annual-report-from-ssms-independent-expert-group-on-electromagnetic-fields-2009 (SSM, 2009)
    - https://www.stralsakerhetsmyndigheten.se/contentassets/63e6735284dc4634830c4dd6003d9b07/201044-recent-research-on-emf-and-health-risk-seventh-annual-report-from-ssms-independent-expert-group-on-electromagnetic-fields-2010 (SSM, 2010)
    - https://www.stralsakerhetsmyndigheten.se/contentassets/7f20edcd0b024940bca450d596568e30/201319-eighth-report-from-ssms-scientific-council-on-electromagnetic-fields (SSM, 2013)
    - https://www.stralsakerhetsmyndigheten.se/contentassets/08b2f497b3ad48cf9e29a1d0008e7d82/201416-recent-research-on-emf-and-health-risk-ninth-report-from-ssms-scientific-council-on-electromagnetic-fields-2014 (SSM, 2014)
    - https://www.stralsakerhetsmyndigheten.se/contentassets/ee7b28e0fee04e80bcaf84c24663a004/201519-recent-research-on-emf-and-health-risk---tenth-report-from-ssms-scientific-council-on-electromagnetic-fields-2015 (SSM, 2015)
    - https://www.stralsakerhetsmyndigheten.se/contentassets/98d67d9e3301450da4b8d2e0f6107313/201615-recent-research-on-emf-and-health-risk-eleventh-report-from-ssms-scientific-council-on-electromagnetic-fields-2016 (SSM, 2016)

- https://www.stralsakerhetsmyndigheten.se/contentassets/f34de8333acd4ac2b22a9b072d9b33f9/201809-recent-research-on-emf-and-health-risk (SSM, 2018)
- https://www.stralsakerhetsmyndigheten.se/contentassets/ea182ee131d049f1b3b1140dd0fbc0f8/201908-recent-research-on-emf-and-health-risk-thirteenth-report-from-ssms-scientific-council-on-electromagnetic-fields-2018.pdf (SSM, 2019)
- https://www.stralsakerhetsmyndigheten.se/contentassets/47542ee6308b4c76b1d25ae0adceca15/2020-04-recent-research-on-emf-and-health-risk---fourteenth-report-from-ssms-scientific-council-on-electromagnetic-fields-2019.pdf (SSM, 2020)
- https://www.stralsakerhetsmyndigheten.se/contentassets/fce87121bd5e47ca95ad16d93d03f638/202108-recent-research-on-emf-and-health-risk.pdf (SSM, 2021)

6 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. 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. 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 International Committee on Electromagnetic Safety (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 (Exposure Reference Level) of 9,040 mG and an occupational exposure limit of 27,100 mG for 60-Hz magnetic fields (ICES, 2019, 2020). 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. Florida and New York have enacted standards to limit magnetic fields at the edge of the right-of-way from transmission lines (NYPSC, 1978, 1990; FDER, 1989; FDEP, 1996). The basis for these limits, however, was to maintain the status quo so that fields from new transmission lines would be no higher than those produced by existing transmission lines.

In a 1985 decision, the Massachusetts Energy Facilities Siting Board (EFSB) approved an edge-of-ROW level of 85 mG as a benchmark for comparing different design alternatives. Since then, this benchmark has not served as a generally applicable standard or guideline. Instead, the EFSB has encouraged the use of practical and cost-effective designs to minimize magnetic-field levels along the edges of transmission line 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 guideline
ICNIRP	Occupational	10,000 mG
	General Public	2,000 mG
ICES	Occupational	27,100 mG
	General Public	9,040 mG

Sources: ICNIRP, 2010; ICES, 2019, 2020.

7 Summary

A significant number of epidemiologic and *in vivo* studies have been published on ELF EMF and health since the WHO 2007 report was released. The weak statistical association between high, average magnetic fields and childhood leukemia reported in two pooled analyses in 2000 (Ahlbom et al., 2000; Greenland et al., 2000) has not been appreciably strengthened by later research. To the contrary, the strength of the association has diminished over time, and the latest pooled analysis of epidemiology studies published on this topic in the past 10 years that analyzed populations of cases and controls three to five times larger than the original pooled analyses reported "no association between MF [magnetic fields] and childhood leukemia" (Amoon et al., 2022). Thus, the conclusion by the WHO in 2007, that there is "[c]onsistent epidemiological evidence" of an association between magnetic-field exposure and childhood leukemia development (WHO 2007, p. 355), is inconsistent with newer data. The previously reported association in some studies remains unexplained and unsupported by experimental studies. The recent *in vivo* experimental studies confirm the lack of experimental data for genotoxic effects of ELF EMF that would support a leukemogenic or other cancer. Publications on other cancer and non-cancer outcomes evaluated provided no substantial new information to alter the previous conclusion that the evidence is inadequate to conclude that ELF EMF exposure is harmful at typical environmental levels.

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

8 References

Ahlbom A, Day N, Feychting M, Roman E, Skinner J, Dockerty J, Linet M, McBride M, Michaelis J, Olsen JH, Tynes T, Verkasalo PK. A pooled analysis of magnetic fields and childhood leukaemia. Br J Cancer 83:692-698, 2000.

Akdag MZ, Dasdag S, Cakir DU, Yokus B, Kizil G, Kizil M. Do 100- and 500-muT ELF magnetic fields alter beta-amyloid protein, protein carbonyl and malondialdehyde in rat brains? Electromagn Biol Med 32:363-372, 2013.

Alcaraz M, Olmos E, Alcaraz-Saura M, Achel DG, Castillo J. Effect of long-term 50 Hz magnetic field exposure on the micronucleated polychromatic erythrocytes of mice. Electromagn Biol Med 33:51-47, 2014.

Amoon AT, Oksuzyan S, Crespi CM, Arah OA, Cockburn M, Vergara X, Kheifets L. Residential mobility and childhood leukemia. Environ Res 164:459-466, 2018a.

Amoon AT, Crespi CM, Ahlbom A, Bhatnagar M, Bray I, Bunch KJ, Clavel J, Feychting M, Hemon D, Johansen C, Kreis C, Malagoli C, Marquant F, Pedersen C, Raaschou-Nielsen O, Röösli M, Spycher BD, Sudan M, Swanson J, Tittarelli A, Tuck DM, Tynes T, Vergara X, Vinceti M, Wunsch-Filho V, Kheifets L. Proximity to overhead power lines and childhood leukaemia: an international pooled analysis. Br J Cancer 119:364-373, 2018b.

Amoon AT, Arah OA, Kheifets L. The sensitivity of reported effects of EMF on childhood leukemia to uncontrolled confounding by residential mobility: a hybrid simulation study and an empirical analysis using CAPS data. Cancer Causes Control 30(8):901-908, 2019.

Amoon AT, Crespi CM, Nguyen A, Zhao X, Vergara X, Arah OA, Kheifets L. The role of dwelling type when estimating the effect of magnetic fields on childhood leukemia in the California Power Line Study (CAPS). Cancer Causes Control 31(6):559-567, 2020.

Amoon AT, Swanson J, Magnani C, Johansen C, Kheifets L. Pooled analysis of recent studies of magnetic fields and childhood leukemia. Environ Res 204(Pt A):111993, 2022 (Epub 2021).

Ancel PY, Goffinet F, EPIPAGE 2 Writing Group. EPIPAGE 2: A preterm birth cohort in France in 2011. BMC Pediatr 14:97, 2014.

Anderson LE, Boorman GA, Morris JE, Sasser LB, Mann PC, Grumbein SL, Hailey JR, McNally A, Sills RC, Haseman JK. Effect of 13 week magnetic field exposures on DMBA-initiated mammary gland carcinomas in female Sprague-Dawley rats. Carcinogenesis 20:1615-20, 1999.

Aslankoc R, Gumral N, Saygin M, Senol N, Asci H, Cankara FN, Comlekci S. The impact of electric fields on testis physiopathology, sperm parameters and DNA integrity—The role of resveratrol. Andrologia 50:e12971, 2018.

Auger N, Park AL, Yacouba S, Goneau M, Zayed J Stillbirth and residential proximity to extremely low frequency power transmission lines: a retrospective cohort study. Occup Environ

Med 69:147-149, 2012.

Auger N, Bilodeau-Bertrand M, Marcoux S, Kosatsky T. Residential exposure to electromagnetic fields during pregnancy and risk of child cancer: A longitudinal cohort study. Environ Res 176:108524, 2019a.

Auger N, Arbour L, Luo W, Lee GE, Bilodeau-Bertrand M, Kosatsky T. Maternal proximity to extremely low frequency electromagnetic fields and risk of birth defects. Eur J Epidemiol 34(7):689-697, 2019b.

Bagheri Hosseinabadi MB, Khanjanib N, Mirzaiic M, Norouzic P, Atashid A. DNA damage from long-term occupational exposure to extremely low frequency electromagnetic fields among power plant workers. Mut Res - Gen Tox En Mut 846:403079, 2019.

Bagheri Hosseinabadi M, Khanjanib N, Atashic A, Norouzic P, Mirbadiec SR, Mirzaiic M. The effect of vitamin E and C on comet assay indices and apoptosis in power plant workers: A double blind randomized controlled clinical trial. Mut Res - Gen Tox En Mut 850–851:503150, 2020.

Bagheri Hosseinabadi M, Khanjani N, Norouzi P, Faghihi-Zarandi A, Darban-Sarokhalil D, Khoramrooz SS, Mirbadie SR, Mirzaii M. The effects of antioxidant vitamins on proinflammatory cytokines and some biochemical parameters of power plant workers: A double-blind randomized controlled clinical trial. Bioelectromagnetics 42(1):18-26, 2021a.

Bagheri Hosseinabadi M, Khanjani N, Norouzi P, Mirbadie SR, Fazli M, Mirzaii M. Oxidative stress associated with long term occupational exposure to extremely low frequency electric and magnetic fields. Work 68(2):379-386, 2021b.

Baum A, Mevissen M, Kamino K, Mohr U, Löscher W. A histopathological study on alterations in DMBA-induced mammary carcinogenesis in rats with 50 Hz, 100 muT magnetic field exposure. Carcinogenesis 16:119-125, 1995.

Bernard N, Alberdi AJ, Tanguy ML, Brugere H, Helissey P, Hubert C, Gendrey N, Guillosson JJ, Nafziger J. Assessing the potential leukemogenic effects of 50 Hz magnetic fields and their harmonics using an animal leukemia model. J Radiat Res 49(6):565-577, 2008.

Bonnet-Belfais M, Lambrozo J, Aurengo A. Comment: childhood leukaemia and power lines--the Geocap study: is proximity an appropriate MF exposure surrogate? Br J Cancer 109:1382-1383, 2013.

Boorman GA, Anderson LE, Morris JE, Sasser LB, Mann PC, Grumbein SL, Hailey JR, McNally A, Sills RC, Haseman JK. Effect of 26 week magnetic field exposures in a DMBA initiation-promotion mammary gland model in Sprague-Dawley rats. Carcinogenesis 20:899-904, 1999a.

Boorman GA, McCormick DL, Findlay JC, Hailey JR, Gauger JR, Johnson TR, Kovatch RM, Sills RC, Haseman JK. Chronic toxicity/oncogenicity evaluation of 60 Hz (power frequency) magnetic fields in F344/N rats. Toxicol Pathol 27:267-278, 1999b.

Bozzoni V, Pansarasa O, Diamanti L, Nosari G, Cereda C, Ceroni M. Amyotrophic lateral sclerosis and environmental factors. Funct Neurol 31:7-19, 2016.

Brouwer M, Koeman T, van den Brandt PA, Kromhout H, Schouten LJ, Peters S, Huss A, Vermeulen R. Occupational exposures and Parkinson's disease mortality in a prospective Dutch cohort. Occup Environ Med 72:448-455, 2015.

Bunch KJ, Keegan TJ, Swanson J, Vincent TJ, Murphy MF. Residential distance at birth from overhead high-voltage powerlines: childhood cancer risk in Britain 1962-2008. Br J Cancer 110:1402-1408, 2014.

Bunch KJ, Swanson J, Vincent TJ, Murphy MF. Magnetic fields and childhood cancer: an epidemiological investigation of the effects of high-voltage underground cables. J Radiol Prot 35:695-705, 2015.

Bunch KJ, Swanson J, Vincent TJ, Murphy MF. Epidemiological study of power lines and childhood cancer in the UK: further analyses. J Radiol Prot 36:437-455, 2016.

Campos-Sanchez E, Vicente-Duenas C, Rodriguez-Hernandez G, Capstick M, Kuster N, Dasenbrock C, Sanchez-Garcia I, and Cobaleda C. Novel Etv6-Runx1 mouse model to study the role of ELF-MF in childhood B-acute lymphoblastic leukemia: A pilot study. Bioelectromagnetics 40:343-353, 2019.

Carlberg M, Koppel T, Ahonen M, Hardell L. Case-control study on occupational exposure to extremely low-frequency electromagnetic fields and glioma risk. Am J Ind Med 60:494-503, 2017.

Carlberg M, Koppel T, Ahonen M, Hardell L. Case-control study on occupational exposure to extremely low-frequency electromagnetic fields and the association with meningioma. Biomed Res Int 2018:5912394, 2018.

Carlberg M, Koppel T, Ahonen M, Hardell L. Case-control study on occupational exposure to extremely low-frequency electromagnetic fields and the association with acoustic neuroma. Environ Res 187:109621, 2020.

Carles C, Esquirol Y, Turuban M, Piel C, Migault L, Pouchieu C, Bouvier G, Fabbro-Peray P, Lebailly P, Baldi I. Residential proximity to power lines and risk of brain tumor in the general population. Environ Res 185:109473, 2020.

Celik M, Donbak L, Unal F, Yüzbasioglu D, Aksoy H, Yilmaz S. Cytogenetic damage in workers from a coal-fired power plant. Mutat Res 627(2):158-163, 2007.

Chang ET, Adami HO, Bailey WH, Boffetta P, Krieger RI, Moolgavkar SH, Mandel JS. Validity of geographically modeled environmental exposure estimates. Crit Rev Toxicol 44:450-466, 2014.

Checkoway H, Ilango S, Li W, Ray RM, Tanner CM, Hu SC, Wang X, Nielsen S, Gao DL, Thomas DB. Occupational exposures and parkinsonism among Shanghai women textile workers. Am J Ind Med 61:886-892, 2018.

Chen GX, Mannetje A, Douwes J, van den Berg LH, Pearce N, Kromhout H, Glass B, Brewer N, McLean DJ. Associations of Occupational Exposures to Electric Shocks and Extremely Low-Frequency Magnetic Fields With Motor Neurone Disease. Am J Epidemiol 190(3):393-402, 2021.

Clavel J, Sermage-Faure C, Demoury C, Rudant J, Goujon-Bellec S, Guyot-Goubin A, Deschamps F, Hemon D. Reply: comment on Childhood leukaemia close to high-voltage power lines--the Geocap study, 2002-2007--is proximity an appropriate MF exposure surrogate? Br J Cancer 109:1383-1384, 2013.

Crespi CM, Vergara XP, Hooper C, Oksuzyan S, Wu S, Cockburn M, Kheifets L. Childhood leukaemia and distance from power lines in California: a population-based case-control study. Br J Cancer 115:122-128, 2016.

Crespi CM, Swanson J, Vergara XP, Kheifets L. Childhood leukemia risk in the California Power Line Study: Magnetic fields versus distance from power lines. Environ Res 171:530-535, 2019.

Das K, Nag C, Ghosh M. Familial, environmental, and occupational risk factors in development of amyotrophic lateral sclerosis. N Am J Med Sci 4:350-355, 2012.

de Vocht F and Lee B. Residential proximity to electromagnetic field sources and birth weight: Minimizing residual confounding using multiple imputation and propensity score matching. Environ Int 69:51-57, 2014.

de Vocht F, Hannam K, Baker P, Agius R. Maternal residential proximity to sources of extremely low frequency electromagnetic fields and adverse birth outcomes in a UK cohort. Bioelectromagnetics 35:201-209, 2014.

Draper G, Vincent T, Kroll ME, Swanson J. Childhood cancer in relation to distance from high voltage power lines in England and Wales: A case-control study. BMJ 330:1290, 2005.

Elliott P, Shaddick G, Douglass M, de Hoogh K, Briggs DJ, Toledano MB. Adult cancers near high-voltage overhead power lines. Epidemiology 24:184-190, 2013.

Elmas O. Effects of electromagnetic field exposure on the heart: a systematic review. Toxicol Ind Health 32:76-82, 2016.

Eskelinen T, Roivainen P, Makela P, Keinanen J, Kauhanen O, Saarikoski S, Juutilainen J. Maternal exposure to extremely low frequency magnetic fields: Association with time to pregnancy and foetal growth. Environ Int 94:620-625, 2016.

Esmailzadeh S, Agajani Delavar M, Gholamian SA, Ahmadi A, Hosseinpour Haydari F, Pourali M. Electromagnetic fields exposure from power lines and human fertility. Iran J Public Health 48(5):986-987, 2019.

European Health Risk Assessment Network on Electromagnetic Fields Exposure (EFHRAN). Report on the Analysis of Risks Associated to Exposure to EMF: *In Vitro* and *In Vivo* (Animals) Studies. Milan, Italy: EFHRAN, 2010.

European Health Risk Assessment Network on Electromagnetic Fields Exposure (EFHRAN). Risk Analysis of Human Exposure to Electromagnetic Fields (Revised). Report D2 of the EFHRAN Project. Milan, Italy: EFHRAN, 2012.

Exponent, Inc. Current Status of Research on Extremely Low Frequency Electric and Magnetic Fields and Health 2014-2018, prepared for the Rhode Island Energy Facilities Siting Board. Bowie, MD: Exponent, Inc., 2019.

Federal-Provincial-Territorial Radiation Protection Committee (FPTRPC). Health Effects and Exposure Guidelines Related to Extremely Low Frequency Electric and Magnetic Fields - An Overview. Ottawa: Health Canada, 2005.

Fedrowitz M, Kamino K, Löscher W. Significant differences in the effects of magnetic field exposure on 7,12-dimethylbenz(a)anthracene-induced mammary carcinogenesis in two substrains of Sprague-Dawley rats. Cancer Res 64:243-251, 2004.

Fedrowitz M and Loscher W. Exposure of Fischer 344 rats to a weak power frequency magnetic field facilitates mammary tumorigenesis in the DMBA model of breast cancer. Carcinogenesis 29:186-193, 2008.

Filippini T, Tesauro M, Fiore M, Malagoli C, Consonni M, Violi F, Iacuzio L, Arcolin E, Oliveri Conti G, Cristaldi A, Zuccarello P, Zucchi E, Mazzini L, Pisano F, Gagliardi I, Patti F, Mandrioli J, Ferrante M, Vinceti M. Environmental and occupational risk factors of amyotrophic lateral sclerosis: A population-based case-control study. Int J Environ Res Public Health 17(8):2882, 2020.

Filippini T, Hatch EE, Vinceti M. Residential exposure to electromagnetic fields and risk of amyotrophic lateral sclerosis: a dose-response meta-analysis. Sci Rep 11(1):11939, 2021.

Fischer H, Kheifets L, Huss A, Peters TL, Vermeulen R, Ye W, Fang F, Wiebert P, Vergara XP, Feychting M. Occupational exposure to electric shocks and magnetic fields and amyotrophic lateral sclerosis in Sweden. Epidemiology 26:824-830, 2015.

Florida Department of Environmental Protection (FDEP). Electric and Magnetic Fields. Chapter 62-814. 1996.

Florida Department of Environmental Regulation (FDER). Electric and Magnetic Fields. Chapter 17-274. 1989.

Fox JT, Sakamuru S, Huang R, Teneva N, Simmons SO, Xia M, Tice RR, Austin CP, Myung K. High-throughput genotoxicity assay identifies antioxidants as inducers of DNA damage response and cell death. Proc Natl Acad Sci USA 109:5423-5428, 2012.

Gauger JR. Household appliance magnetic field survey. IEEE Trans Power App Syst 104:2436-2444, 1985.

Gervasi F, Murtas R, Decarli A, Russo AG. Residential distance from high-voltage overhead power lines and risk of Alzheimer's dementia and Parkinson's disease: a population-based case-control study in a metropolitan area of Northern Italy. Int J Epidemiol 48(6):1949-1957, 2019.

Glinka M, Sieron A, Birkner E, Cieslar G. Influence of extremely low-frequency magnetic field on the activity of antioxidant enzymes during skin wound healing in rats. Electromagn Biol Med 32:463-470, 2013.

Gobba F, Bravo G, Rossi P, Contessa GM, Scaringi M. Occupational and environmental exposure to extremely low frequency-magnetic fields: a personal monitoring study in a large group of workers in Italy. J Expo Sci Environ Epidemiol 21:634-645, 2011.

Goheen SC, Gaither K, Anantatmula SM, Mong GM, Sasser LB, Lessor D. Corona discharge influences ozone concentrations near rats. Bioelectromagnetics 25(2):107-113, 2004.

Goodman M, Bostick RM, Kucuk O, Jones DP. Clinical trials of antioxidants as cancer prevention agents: past, present, and future. Free Radic Biol Med 51:1068-1084, 2011.

Gordis L. Epidemiology. Philadelphia: WB Saunders Company, 2000.

Grebeneva OV, Rybalkina DH, Ibrayeva LK, Shadetova AZ, Drobchenko EA, Aleshina NY. Evaluating occupational morbidity among energy enterprise employees in industrial region of Kazakhstan. ROMJ 10(3):e0319, 2021.

Greenland S, Sheppard AR, Kaune WT, Poole C, Kelsh MA. A pooled analysis of magnetic fields, wire codes, and childhood leukemia. Childhood Leukemia-EMF Study Group. Epidemiology 11:624-634, 2000.

Grell K, Meersohn A, Schüz J, Johansen C. Risk of neurological diseases among survivors of electric shocks: a nationwide cohort study, Denmark, 1968-2008. Bioelectromagnetics 33:459-465, 2012.

Grimes DR and Heathers J. Association between magnetic field exposure and miscarriage risk is not supported by the data. Sci Rep 11(1):22143, 2021.

Grundy A, Harris SA, Demers PA, Johnson KC, Agnew DA, Villeneuve PJ. Occupational exposure to magnetic fields and breast cancer among Canadian men. Cancer Med 5:586-596, 2016.

Gunnarsson LG and Bodin L. Amyotrophic lateral sclerosis and occupational exposures: A systematic literature review and meta-analyses. Int J Environ Res Public Health 15(11):2371, 2018.

Gunnarsson LG and Bodin L. Occupational exposures and neurodegenerative diseases: A systematic literature review and meta-analyses. Int J Environ Res Public Health 16(3):337, 2019.

Habash M, Gogna P, Krewski D, Habash RWY. Scoping review of the potential health effects of exposure to extremely low-frequency electric and magnetic fields. Crit Rev Biomed Eng 47(4):323-347, 2019.

Han Y, Han L, Yao Y, Lia Y, Liu X. Key factors in FTIR spectroscopic analysis of DNA: The sampling technique, pretreatment temperature and sample concentration. Anal Methods 10:2436-2443, 2018.

Hardell L, Carlberg M, Mild KH. Case-control study of the association between the use of cellular and cordless telephones and malignant brain tumors diagnosed during 2000-2003. Environ Res 100:232-241, 2006.

Hardell L, Carlberg M, Söderqvist F, Mild KH. Case-control study of the association between malignant brain tumours diagnosed between 2007 and 2009 and mobile and cordless phone use. Int J Oncol 43(6):1833-1845, 2013.

Harris AW, Basten A, Gebski V, Noonan D, Finnie J, Bath ML, Bangay MJ, Repacholi MH. A test of lymphoma induction by long-term exposure of E mu-Pim1 trangenic mice to 50 Hz magnetic fields. Radiat Res 149:300-307, 1998.

Hassan NS and Abdelkawi SA. Assessing of plasma protein denaturation induced by exposure to cadmium, electromagnetic fields and their combined actions on rat. Electromagn Biol Med 33:147-153, 2014.

Health Council of the Netherlands (HCN). BioInitiative Report. The Hague: HCN, 2008a.

Health Council of the Netherlands (HCN). High-Voltage Power Lines. Publication Number: 2008/04E. The Hague: HCN, 2008b.

Health Council of the Netherlands (HCN). Electromagnetic Fields: Annual Update. Publication No. 2009/02. The Hague: HCN, 2009a.

Health Council of the Netherlands (HCN). Advisory letter - Power lines and Alzheimer's disease. The Hague: HCN, 2009b.

Health Protection Agency (HPA). Power Frequency Electromagnetic Fields, Melatonin and the Risk of Breast Cancer: Report of an Independent Advisory Group on Non-ionising Radiation. Documents of the Health Protection Agency. Series B: Radiation, Chemical and Environmental Hazards. Oxfordshire: HPA, 2006.

Hill AB. The Environment and Disease: Association or Causation? Proc R Soc Med 58: 295-300, 1965.

Huang LY, Hu HY, Wang ZT, Ma YH, Dong Q, Tan L, Yu JT. Association of occupational factors and dementia or cognitive impairment: A systematic review and meta-analysis. J Alzheimers Dis 78(1):217-227, 2020.

Huss A, Spoerri A, Egger M, Kromhout H, Vermeulen R. Occupational extremely low frequency magnetic fields (ELF-MF) exposure and hematolymphopoietic cancers - Swiss National Cohort analysis and updated meta-analysis. Environ Res 164:467-474, 2018a.

Huss A, Peters S, Vermeulen R. Occupational exposure to extremely low-frequency magnetic fields and the risk of ALS: A systematic review and meta-analysis. Bioelectromagnetics 39:156-163, 2018b.

Ingle ME, Minguez-Alarcon L, Lewis RC, Williams PL, Ford JB, Dadd R, Hauser R, Meeker JD, Team ES. Association of personal exposure to power-frequency magnetic fields with pregnancy outcomes among women seeking fertility treatment in a longitudinal cohort study. Fertil Steril 114(5):1058-1066, 2020.

Ingre C, Roos PM, Piehl F, Kamel F, Fang F. Risk factors for amyotrophic lateral sclerosis. Clin Epidemiol 7:181-193, 2015.

International Agency for Research on Cancer (IARC). The Use of Short- and Medium-Term Tests for Carcinogens and Data on Genetic Effects in Carcinogenic Hazard Evaluation. Lyon, France: International Agency for Research on Cancer (IARC), 1999.

International Agency for Research on Cancer (IARC). IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Volume 80: Static and Extremely Low-Frequency (ELF) Electric and Magnetic Fields. Lyon, France: IARC Press, 2002.

International Commission on Non-ionizing Radiation Protection (ICNIRP). Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz to 100 kHz). Health Phys 99: 818-836, 2010.

International Commission on Non-Ionizing Radiation Protection (ICNIRP). Gaps in Knowledge Relevant to the "Guidelines for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1 Hz-100 kHz)." Health Phys 118(5):533-542, 2020.

International Committee for Electromagnetic Safety (ICES). IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz. New York: IEEE, 2019.

International Committee on Electromagnetic Safety (ICES). IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz (Std. C95.1): Corrigenda 2. New York: IEEE, 2020.

Jalilian H, Teshnizi SH, Röösli M, Neghab M. Occupational exposure to extremely low frequency magnetic fields and risk of Alzheimer disease: A systematic review and meta-analysis. Neurotoxicology 69:242-252, 2018.

Jalilian H, Najafi K, Khosravi Y, Roosli M. Amyotrophic lateral sclerosis, occupational exposure to extremely low frequency magnetic fields and electric shocks: a systematic review and meta-analysis. Rev Environ Health 36(1):129-142, 2021.

Khan MW, Juutilainen J, Auvinen A, Naarala J, Pukkala E, Roivainen P. A cohort study on adult hematological malignancies and brain tumors in relation to magnetic fields from indoor transformer stations. Int J Hyg Environ Health 233:113712, 2021.

Kheifets L and Oksuzyan S. Exposure assessment and other challenges in non-ionizing radiation studies of childhood leukaemia. Radiat Prot Dosimetry 132:139-147, 2008.

Kheifets L, Monroe J, Vergara X, Mezei G, Afifi AA. Occupational electromagnetic fields and leukemia and brain cancer: an update to two meta-analyses. J Occup Environ Med 50:677-688, 2008.

Kheifets L, Bowman JD, Checkoway H, Feychting M, Harrington JM, Kavet R, Marsh G, Mezei G, Renew DC, van Wijngaarden E. Future needs of occupational epidemiology of extremely low frequency electric and magnetic fields: review and recommendations. Occup Environ Med 66:72-80, 2009.

Kheifets L, Ahlbom A, Crespi CM, Draper G, Hagihara J, Lowenthal RM, Mezei G, Oksuzyan S, Schüz J, Swanson J, Tittarelli A, Vinceti M, Wunsch Filho V. Pooled analysis of recent studies on magnetic fields and childhood leukaemia. Br J Cancer 103:1128-1135, 2010a.

Kheifets L, Ahlbom A, Crespi CM, Feychting M, Johansen C, Monroe J, Murphy MF, Oksuzyan S, Preston-Martin S, Roman E, Saito T, Savitz D, Schüz J, Simpson J, Swanson J, Tynes T, Verkasalo P, Mezei G. A pooled analysis of extremely low-frequency magnetic fields and childhood brain tumors. Am J Epidemiol 172:752-761, 2010b.

Kheifets L, Crespi CM, Hooper C, Cockburn M, Amoon AT, Vergara XP. Residential magnetic fields exposure and childhood leukemia: a population-based case-control study in California. Cancer Causes Control 28:1117-1123, 2017.

Koeman T, van den Brandt PA, Slottje P, Schouten LJ, Goldbohm RA, Kromhout H, Vermeulen R. Occupational extremely low-frequency magnetic field exposure and selected cancer outcomes in a prospective Dutch cohort. Cancer Causes Control 25:203-214, 2014.

Koeman T, Schouten LJ, van den Brandt PA, Slottje P, Huss A, Peters S, Kromhout H, Vermeulen R. Occupational exposures and risk of dementia-related mortality in the prospective Netherlands Cohort Study. Am J Ind Med 58:625-635, 2015.

Koeman T, Slottje P, Schouten LJ, Peters S, Huss A, Veldink JH, Kromhout H, van den Brandt PA, Vermeulen R. Occupational exposure and amyotrophic lateral sclerosis in a prospective cohort. Occup Environ Med 74: 578-585, 2017.

Korr H, Angstman NB, Born TB, Bosse K, Brauns B, Demmler M, Fueller K, Kantor O, Kever BM, Rahimyar N, Salimi S, Silny J, Schmitz C. 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. PLoS One 9:e109774, 2014.

Kyriakopoulou A, Meimeti E, Moisoglou I, Psarrou A, Provatopoulou X, Dounias G. Parental occupational exposures and risk of childhood acute leukemia. Mater Sociomed 30:209-214, 2018.

Lai H and Singh NP. Magnetic-field induced DNA strand breaks in brain cells of the rat. Environ Health Perspect 113:687-694, 2004.

Lee GM, Neutra RR, Hristova L, Yost M, Hiatt RA. A nested case-control study of residential and personal magnetic field measures and miscarriages. Epidemiology 13:21-31, 2002.

Lewis RC, Evenson KR, Savitz DA, Meeker JD. Temporal variability of daily personal magnetic field exposure metrics in pregnant women. J Expo Sci Environ Epidemiol 25:58-64, 2015.

Lewis RC, Hauser R, Maynard AD, Neitzel RL, Wang L, Kavet R, Meeker JD. Exposure to power-frequency magnetic fields and the risk of infertility and adverse pregnancy outcomes: update on the human evidence and recommendations for future study designs. J Toxicol Environ Health B Crit Rev 19:29-45, 2016.

Li DK, Odouli R, Wi S, Janevic T, Golditch I, Bracken TD, Senior R, Rankin R, Iriye R. A population-based prospective cohort study of personal exposure to magnetic fields during pregnancy and the risk of miscarriage. Epidemiology 13:9-20, 2002.

Li W, Ray RM, Thomas DB, Yost M, Davis S, Breslow N, Gao DL, Fitzgibbons ED, Camp JE, Wong E, Wernli KJ, Checkoway H. Occupational exposure to magnetic fields and breast cancer among women textile workers in Shanghai, China. Am J Epidemiol 178:1038-1045, 2013.

Li L, Xiong DF, Liu JW, Li ZX, Zeng GC, Li HL. A cross-sectional study on oxidative stress in workers exposed to extremely low frequency electromagnetic fields. Int J Radiat Biol 91:420-425, 2015.

Li DK, Chen H, Ferber JR, Odouli R, Quesenberry C. Exposure to magnetic field non-ionizing radiation and the risk of miscarriage: A prospective cohort study. Sci Rep 7:17541, 2017.

Li DK, Chen H, Ferber JR, Hirst AK, Odouli R. Association between maternal exposure to magnetic field nonionizing radiation during pregnancy and risk of attention-deficit/hyperactivity disorder in offspring in a longitudinal birth cohort. JAMA Netw Open 3(3):e201417, 2020.

Li DK. Notice of retraction and replacement. Li et al. Association between maternal exposure to magnetic field non-ionizing radiation during pregnancy and risk of attention-deficit/hyperactivity disorder in offspring in a longitudinal birth cohort. JAMA Netw Open 2020;3(3):e201417. JAMA Netw Open 4(2):e2033605, 2021.

Linet MS, Wacholder S, Zahm SH. Interpreting epidemiologic research: Lessons from studies of childhood cancer. Pediatrics 112:218-232, 2003.

Löscher W and Mevissen M. Linear relationship between flux density and tumor co-promoting effect of prolonged magnetic field exposure in a breast cancer model. Cancer Lett 96:175-180, 1995.

Löscher W, Mevissen M, Lehmacher W, Stamm A. Tumor promotion in a breast cancer model by exposure to a weak alternating magnetic field. Cancer Lett 71:75-81, 1993.

Löscher W, Wahnschaffe U, Mevissen M, Lerchl A, Stamm A. Effects of weak alternating magnetic fields on nocturnal melatonin production and mammary carcinogenesis in rats. Oncology 51:288-295, 1994.

Löscher W, Mevissen M, Haussler B. Seasonal influence on 7,12-dimethylbenz[a]anthracene-induced mammary carcinogenesis in Spague-Dawley rats under controlled laboratory conditions. Pharmacol Toxicol 81:265-270, 1997.

Luo X, Chen M, Duan Y, Duan W, Zhang H, He Y, Yin C, Sun G, Sun X. Chemoprotective action of lotus seedpod procyanidins on oxidative stress in mice induced by extremely low-frequency electromagnetic field exposure. Biomed Pharmacother 82:640-648, 2016.

Magnani A, Balbo P, Facchini E, Occhetta E, Marino P. Lack of interference of electromagnetic navigation bronchoscopy to implanted cardioverter-defibrillator: in-vivo study. Europace 16:1767-1771, 2014.

Mahram M and Ghazavi M. The effect of extremely low frequency electromagnetic fields on pregnancy and fetal growth, and development. Arch Iran Med 16:221-224, 2013.

Mandeville R, Franco E, Sidrac-Ghall S, Paris-Nadon L, Rocheleau N, Mercier G, Desy M, Gaboury L. Evaluation of the potential carcinogenicity of 60 Hz linear sinusoidal continuous-wave magnetic fields in Fisher F344 rats. FAESB Journal 11:1127-1136, 1997.

Manikonda PK, Rajendra P, Devendranath D, Gunasekaran B, Channakeshava, Aradhya SR, Sashidhar RB, Subramanyam C. Extremely low frequency magnetic fields induce oxidative stress in rat brain. Gen Physiol Biophys 33:81-90, 2014.

McCormick DL, Ryan B, Findlay JC, Gauger JR, Johnson TR, Morrissey R, Boorman GA. Exposure to 60 Hz magnetic fields and risk of lymphoma in PIM transgenic and TSG-*p53* (*p53* knockout) mice. Carcinogenesis 19:1649-1653, 1998.

McCormick DL, Boorman GA, Findlay JC, Hailey JR, Johnson TR, Gauger JR, Pletcher JM, Sills RC, Haseman JK. Chronic toxicity/oncogenicity evaluation of 60 Hz (power frequency) magnetic fields in B6C3F1 mice. Toxicol Pathol 27:279-285, 1999.

Mevissen M, Stamm A, Buntenkotter S, Zwingleberg R, Wahnschaffe U, Löscher W. Effects of magnetic fields on mmmary tumor development induced by 7,12-dimethylbenz(a)anthracene in rats. Bioelectromagnetics 14:131-143, 1993a.

Mevissen M, Stamm A, Buntenkotter S, Zwingleberg R, Wahnschaffe U, Löscher W. Effects of AC Magnetic Field on DMBA-induced Mammary Carcinogenesis in Sprague-Dawley Rats. In Electricity and Magnetism in Biology and Medicine, Blank M (Ed.). San Francisco, CA: San Francisco Press, 1993b.

Mevissen M, Lerchl A, Löscher W. Study on pineal function and DMBA-induced breast cancer formation in rats during exposure to a 100-mG, 50 Hz magnetic field. J Toxicol Environ Health 48:169-185, 1996a

Mevissen M, Lerchl A, Szamel M, and Löscher W. Exposure of DMBA-treated female rats in a 50-Hz, 50-μT magneticfield: effects on mammary-tumor growth, melatonin levels, and T-lymphocyte activation. Carcinogenesis 17:903-910, 1996b.

Mevissen M, Haussler M, Lerchl A, Löscher W. Acceleration of mammary tumorigenesis by exposure of 7,12-dimethylbenz[a]anthracene-treated female rats in a 50-Hz, 100-microT magnetic field: replication study. J Toxicol Environ Health A 53:401-418, 1998.

Mezei G, Bracken TD, Senior R, Kavet R. Analyses of magnetic-field peak-exposure summary measures. J Expo Sci Environ Epidemiol 16:477-485, 2006.

Mezei G, Gadallah M, Kheifets L. Residential magnetic field exposure and childhood brain cancer: a meta-analysis. Epidemiology 19:424-430, 2008.

Migault L, Piel C, Carles C, Delva F, Lacourt A, Cardis E, Zaros C, de Seze R, Baldi I, Bouvier G. Maternal cumulative exposure to extremely low frequency electromagnetic fields and pregnancy outcomes in the Elfe cohort. Environ Int 112: 165-173, 2018.

Migault L, Garlantezec R, Piel C, Marchand-Martin L, Orazio S, Cheminat M, Zaros C, Carles C, Cardis E, Ancel PY, Charles MA, de Seze R, Baldi I, Bouvier G. Maternal cumulative exposure to extremely low frequency electromagnetic fields, prematurity and small for gestational age: a pooled analysis of two birth cohorts. Occup Environ Med 77(1):22-31, 2020.

National Institute of Environmental Health Sciences (NIEHS). EMF Questions & Answers. NIH Publication 02-4493. Research Triangle Park, NC: NIEHS, 2002.

National Radiological Protection Board (NRPB). Magnetic fields and miscarriage. Radiol Prot Bull No 1 (The eBulletin), June 2002.

National Radiological Protection Board (NRPB). Review of the Scientific Evidence for Limiting Exposure to Electromagnetic Fields (0-300 GHz). Volume 15, No. 3. Chilton, UK: NRPB, 2004.

National Toxicology Program (NTP). Descriptions of NTP Study Types. U.S. Department of Health and Human Services, 2015. https://ntp.niehs.nih.gov/testing/types/index.html.

National Toxicology Program (NTP). Report on Carcinogens, Fifteenth Edition. Research Triangle Park, NC: U.S. Department of Health and Human Services, 2021.

New York Public Service Commission (NYPSC). Opinion No. 78-13. Opinion and Order Determining Health and Safety Issues, Imposing Operating Conditions, and Authorizing, in Case 26529, Operation Pursuant to those Conditions, 1978.

New York Public Service Commission (NYPSC). Statement of Interim Policy on Magnetic Fields of Major Transmission Facilities. Cases 26529 and 26559 Proceeding on Motion of the Commission, 1990.

Núñez-Enríquez JC, Correa-Correa V, Flores-Lujano J, Perez-Saldivar ML, Jimenez-Hernandez E, Martin-Trejo JA, Espinoza-Hernandez LE, Medina-Sanson A, Cardenas-Cardos R, Flores-Villegas LV, Penaloza-Gonzalez JG, Torres-Nava JR, Espinosa-Elizondo RM, Amador-Sanchez R, Rivera-Luna R, Dosta-Herrera JJ, Mondragon-Garcia JA, Gonzalez-Ulibarri JE, Martinez-Silva SI, Espinoza-Anrubio G, Duarte-Rodriguez DA, Garcia-Cortes LR, Gil-Hernandez AE, Mejia-Arangure JM. Extremely low-frequency magnetic fields and the risk of childhood B-lineage acute lymphoblastic leukemia in a city with high incidence of leukemia and elevated exposure to ELF magnetic fields. Bioelectromagnetics 41(8):581-597, 2021.

Odutola MK, Benke G, Fritschi L, Giles GG, van Leeuwen MT, Vajdic CM. A systematic review and meta-analysis of occupational exposures and risk of follicular lymphoma. Environ Res 197:110887, 2021.

Okokon EO, Roivainen P, Kheifets L, Mezei G, Juutilainen J. Indoor transformer stations and

ELF magnetic field exposure: use of transformer structural characteristics to improve exposure assessment. J Expo Sci Environ Epidemiol 24(1):100-104, 2014.

Orel VE, Krotevych M, Dasyukevich O, Rykhalskyi O, Syvak L, Tsvir H, Tsvir D, Garmanchuk L, Orel Vcapital Ve C, Sheina I, Rybka V, Shults NV, Suzuki YJ, Gychka SG. Effects induced by a 50 Hz electromagnetic field and doxorubicin on Walker-256 carcinosarcoma growth and hepatic redox state in rats. Electromagn Biol Med 40(4):475-487, 2021.

Organisation for Economic Cooperation and Development (OECD). Guidance Document on Revisions to OECD Genetic Toxicology Test Guidelines. Paris, France: OECD, 2015.

Pedersen C, Raaschou-Nielsen O, Rod NH, Frei P, Poulsen AH, Johansen C, Schüz J. Distance from residence to power line and risk of childhood leukemia: a population-based case-control study in Denmark. Cancer Causes Control 25:171-177, 2014a.

Pedersen C, Brauner EV, Rod NH, Albieri V, Andersen CE, Ulbak K, Hertel O, Johansen C, Schüz J, Raaschou-Nielsen O. Distance to high-voltage power lines and risk of childhood leukemia - an analysis of confounding by and interaction with other potential risk factors. PLoS One 9:e107096, 2014b.

Pedersen C, Johansen C, Schüz J, Olsen JH, Raaschou-Nielsen O. Residential exposure to extremely low-frequency magnetic fields and risk of childhood leukaemia, CNS tumour and lymphoma in Denmark. Br J Cancer 113:1370-1374, 2015.

Pedersen C, Poulsen AH, Rod NH, Frei P, Hansen J, Grell K, Raaschou-Nielsen O, Schüz J, Johansen C. Occupational exposure to extremely low-frequency magnetic fields and risk for central nervous system disease: an update of a Danish cohort study among utility workers. Int Arch Occup Environ Health 90:619-628, 2017.

Peters S, Visser AE, D'Ovidio F, Beghi E, Chio A, Logroscino G, Hardiman O, Kromhout H, Huss A, Veldink J, Vermeulen R, van den Berg LH, Euro MC. Associations of electric shock and extremely low-frequency magnetic field exposure with the risk of amyotrophic lateral sclerosis. Am J Epidemiol 188(4):796-805, 2019.

Qi G, Zuo X, Zhou L, Aoki E, Okamula A, Watanebe M, Wang H, Wu Q, Lu H, Tuncel H, Watanabe H, Zeng S, Shimamoto F. Effects of extremely low-frequency electromagnetic fields (ELF-EMF) exposure on B6C3F1 mice. Environ Health Prev Med 20: 287-293, 2015.

Rageh MM, El-Garhy MR, Mohamad EA. Magnetic fields enhance the anti-tumor efficacy of low dose cisplatin and reduce the nephrotoxicity. Naunyn Schmiedebergs Arch Pharmacol 393(8):1475-1485, 2020.

Ren Y, Chen J, Miao M, Li DK, Liang H, Wang Z, Yang F, Sun X, Yuan W. Prenatal exposure to extremely low frequency magnetic field and its impact on fetal growth. Environ Health 18(1):6, 2019.

Ries L, Smith MA, Gurney JG, Linet M, Tamra T, Young JL, Bunin GR, eds. Cancer Incidence and Survival among Children and Adolescents: United States SEER Program 1975-1995. NIH Publication No. 99-4649. Bethesda, MD: National Cancer Institute, 1999.

Rodriguez- Hernandez G, Hauer J, Martin- Lorenzo A, Schafer D, Bartenhagen C, Garcia- Ramirez I, Auer F, Gonzalez- Herrero I, Ruiz- Roca L, Gombert M, Okpanyi V, FischerU, Chen C, Dugas M, Bhatia S, Linka RM, Garcia- Suquia M, Rascon- Trincado MV, Garcia- Sanchez A, Blanco O, Garcia- Cenador MB, Garcia- Criado FJ, Cobaleda C, Alonso- Lopez D, De Las Rivas J, Muschen M, Vicente- Duenas C, Sanchez- Garcia I, Borkhardt A. Infection exposure promotes ETV6- RUNX1 precursor B- cell leukemia via impaired H3K4 demethylases. Cancer Res 77:4365–4377, 2017.

Rothman KJ and Greenland S. Modern Epidemiology. Philadelphia: Lippencott-Raven Publishers, 1998.

Sadeghi T, Ahmadi A, Javadian M, Gholamian SA, Delavar MA, Esmailzadeh S, Ahmadi B, Hadighi MSH. Preterm birth among women living within 600 meters of high voltage overhead Power Lines: a case-control study. Rom J Intern Med 55:145-150, 2017.

Saha S, Woodbine L, Haines J, Coster M, Ricket N, Barazzuol L, Ainsbury E, Sienkiewicz Z, Jeggo P. 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. J R Soc Interface 11:20140783, 2014.

Salvan A, Ranucci A, Lagorio S, Magnani C. Childhood leukemia and 50 Hz magnetic fields: findings from the Italian SETIL case-control study. Int J Environ Res Public Health 12:2184-2204, 2015.

Savitz DA, Pearce NE, Poole C. Methodological issues in the epidemiology of electromagnetic fields and cancer. Epidemiol Rev 11:59-78, 1989.

Savitz DA, Liao D, Sastre A, Kleckner RC, Kavet R. Magnetic field exposure and cardiovascular disease mortality among electric utility workers. Am J Epidemiol 149:135-142, 1999.

Savitz DA. Magnetic fields and miscarriage. Epidemiology 13:1-4, 2002.

Savitz DA, Herring AH, Mezei G, Evenson KR, Terry JW, Jr., Kavet R. Physical activity and magnetic field exposure in pregnancy. Epidemiology 17:222-225, 2006.

Sayin VI, Ibrahim MX, Larsson E, Nilsson JA, Lindahl P, Bergo MO. Antioxidants accelerate lung cancer progression in mice. Sci Transl Med 6:221ra15, 2014.

Scientific Committee of Emerging and Newly Identified Health Risks (SCENIHR). Possible Effects of Electromagnetic Fields (EMF) on Human Health. Brussels, Belgium: European Commission, 2007.

Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR). Health Effects of Exposure to EMF. Brussels, Belgium: European Commission, 2009.

Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR). Memorandum on the use of the scientific literature for human risk assessment purposes – weighing of evidence and expression of uncertainty. Brussels, Belgium: European Commission, 2012.

Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR). Opinion on Potential Health Effects of Exposure to Electromagnetic Fields (EMF). Brussels, Belgium: European Commission, 2015.

Seomun G, Lee J, Park J. Exposure to extremely low-frequency magnetic fields and childhood cancer: A systematic review and meta-analysis. PLoS One 16(5):e0251628, 2021.

Sermage-Faure C, Demoury C, Rudant J, Goujon-Bellec S, Guyot-Goubin A, Deschamps F, Hemon D, Clavel J. Childhood leukaemia close to high-voltage power lines--the Geocap study, 2002-2007. Br J Cancer 108:1899-1906, 2013.

Shamsi Mahmoudabadi F, Ziaei S, Firoozabadi M, Kazemnejad A. Exposure to extremely low frequency electromagnetic fields during pregnancy and the risk of spontaneous abortion: A case-control study. J Res Health Sci 13:131-134, 2013.

Soffritti M and Giuliani L. The carcinogenic potential of non-ionizing radiations: The cases of S-50 Hz MF and 1.8 GHz GSM radiofrequency radiation. Basic Clin Pharmacol Toxicol 125 Suppl 3:58-69, 2019.

Soffritti M, Tibaldi E, Bua L, Padovani M, Falcioni L, Lauriola M, Manservigi M, Manservisi F, Belpoggi F. Life-span carcinogenicity studies on Sprague-Dawley rats exposed to gamma-radiation: design of the project and report on the tumor occurrence after post-natal radiation exposure (6 weeks of age) delivered in a single acute exposure. Am J Ind Med 58:46-60, 2015.

Soffritti M, Tibaldi E, Padovani M, Hoel DG, Giuliani L, Bua L, Lauriola M, Falcioni L, Manservigi M, Manservisi F, Panzacchi S, Belpoggi F. Life-span exposure to sinusoidal-50 Hz magnetic field and acute low-dose gamma radiation induce carcinogenic effects in Sprague-Dawley rats. Int J Radiat Biol 92:202-214, 2016a.

Soffritti M, Tibaldi E, Padovani M, Hoel DG, Giuliani L, Bua L, Lauriola M, Falcioni L, Manservigi M, Manservisi F, Belpoggi F. Synergism between sinusoidal-50 Hz magnetic field and formaldehyde in triggering carcinogenic effects in male Sprague-Dawley rats. Am J Ind Med 59:509-521, 2016b.

Sommer AM and Lerchl A. The risk of lymphoma in AKR/J mice does not rise with chronic exposure to 50 Hz magnetic fields (1 microT and 100 microT). Radiat Res 162:194-200, 2004.

Sorahan T. Cancer incidence in UK electricity generation and transmission workers, 1973-2008. Occup Med (Lond) 62:496-505, 2012.

Souques M, Magne I, Plante M, Point S. Letter to editor regarding "residential proximity to power lines and risk of brain tumor in the general population" by Carles C. and coll. Environ Res. 2020;185:109473. Doi: 10.1016/j.envres. 2020.109473. Environ Res 191:109904, 2020.

Stroup DF, Thacker SB, Olson CM, Glass RM, Hutwagner L. Characteristics of meta-analyses related to acceptance for publication in a medical journal. J Clinical Epidemiol 54:655-660, 2001.

Su L, Fei Y, Wei X, Guo J, Jiang X, Lu L, Chen G. Associations of parental occupational exposure to extremely low-frequency magnetic fields with childhood leukemia risk. Leuk Lymphoma 57:2855-2862, 2016.

Su L, Zhao C, Jin Y, Lei Y, Lu L, Chen G. Association between parental occupational exposure to extremely low frequency magnetic fields and childhood nervous system tumors risk: A meta-analysis. Sci Total Environ 642:1406-1414, 2018.

Sudan M, Arah OA, Becker T, Levy Y, Sigsgaard T, Olsen J, Vergara X, Kheifets L. Re-examining the association between residential exposure to magnetic fields from power lines and childhood asthma in the Danish National Birth Cohort. PLoS One 12:e0177651, 2017.

Suri S, Dehghan SF, Sahlabadi AS, Ardakani SK, Moradi N, Rahmati M, Tehrani FR. Relationship between exposure to Extremely Low-Frequency (ELF) magnetic field and the level of some reproductive hormones among power plant workers. J Occup Health 62(1):e12173, 2020.

Swanson J, Vincent TJ, Bunch KJ. Relative accuracy of grid references derived from postcode and address in UK epidemiological studies of overhead power lines. J Radiol Prot 34(4):N81-86, 2014.

Swanson J and Bunch KJ. Reanalysis of risks of childhood leukaemia with distance from overhead power lines in the UK. J Radiol Prot 38:N30-N35, 2018.

Swanson J, Kheifets L, Vergara X. Changes over time in the reported risk for childhood leukaemia and magnetic fields. J Radiol Prot 39(2):470-488, 2019.

Swedish Radiation Protection Authority (SSI). Reports from SSI's International Independent Expert Group on Electromagnetic Fields 2003 and 2004. SSI Rapport 2005:01. Stockholm, Sweden: SSI, 2005.

Swedish Radiation Protection Authority (SSI). Third annual report from SSI's Independent Expert Group on Electromagnetic Fields, 2005: Recent Research on EMF and Health Risks. SSI Rapport 2006:02. Stockholm, Sweden: SSI, 2006.

Swedish Radiation Protection Authority (SSI). Fourth annual report from SSI's Independent Expert Group on Electromagnetic Fields, 2006: Recent Research on EMF and Health Risks. SSI Rapport 2007:04. Stockholm, Sweden: Swedish Radiation Protection Authority, 2007.

Swedish Radiation Protection Authority (SSI). Fifth annual report from SSI's Independent Expert Group on Electromagnetic Fields, 2007. SSI Rapport 2008:12. Stockholm, Sweden: Swedish Radiation Protection Authority, 2008.

Swedish Radiation Safety Authority (SSM). Recent Research on EMF and Health Risks: Sixth annual report from SSM's independent Expert Group on Electromagnetic Fields 2009. SSM Rapport 2009:36. Stockholm, Sweden: SSM, 2009.

Swedish Radiation Safety Authority (SSM). Recent Research on EMF and Health Risks: Seventh annual report from SSMs independent Expert Group on Electromagnetic Fields 2010. SSM Rapport 2010:44. Stockholm, Sweden: SSM, 2010.

Swedish Radiation Safety Authority (SSM). Eighth Report from SSM:s Scientific Council on Electromagnetic Fields. Research 2013:19. Stockholm, Sweden: Swedish Radiation Safety Authority (SSM), 2013.

Swedish Radiation Safety Authority (SSM). Recent Research on EMF and Health Risk. Ninth report from SSM's Scientific Council on Electromagnetic Fields. Research 2014:16. Stockholm, Sweden: Swedish Radiation Safety Authority (SSM), 2014.

Swedish Radiation Safety Authority (SSM). Recent Research on EMF and Health Risk - Tenth report from SSM's Scientific Council on Electromagnetic Fields. Research 2015:19. Stockholm, Sweden: Swedish Radiation Safety Authority (SSM), 2015.

Swedish Radiation Safety Authority (SSM). Recent Research on EMF and Health Risk - Eleventh report from SSM's Scientific Council on Electromagnetic Fields, 2016. Including Thirteen years of electromagnetic field research monitored by SSM's Scientific Council on EMF and health: How has the evidence changed over time? Research 2016:15. Stockholm, Sweden: Swedish Radiation Safety Authority (SSM), 2016.

Swedish Radiation Safety Authority (SSM). Recent Research on EMF and Health Risk - Twelfth report from SSM's Scientific Council on Electromagnetic Fields, 2017. Research 2018:09. Stockholm, Sweden: Swedish Radiation Safety Authority (SSM), 2018.

Swedish Radiation Safety Authority (SSM). Recent Research on EMF and Health Risk - Thirteenth report from SSM's Scientific Council on Electromagnetic Fields, 2018. Research 2019:08. Stockholm, Sweden: Swedish Radiation Safety Authority (SSM), 2019.

Swedish Radiation Safety Authority (SSM). Recent Research on EMF and Health Risk - Fourteenth report from SSM's Scientific Council on Electromagnetic Fields, 2019. Research 2020:04. Stockholm, Sweden: Swedish Radiation Safety Authority (SSM), 2020.

Swedish Radiation Safety Authority (SSM). Research 2021:08. Recent Research on EMF and Health Risk - Fifteenth report from SSM's Scientific Council on Electromagnetic Fields, 2020. Stockholm, Sweden: Swedish Radiation Safety Authority (SSM), 2021.

Tabrizi MM and Bidgoli SA. Increased risk of childhood acute lymphoblastic leukemia (ALL) by prenatal and postnatal exposure to high voltage power lines: a case control study in Isfahan, Iran. Asian Pac J Cancer Prev 16:2347-2350, 2015.

Tabrizi MM and Hosseini SA. Role of Electromagnetic Field Exposure in Childhood Acute Lymphoblastic Leukemia and No Impact of Urinary Alpha- Amylase--a Case Control Study in Tehran, Iran. Asian Pac J Cancer Prev 16:7613-7618, 2015.

Talibov M, Guxens M, Pukkala E, Huss A, Kromhout H, Slottje P, Martinsen JI, Kjaerheim K, Sparen P, Weiderpass E, Tryggvadottir L, Uuksulainen S, Vermeulen R. Occupational exposure to extremely low-frequency magnetic fields and electrical shocks and acute myeloid leukemia in four Nordic countries. Cancer Causes Control 26:1079-1085, 2015.

Talibov M, Olsson A, Bailey H, Erdmann F, Metayer C, Magnani C, Petridou E, Auvinen A, Spector L, Clavel J, Roman E, Dockerty J, Nikkila A, Lohi O, Kang A, Psaltopoulou T, Miligi L, Vila J, Cardis E, Schuz J. Parental occupational exposure to low-frequency magnetic fields and risk of leukaemia in the offspring: findings from the Childhood Leukaemia International Consortium (CLIC). Occup Environ Med 76(10):746-753, 2019.

Touitou Y, Lambrozo J, Mauvieux B, and Riedel M. Evaluation in Humans of Elf-Emf Exposure on Chromogranin a, a Marker of Neuroendocrine Tumors and Stress. Chronobiol Int 37:60-67, 2020.

Turner MC, Benke G, Bowman JD, Figuerola J, Fleming S, Hours M, Kincl L, Krewski D, McLean D, Parent ME, Richardson L, Sadetzki S, Schlaefer K, Schlehofer B, Schüz J, Siemiatycki J, Van Tongeren M, Cardis E. Occupational exposure to extremely low frequency magnetic fields and brain tumour risks in the INTEROCC study. Cancer Epidemiol Biomarkers Prev 23:1863-1872, 2014.

US Department of Health Education and Welfare (HEW). Smoking and Health: Report of the Advisory Committee to the Surgeon General of the Public Health Service. PHS Publication No. 1103. Washington, DC: HEW, Public Health Service, Center for Disease Control, 1964.

US Department of Health and Human Services (HHS). Health Consequences of Smoking: A Report to the Surgeon General. Washington, DC: HHS, 2004.

US Environmental Protection Agency (USEPA). Reference Dose (RfD): Description and Use in Health Risk Assessments. Washington, DC: USEPA, 1993.

US Environmental Protection Agency (USEPA). Proposed Guidelines for Carcinogen Risk Assessments. EPA/600/P-92/003C. Washington, DC: USEPA, 1996.

US Environmental Protection Agency (USEPA). Update on Ramazzini Institute Data in IRIS Assessments. https://www.epa.gov/iris/update-ramazzini-institute-data-iris-assessments. Last updated June 14, 2017.

van der Mark M, Vermeulen R, Nijssen PC, Mulleners WM, Sas AM, van Laar T, Kromhout H, Huss A. Extremely low-frequency magnetic field exposure, electrical shocks and risk of Parkinson's disease. Int Arch Occup Environ Health 88:227-234, 2014.

Vandentorren S, Bois C, Pirus C, Sarter H, Salines G, Leridon H. Rationales, design and recruitment for the Elfe longitudinal study. BMC Pediatr 9:58, 2009.

Vergara X, Kheifets L, Greenland S, Oksuzyan S, Cho YS, Mezei G. Occupational exposure to extremely low-frequency magnetic fields and neurodegenerative disease: a meta-analysis. J Occup Environ Med 55:135-146, 2013.

Vergara X, Mezei G, Kheifets L. Case-control study of occupational exposure to electric shocks and magnetic fields and mortality from amyotrophic lateral sclerosis in the US, 1991-1999. J Expo Sci Environ Epidemiol 25:65-71, 2015.

Vinceti M, Malagoli C, Fabbi S, Kheifets L, Violi F, Poli M, Caldara S, Sesti D, Violanti S, Zanichelli P, Notari B, Fava R, Arena A, Calzolari R, Filippini T, Iacuzio L, Arcolin E, Mandrioli J, Fini N, Odone A, Signorelli C, Patti F, Zappia M, Pietrini V, Oleari P, Teggi S, Ghermandi G, Dimartino A, Ledda C, Mauceri C, Sciacca S, Fiore M, Ferrante M. Magnetic fields exposure from high-voltage power lines and risk of amyotrophic lateral sclerosis in two Italian populations. Amyotroph Lateral Scler Frontotemporal Degener 18:583-589, 2017.

Wang X, Zhao K, Wang D, Adams W, Fu Y, Sun H, Liu X, Yu H, Ma Y. Effects of exposure to a 50 Hz sinusoidal magnetic field during the early adolescent period on spatial memory in mice. Bioelectromagnetics 34:275-284, 2013.

Wilson JW, Haines J, Sienkiewicz Z, Dubrova YE. The effects of extremely low frequency magnetic fields on mutation induction in mice. Mutat Res 773:22-26, 2015.

Woodbine L, Haines J, Coster M, Barazzuol L, Ainsbury E, Sienkiewicz Z, Jeggo P. The rate of X-ray-induced DNA double-strand break repair in the embryonic mouse brain is unaffected by exposure to 50 Hz magnetic fields. Int J Radiat Biol 91:495-499, 2015.

World Health Organization (WHO). International Programme on Chemical Safety (IPCS). Environmental Health Criteria 170 Assessing Human Health Risks of Chemicals: Derivation of Guidance Values for Health-based Exposure Limits. Geneva, Switzerland: WHO, 1994.

World Health Organization (WHO). Framework for Developing Health-Based Standards. Geneva, Switzerland: World Health Organization: WHO, 2006.

World Health Organization (WHO). Environmental Health Criteria 238: Extremely Low Frequency (ELF) Fields. Geneva, Switzerland: WHO, 2007.

Yadamani S, Neamati A, Homayouni-Tabrizi M, Beyramabadi SA, Yadamani S, Gharib A, Morsali A, Khashi M. Treatment of the breast cancer by using low frequency electromagnetic fields and Mn(II) complex of a Schiff base derived from the pyridoxal. Breast 41:107-112, 2018.

Yasui M, Kikuchi T, Ogawa M, Otaka Y, Tsuchitani M, Iwata H. Carcinogenicity test of 50 Hz sinusoidal magnetic fields in rats. Leuk Lymphoma 49:531-540, 1997.

Yu Y, Su FC, Callaghan BC, Goutman SA, Batterman SA, Feldman EL. Environmental risk factors and amyotrophic lateral sclerosis (ALS): A case-control study of ALS in Michigan. PLoS One 9:e101186, 2014.

Zaffanella LE. Survey of Residential Magnetic Field Sources. Volume 2: Protocol, Data Analysis, and Management. EPRI TR-102759-V2. Palo Alto, CA: EPRI, 1993.

Zaffanella LE and Kalton GW. Survey of Personal Magnetic Field Exposure Phase II: 1,000 Person Survey. EMF Rapid Program, Engineering Project #6. Lee, MS: Enertech Consultants, 1998.

Zarei S, Vahab M, Oryadi-Zanjani MM, Alighanbari N, Mortazavi SM. Mother’s exposure to electromagnetic fields before and during pregnancy is associated with risk of speech problems in offspring. J Biomed Phys Eng 9(1):61-68, 2019.

Zendehdel R, Yu IJ, Hajipour-Verdom B, and Panjali Z. DNA effects of low level occupational exposure to extremely low frequency electromagnetic vields (50/60 Hz). Toxicol Ind Health

35:424-430, 2019.

Zendehdel R, Asadi S, Alizadeh S, Ranjbarian M. Quality assessment of DNA and hemoglobin by Fourier transform infrared spectroscopy in occupational exposure to extremely low-frequency magnetic field. Environ Sci Pollut Res Int 27(36):45374-45380, 2020.

Zhao YL, Qu Y, Ou YN, Zhang YR, Tan L, Yu JT. Environmental factors and risks of cognitive impairment and dementia: A systematic review and meta-analysis. Ageing Res Rev 72:101504, 2021.

Zhou H, Chen G, Chen C, Yu Y, Xu Z. Association between extremely low-frequency electromagnetic fields occupations and amyotrophic lateral sclerosis: A meta-analysis. PLoS One 7: e48354, 2012.

APPENDIX B AGENCY CORRESPONDENCE

STATE OF RHODE ISLAND

HISTORICAL PRESERVATION & HERITAGE COMMISSION

Old State House 150 Benefit Street Providence, RI 02903

Telephone 401-222-2678 Fax 401-222-2968
www.preservation.ri.gov

TTY 401-222-3700

16 May, 2022

Jaime Donta
Power Engineers
Via email

Re: Permit 21-21 modification request
173531 G185S Shieldwire Project and L190 Asset Condition Refurbishment Project

Dear Ms. Donta,

The RIHPHC has reviewed your request to extend Permit 21-21 to include the excavation of two 4 x 4 meter square unites, excavated to 40 cms below the ground surface, the depth at which the four previously exposed features were observed. If there are features in these two unites, we agree that since impacts are not avoidable at these two locations, it is appropriate that any features encountered by mapped, photographed, bisected, and screened (with the caveat that any indication that a feature is a burial should halt the excavation process), and a 25% sample of non-feature soil further excavated.

This permit modification extends until 16 May, 2023.

These comments are provided in accordance with Section 106 of the National Historic Preservation Act. If you have any questions, please contact Charlotte Taylor or Timothy Ives, archaeologists at this office.

Very truly yours, Sincerely,

Charlotte Taylor (for)

Jeffrey D. Emidy
Acting Executive Director
Acting State Historic Preservation Officer

220516.08

STATE OF RHODE ISLAND

HISTORICAL PRESERVATION & HERITAGE COMMISSION

Old State House 150 Benefit Street Providence, RI 02903

Telephone 401-222-2678 Fax 401-222-2968
TTY 401-222-3700 www.preservation.ri.gov

1 April, 2022

Jaime Donta
Power Engineers
Via email-- jaime.donta@powereng.com

RE: G185S Shieldwire Replacement and L190 Asset Condition Refurbishment Project
Summary of Phase 1 Results and Permit Modification Request for Phase 2 Survey
Phase 2 Survey Research Design

Dear Ms. Donta,

We have reviewed your summary of the Phase I results for the above-referenced project, and your proposal for Phase II work for the identified sites. In as much as the proposed additional survey work will be limited to the impact areas already tested, we are modifying your existing permit #21-21 at your request to include the Phase II work as described. This permit will be valid from 4/11/22 until 4/1/2023.

These comments are provided in accordance with Section 106 of the National Historic Preservation Act. If you have any questions, please contact Charlotte Taylor, Senior Archaeologist, or Elizabeth Totten, Project Review Coordinator, at this office.

Sincerely,

Charlotte Taylor (for)

Jeffrey D. Emidy
Acting Executive Director
Acting State Historic Preservation Officer

Cc: John Brown
Bettina Washington
David Weeden

220401.01

POWER ENGINEERS, INC.
2 HAMPSHIRE STREET
SUITE 301
FOXBOROUGH, MA 02035 USA

PHONE 774-643-1800
FAX 774-643-1899

March 14, 2022

Ms. Charlotte Taylor
RIHPHC
150 Benefit Street
Providence, RI

Subject: 173531 G185S Shieldwire Replacement Project and L190 Asset Condition Refurbishment Project (RIHPHC Permit #21-21)

Dear Charlotte:

Please find enclosed a permit modification request to allow for Phase 2/Site Examination survey under RIHPHC Permit #21-21. As we discussed previously, I have included a detailed discussion of the results of the Phase 1 survey conducted between July and December of last year, and I propose to submit a combined Phase 1 and Phase 2 technical summary report upon completion of the Phase 2.

POWER cultural staff will be teaming on the Phase 2 field effort with staff from Gray & Pape Heritage Management in Providence. POWER will complete the reporting and any subsequent monitoring. Please find enclosed a combined scope of work labor hours table for the Phase 2 field work and reporting, as well as for monitoring efforts to be conducted during the construction phase of this project as part of the avoidance and protection plan.

Don't hesitate to reach out if you have any questions, need more information, etc. Thanks!

Sincerely,

Jaime M. Donta
Eastern Cultural Dept. Northeast Area Lead

c: Karen Hanecak, POWER
Laura Ernst, TNEC
Michael Retter, TNEC
Kimberly Smith, Gray & Pape

STATE OF RHODE ISLAND

HISTORICAL PRESERVATION & HERITAGE COMMISSION

Old State House 150 Benefit Street Providence, RI 02903

Telephone 401-222-2678
TTY 401-222-3700

Fax 401-222-2968
www.preservation.ri.gov

10 September, 2021

Jaime Moore Donta
Power Engineers, Inc.
2 Hampshire Street, Suite 301
Foxborough, MA 02035
(via email)

RE: Amendment to Permit 21-21 for additional testing
159157TNEC G185S/L190 Asset Condition Refurbishment Project

Dear Ms. Donta,

At your request, the Rhode Island Historical Preservation and Heritage Commission staff has extended permit 21-21 to include addition testing in agricultural fields not included in the original proposal. The permit as extended is now valid till 9/10/2022.

These comments are provided in accordance with Section 106 of the National Historic Preservation Act. If you have any questions, please contact Charlotte Taylor or Tim Ives, archaeologists at this office.

Very truly yours,

Charlotte Taylor for

Jeffrey Emidy
Acting Executive Director

Cc: John Brown, NITHPO, via email

210910.06

I, **Jaime M. Donta**, certify that the information contained in this application is correct, and that I will comply with applicable federal and state legislation, regulations and standards, and any special conditions appended to this application (see below). I understand that any change to the specifications of this permit, the research design, or project scope of work, without the approval of the RIHPHC, may result in the revocation of this permit and the cessation of archaeological investigations. I also understand that should I fail to satisfy the conditions of this permit (items 7,8,9,10,11,) the RIHPHC may decide not to issue me, or my employer, permits for future projects until the deficiencies under this permit are resolved.

I, **Michael J. Retter**, agree to comply with applicable federal and state legislation and special conditions attached to this permit. I also agree to maintain adequate security at the project area, and, if determined necessary by the RIHPHC, will take steps, as required by the RIHPHC, to prevent trespassers or other unauthorized individuals from causing harm to the archaeological site or sites under investigation.

21-25 9/10/21 - 9/10/22 ______ Jaime M. Donta ______

Permit effective date Signature of Applicant

Jeffrey D. Emidy ______ Michael J. Retter ______

Approved
Rhode Island Historical Preservation
and Heritage Commission

Property owner or project proponent

Reviewed by: ____________________, RIHP&HC staff archaeologist

See below for any attached Special Conditions that may apply to this permit:

1. Native American special condition yes ___ no ___

2. Other special condition yes ___ no ___

The RIHP&HC reserves the right to amend the terms and conditions of this permit based on new information received in the course of the project.

Form revised 12/10

POWER ENGINEERS

POWER ENGINEERS, INC.

2 HAMPSHIRE STREET
SUITE 301
FOXBOROUGH, MA 02035 USA

PHONE 774-643-1800
FAX 774-643-1899

June 1, 2021

Ms. Charlotte Taylor
Rhode Island Historical Preservation & Heritage Commission
Old State House
150 Benefit Street
Providence, RI 02903

Subject: 159157 G185S Shieldwire Replacement and L190 Asset Condition Refurbishment Project

Dear Charlotte:

Please find attached a Phase 1C permit application and research design for The Narragansett Electric Company's G185S Shieldwire Replacement and L190 Asset Condition Refurbishment Project in Warwick, North Kingstown, East Greenwich, Exeter, and South Kingstown. You previously commented on the portion of this Project that addressed geotechnical investigations (on March 20, 2021). The attached permit application and research design represent the construction phase of work on this Project. POWER Engineers Consulting proposes pending receipt of this permit to conduct Phase 1C testing in most areas of anticipated impacts. Areas of the Project that fall within agricultural fields are proposed to be tested at a later date, following outreach to landowners, harvest of produce, and refinement of Project impacts. POWER also proposes to prepare an Archaeological Site Avoidance and Protection Plan for known resources, including above-ground resources such as stone walls, that are within the Project area but not currently within impact areas.

Please don't hesitate to reach out if you have any questions, or if I can provide more information. Thank you for the opportunity to submit this permit application and research design.

Sincerely,

Jaime M. Donta

Jaime M. Donta
Eastern Cultural Resources Northeast Area Lead

Enclosure(s):

c: Laura Ernst, TNEC
Karen Hanecak, POWER

IF ENCLOSURES ARE NOT AS NOTED, PLEASE NOTIFY US AT ONCE.

I, **Jaime Donta**, certify that the information contained in this application is correct, and that I will comply with applicable federal and state legislation, regulations and standards, and any special conditions appended to this application (see below). I understand that any change to the specifications of this permit, the research design, or project scope of work, without the approval of the RIHPHC, may result in the revocation of this permit and the cessation of archaeological investigations. I also understand that should I fail to satisfy the conditions of this permit (items 7,8,9,10,11,) the RIHPHC may decide not to issue me, or my employer, permits for future projects until the deficiencies under this permit are resolved.

I, **Laura Ernst**, agree to comply with applicable federal and state legislation and special conditions attached to this permit. I also agree to maintain adequate security at the project area, and, if determined necessary by the RIHPHC, will take steps, as required by the RIHPHC, to prevent trespassers or other unauthorized individuals from causing harm to the archaeological site or sites under investigation.

#21-21 6/24/21-6/24/22 ______ Jaime M. Donta ______

Permit effective date Signature of Applicant

______________________ Laura Ernst

Approved
Rhode Island Historical Preservation
and Heritage Commission

Property owner or project proponent

Reviewed by: ______________________, RIHP&HC staff archaeologist

See below for any attached Special Conditions that may apply to this permit:

1. Native American special condition yes ___ no ___

2. Other special condition yes ___ no ___

The RIHP&HC reserves the right to amend the terms and conditions of this permit based on new information received in the course of the project.

Form revised 12/10

United States Department of the Interior

FISH AND WILDLIFE SERVICE
New England Ecological Services Field Office
70 Commercial Street, Suite 300
Concord, NH 03301-5094
Phone: (603) 223-2541 Fax: (603) 223-0104
http://www.fws.gov/newengland

In Reply Refer To: September 13, 2021
Consultation Code: 05E1NE00-2021-SLI-4739
Event Code: 05E1NE00-2021-E-14543
Project Name: G185S and L190 115 kV Transmission Lines Asset Condition Refurbishment Project

Subject: List of threatened and endangered species that may occur in your proposed project location or may be affected by your proposed project

To Whom It May Concern:

The enclosed species list identifies threatened, endangered, proposed and candidate species, as well as proposed and final designated critical habitat, that may occur within the boundary of your proposed project and/or may be affected by your proposed project. The species list fulfills the requirements of the U.S. Fish and Wildlife Service (Service) under section 7(c) of the Endangered Species Act (Act) of 1973, as amended (16 U.S.C. 1531 *et seq.*).

New information based on updated surveys, changes in the abundance and distribution of species, changed habitat conditions, or other factors could change this list. Please feel free to contact us if you need more current information or assistance regarding the potential impacts to federally proposed, listed, and candidate species and federally designated and proposed critical habitat. Please note that under 50 CFR 402.12(e) of the regulations implementing section 7 of the Act, the accuracy of this species list should be verified after 90 days. This verification can be completed formally or informally as desired. The Service recommends that verification be completed by visiting the ECOS-IPaC website at regular intervals during project planning and implementation for updates to species lists and information. An updated list may be requested through the ECOS-IPaC system by completing the same process used to receive the enclosed list.

The purpose of the Act is to provide a means whereby threatened and endangered species and the ecosystems upon which they depend may be conserved. Under sections 7(a)(1) and 7(a)(2) of the Act and its implementing regulations (50 CFR 402 *et seq.*), Federal agencies are required to utilize their authorities to carry out programs for the conservation of threatened and endangered species and to determine whether projects may affect threatened and endangered species and/or designated critical habitat.

A Biological Assessment is required for construction projects (or other undertakings having similar physical impacts) that are major Federal actions significantly affecting the quality of the human environment as defined in the National Environmental Policy Act (42 U.S.C. 4332(2)(c)). For projects other than major construction activities, the Service suggests that a biological evaluation similar to a Biological Assessment be prepared to determine whether the project may affect listed or proposed species and/or designated or proposed critical habitat. Recommended contents of a Biological Assessment are described at 50 CFR 402.12.

If a Federal agency determines, based on the Biological Assessment or biological evaluation, that listed species and/or designated critical habitat may be affected by the proposed project, the agency is required to consult with the Service pursuant to 50 CFR 402. In addition, the Service recommends that candidate species, proposed species and proposed critical habitat be addressed within the consultation. More information on the regulations and procedures for section 7 consultation, including the role of permit or license applicants, can be found in the "Endangered Species Consultation Handbook" at:

http://www.fws.gov/endangered/esa-library/pdf/TOC-GLOS.PDF

Please be aware that bald and golden eagles are protected under the Bald and Golden Eagle Protection Act (16 U.S.C. 668 *et seq.*), and projects affecting these species may require development of an eagle conservation plan (http://www.fws.gov/windenergy/eagle_guidance.html). Additionally, wind energy projects should follow the wind energy guidelines (http://www.fws.gov/windenergy/) for minimizing impacts to migratory birds and bats.

Guidance for minimizing impacts to migratory birds for projects including communications towers (e.g., cellular, digital television, radio, and emergency broadcast) can be found at: http://www.fws.gov/migratorybirds/CurrentBirdIssues/Hazards/towers/towers.htm; http://www.towerkill.com; and http://www.fws.gov/migratorybirds/CurrentBirdIssues/Hazards/towers/comtow.html.

We appreciate your concern for threatened and endangered species. The Service encourages Federal agencies to include conservation of threatened and endangered species into their project planning to further the purposes of the Act. Please include the Consultation Tracking Number in the header of this letter with any request for consultation or correspondence about your project that you submit to our office.

Attachment(s):

- Official Species List

Official Species List

This list is provided pursuant to Section 7 of the Endangered Species Act, and fulfills the requirement for Federal agencies to "request of the Secretary of the Interior information whether any species which is listed or proposed to be listed may be present in the area of a proposed action".

This species list is provided by:

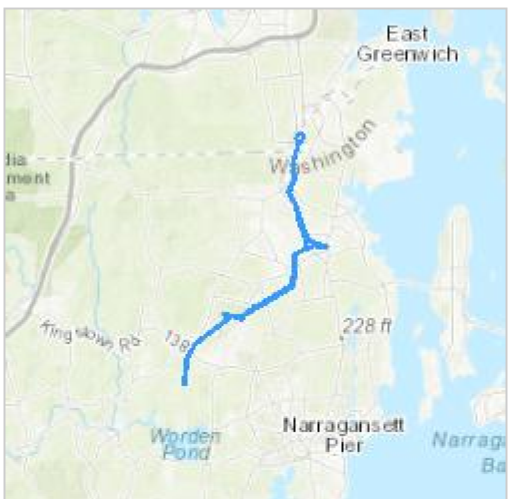
New England Ecological Services Field Office
70 Commercial Street, Suite 300
Concord, NH 03301-5094
(603) 223-2541

Project Summary

Consultation Code:	05E1NE00-2021-SLI-4739
Event Code:	Some(05E1NE00-2021-E-14543)
Project Name:	G185S and L190 115 kV Transmission Lines Asset Condition Refurbishment Project
Project Type:	TRANSMISSION LINE
Project Description:	The Narragansett Electric Company (TNEC) is proposing maintenance activities on two existing 115-kilovolt (kV) transmission lines (the G185S and L190) co-located within an existing rights-of-way (ROW) extending from the Davisville Taps in East Greenwich, RI to the West Kingston No. 62 Substation (Project). The Project traverses the municipalities of East Greenwich, North Kingstown, Exeter, and South Kingstown in Kent and Washington Counties, Rhode Island. The purpose of this work is to repair and upgrade the existing electric infrastructure including replacing certain wood pole structures with steel pole structures, replacing shield wire with optical ground wire, and reconductoring the L190 Line. There is proposed minimal tree-clearing and vegetation removal in certain areas within the existing ROW for accessibility to existing structures and to create a safe work area, such as work pads, for personnel and equipment. Temporary construction matting may be used for access and work space in wetlands within the ROW.

Project Location:

Approximate location of the project can be viewed in Google Maps: https://www.google.com/maps/@41.541847849999996,-71.49277614451682,14z



Counties: Kent and Washington counties, Rhode Island

Endangered Species Act Species

There is a total of 2 threatened, endangered, or candidate species on this species list.

Species on this list should be considered in an effects analysis for your project and could include species that exist in another geographic area. For example, certain fish may appear on the species list because a project could affect downstream species.

IPaC does not display listed species or critical habitats under the sole jurisdiction of NOAA Fisheries[1], as USFWS does not have the authority to speak on behalf of NOAA and the Department of Commerce.

See the "Critical habitats" section below for those critical habitats that lie wholly or partially within your project area under this office's jurisdiction. Please contact the designated FWS office if you have questions.

---

1. NOAA Fisheries, also known as the National Marine Fisheries Service (NMFS), is an office of the National Oceanic and Atmospheric Administration within the Department of Commerce.

Mammals

NAME	STATUS
Northern Long-eared Bat *Myotis septentrionalis* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/9045	Threatened

Insects

NAME	STATUS
Monarch Butterfly *Danaus plexippus* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/9743	Candidate

Critical habitats

THERE ARE NO CRITICAL HABITATS WITHIN YOUR PROJECT AREA UNDER THIS OFFICE'S JURISDICTION.

United States Department of the Interior

FISH AND WILDLIFE SERVICE
New England Ecological Services Field Office
70 Commercial Street, Suite 300
Concord, NH 03301-5094
Phone: (603) 223-2541 Fax: (603) 223-0104
http://www.fws.gov/newengland

In Reply Refer To: September 13, 2021
Consultation code: 05E1NE00-2021-TA-4739
Event Code: 05E1NE00-2021-E-14544
Project Name: G185S and L190 115 kV Transmission Lines Asset Condition Refurbishment Project

Subject: Verification letter for the 'G185S and L190 115 kV Transmission Lines Asset Condition Refurbishment Project' project under the January 5, 2016, Programmatic Biological Opinion on Final 4(d) Rule for the Northern Long-eared Bat and Activities Excepted from Take Prohibitions.

Dear Devon Robinson:

The U.S. Fish and Wildlife Service (Service) received on September 13, 2021 your effects determination for the 'G185S and L190 115 kV Transmission Lines Asset Condition Refurbishment Project' (the Action) using the northern long-eared bat (*Myotis septentrionalis*) key within the Information for Planning and Consultation (IPaC) system. This IPaC key assists users in determining whether a Federal action is consistent with the activities analyzed in the Service’s January 5, 2016, Programmatic Biological Opinion (PBO). The PBO addresses activities excepted from "take"[1] prohibitions applicable to the northern long-eared bat under the Endangered Species Act of 1973 (ESA) (87 Stat.884, as amended; 16 U.S.C. 1531 et seq.).

Based upon your IPaC submission, the Action is consistent with activities analyzed in the PBO. The Action may affect the northern long-eared bat; however, any take that may occur as a result of the Action is not prohibited under the ESA Section 4(d) rule adopted for this species at 50 CFR §17.40(o). Unless the Service advises you within 30 days of the date of this letter that your IPaC-assisted determination was incorrect, this letter verifies that the PBO satisfies and concludes your responsibilities for this Action under ESA Section 7(a)(2) with respect to the northern long-eared bat.

Please report to our office any changes to the information about the Action that you submitted in IPaC, the results of any bat surveys conducted in the Action area, and any dead, injured, or sick northern long-eared bats that are found during Action implementation. If the Action is not completed within one year of the date of this letter, you must update and resubmit the information required in the IPaC key.

This IPaC-assisted determination allows you to rely on the PBO for compliance with ESA Section 7(a)(2) only for the northern long-eared bat. It **does not** apply to the following ESA-protected species that also may occur in the Action area:

- Monarch Butterfly *Danaus plexippus* Candidate

If the Action may affect other federally listed species besides the northern long-eared bat, a proposed species, and/or designated critical habitat, additional consultation between you and this Service office is required. If the Action may disturb bald or golden eagles, additional coordination with the Service under the Bald and Golden Eagle Protection Act is recommended.

[1]Take means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct [ESA Section 3(19)].

Action Description
You provided to IPaC the following name and description for the subject Action.

1. Name

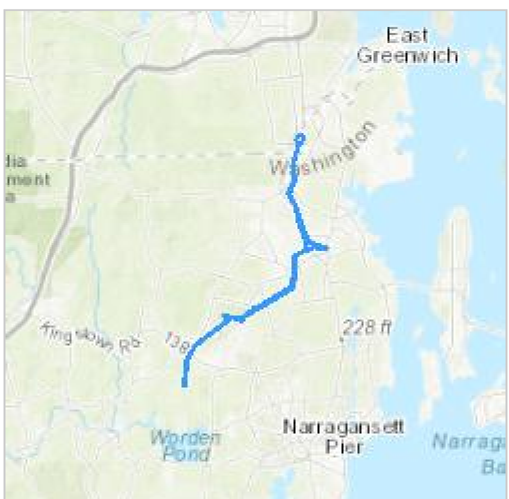
G185S and L190 115 kV Transmission Lines Asset Condition Refurbishment Project

2. Description

The following description was provided for the project 'G185S and L190 115 kV Transmission Lines Asset Condition Refurbishment Project':

> The Narragansett Electric Company (TNEC) is proposing maintenance activities on two existing 115-kilovolt (kV) transmission lines (the G185S and L190) co-located within an existing rights-of-way (ROW) extending from the Davisville Taps in East Greenwich, RI to the West Kingston No. 62 Substation (Project). The Project traverses the municipalities of East Greenwich, North Kingstown, Exeter, and South Kingstown in Kent and Washington Counties, Rhode Island. The purpose of this work is to repair and upgrade the existing electric infrastructure including replacing certain wood pole structures with steel pole structures, replacing shield wire with optical ground wire, and reconductoring the L190 Line. There is proposed minimal tree-clearing and vegetation removal in certain areas within the existing ROW for accessibility to existing structures and to create a safe work area, such as work pads, for personnel and equipment. Temporary construction matting may be used for access and work space in wetlands within the ROW.

Approximate location of the project can be viewed in Google Maps: https://www.google.com/maps/@41.541847849999996,-71.49277614451682,14z



Determination Key Result

This Federal Action may affect the northern long-eared bat in a manner consistent with the description of activities addressed by the Service’s PBO dated January 5, 2016. Any taking that may occur incidental to this Action is not prohibited under the final 4(d) rule at 50 CFR

§17.40(o). Therefore, the PBO satisfies your responsibilities for this Action under ESA Section 7(a)(2) relative to the northern long-eared bat.

Determination Key Description: Northern Long-eared Bat 4(d) Rule

This key was last updated in IPaC on May 15, 2017. Keys are subject to periodic revision.

This key is intended for actions that may affect the threatened northern long-eared bat.

The purpose of the key for Federal actions is to assist determinations as to whether proposed actions are consistent with those analyzed in the Service’s PBO dated January 5, 2016.

Federal actions that may cause prohibited take of northern long-eared bats, affect ESA-listed species other than the northern long-eared bat, or affect any designated critical habitat, require ESA Section 7(a)(2) consultation in addition to the use of this key. Federal actions that may affect species proposed for listing or critical habitat proposed for designation may require a conference under ESA Section 7(a)(4).

Determination Key Result

This project may affect the threatened Northern long-eared bat; therefore, consultation with the Service pursuant to Section 7(a)(2) of the Endangered Species Act of 1973 (87 Stat.884, as amended; 16 U.S.C. 1531 et seq.) is required. However, based on the information you provided, this project may rely on the Service's January 5, 2016, *Programmatic Biological Opinion on Final 4(d) Rule for the Northern Long-Eared Bat and Activities Excepted from Take Prohibitions* to fulfill its Section 7(a)(2) consultation obligation.

Qualification Interview

1. Is the action authorized, funded, or being carried out by a Federal agency?

   Yes

2. Have you determined that the proposed action will have "no effect" on the northern long-eared bat? (If you are unsure select "No")

   No

3. Will your activity purposefully **Take** northern long-eared bats?

   No

4. [Semantic] Is the project action area located wholly outside the White-nose Syndrome Zone?

   Automatically answered
   No

5. Have you contacted the appropriate agency to determine if your project is near a known hibernaculum or maternity roost tree?

   Location information for northern long-eared bat hibernacula is generally kept in state Natural Heritage Inventory databases – the availability of this data varies state-by-state. Many states provide online access to their data, either directly by providing maps or by providing the opportunity to make a data request. In some cases, to protect those resources, access to the information may be limited. A web page with links to state Natural Heritage Inventory databases and other sources of information on the locations of northern long-eared bat roost trees and hibernacula is available at [www.fws.gov/midwest/endangered/mammals/nleb/nhisites.html.](www.fws.gov/midwest/endangered/mammals/nleb/nhisites.html)

   Yes

6. Will the action affect a cave or mine where northern long-eared bats are known to hibernate (i.e., hibernaculum) or could it alter the entrance or the environment (physical or other alteration) of a hibernaculum?

   No

7. Will the action involve Tree Removal?

   Yes

8. Will the action only remove hazardous trees for the protection of human life or property?

   No

9. Will the action remove trees within 0.25 miles of a known northern long-eared bat hibernaculum at any time of year?

   No

10. Will the action remove a known occupied northern long-eared bat maternity roost tree or any trees within 150 feet of a known occupied maternity roost tree from June 1 through July 31?

    No

Project Questionnaire

If the project includes forest conversion, report the appropriate acreages below. Otherwise, type ‘0’ in questions 1-3.

1. Estimated total acres of forest conversion:

0.5

2. If known, estimated acres of forest conversion from April 1 to October 31

0.5

3. If known, estimated acres of forest conversion from June 1 to July 31

0

If the project includes timber harvest, report the appropriate acreages below. Otherwise, type ‘0’ in questions 4-6.

4. Estimated total acres of timber harvest

0

5. If known, estimated acres of timber harvest from April 1 to October 31

0

6. If known, estimated acres of timber harvest from June 1 to July 31

0

If the project includes prescribed fire, report the appropriate acreages below. Otherwise, type ‘0’ in questions 7-9.

7. Estimated total acres of prescribed fire

0

8. If known, estimated acres of prescribed fire from April 1 to October 31

0

9. If known, estimated acres of prescribed fire from June 1 to July 31

0

If the project includes new wind turbines, report the megawatts of wind capacity below. Otherwise, type ‘0’ in question 10.

10. What is the estimated wind capacity (in megawatts) of the new turbine(s)?

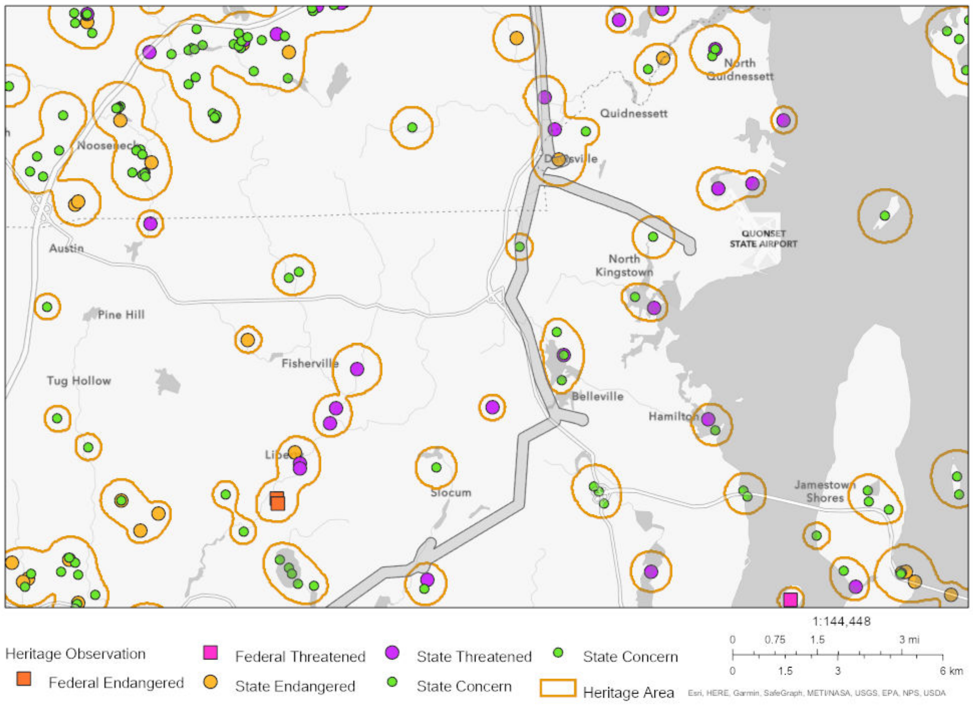
0

Natural Heritage Screening Report for RIDOT

Area of Interest (AOI) Information

Area : 121,452,776.49 ft²

Feb 23 2021 10:08:34 Eastern Standard Time



Summary

Name	Count	Area(ft²)	Length(ft)
Heritage Species	10	N/A	N/A

Heritage Species

#	RINHSEO_Code	Family	Genus	Species	COMNAME	RI__STAT	LAST_OBS	ObsYear	Count
1	PDLIN020K2*002*RI	Linaceae	Linum	medium ssp. texanum	Common Yellow Flax	State Threatened	Young	2,013	1
2	PDLIN020K2*002*RI	Linaceae	Linum	medium ssp. texanum	Common Yellow Flax	State Threatened	Underwood	2,005	1
3	PPLYC03010*002*RI	Lycopodiaceae	Lycopodiella	alopecuroides	Foxtail-clubmoss	State Endangered	Ruhren	2,009	1
4	PPLYC03010*002*RI	Lycopodiaceae	Lycopodiella	alopecuroides	Foxtail-clubmoss	State Endangered	Ruhren	2,008	1
5	PPLYC03010*002*RI	Lycopodiaceae	Lycopodiella	alopecuroides	Foxtail-clubmoss	State Endangered	Enser	1,992	1
6	PPLYC03010*002*RI	Lycopodiaceae	Lycopodiella	alopecuroides	Foxtail-clubmoss	State Endangered	Haines	2,003	1
7	PPLYC03010*002*RI	Lycopodiaceae	Lycopodiella	alopecuroides	Foxtail-clubmoss	State Endangered	*No Data*	1,993	1
8	PPLYC03010*002*RI	Lycopodiaceae	Lycopodiella	alopecuroides	Foxtail-clubmoss	State Endangered	Enser	2,002	1
9	PPLYC03010*002*RI	Lycopodiaceae	Lycopodiella	alopecuroides	Foxtail-clubmoss	State Endangered	Ruhren	2,006	1
10	PDLNT02080*003*RI	Lentibulariaceae	Utricularia	gibba	Humped Bladderwort	State Concern	McGrady	2,009	1

Hanecak, Karen

From: Robinson, Devon
Sent: Monday, January 10, 2022 12:43 AM
To: Hanecak, Karen
Subject: FW: [EXTERNAL] : Requesting Northern Long-Eared Bat Information - G185/L190 Transmission Line ROW

From: Brown, Charles (DEM) <charles.brown@dem.ri.gov>
Sent: Monday, September 13, 2021 12:41 PM
To: Robinson, Devon <devon.robinson@powereng.com>
Subject: RE: [EXTERNAL] : Requesting Northern Long-Eared Bat Information - G185/L190 Transmission Line ROW

Hi Devon,
I have reviewed the submitted map for the Shield Wire Replacement Project from East Greenwich to West Kingston. There are no known northern long-eared bat maternity roost trees or hibernacula in the proposed project area or within 5 miles of the project area. We have capture records for northern long-eared bat within the Great Swamp Management Area but not in the vicinity of the West Kingston substation.
If you have any other questions please let me know.
Charlie Brown
Wildlife Biologist
R.I. Division of Fish and Wildlife
(401) 789-0281

From: devon.robinson@powereng.com <devon.robinson@powereng.com>
Sent: Friday, September 10, 2021 1:44 PM
To: Brown, Charles (DEM) <charles.brown@dem.ri.gov>
Subject: [EXTERNAL] : Requesting Northern Long-Eared Bat Information - G185/L190 Transmission Line ROW

Charlie,

I am contacting you to request some information on the Northern Long-Eared Bat (NLEB). I am working on a project for National Grid that travels through East Greenwich, North Kingstown, Exeter, and South Kingstown, Rhode Island. I am looking to see if there are any known NLEB maternity roosts and/or hibernacula locations in the vicinity of the project. As part of the USFWS IPaC process, the appropriate agency needs to be contacted to verify that the project is not near a known NLEB hibernaculum or maternity roost. The project consists of work within an existing transmission line right-of-way which spans from the Davisville Taps just North of South Road in East Greenwich to West Kingstown Substation just South of Great Neck Road in South Kingstown. Please refer to the attached map. Could you please provide locations of any known NLEB hibernacula and/or maternity roosts that are within the project area or within ~5 miles of the project? Please let me know if you have any questions.

Thank you,

Devon

DEVON ROBINSON
ASSISTANT ENVIRONMENTAL SPECIALIST