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THE NARRAGANSETT ELECTRIC COMPANY

V148S TRANSMISSION LINE

ASSET CONDITION REFURBISHMENT PROJECT

Rhode Island Energy Facility Siting Board

Siting Report

Prepared for:

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280 Melrose Street
Providence, RI 02907

BSC Project No. 89594.67

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THE NARRAGANSETT ELECTRIC COMPANY
Rhode Island Energy Facility Siting Board – Siting Report

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Siting Report

PREPARED FOR:

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280 MELROSE STREET
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FOR SUBMITTAL TO:

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ACRONYMS AND ABBREVIATIONS

AAC	All Aluminum Cable
ACGIH	American Conference of Governmental and Industrial Hygienists
ACI	American Concrete Institute
ACSR	Aluminum Conductor Steel-Reinforced cable
ACSS	Aluminum Conductor Steel-Supported cable
ANSI	American National Standards Institute
AOI	Area Of Interest (Soil Mapping)
APE	Area of Potential Effects (Cultural resources assessment)
ASCE	American Society of Civil Engineers
ASF	Areas Subject to Flooding
ASSF	Areas Subject to Storm Flowage
BMP	Best Management Practices
BSC	BSC Group, Inc.
CFR	Code of Federal Regulations
Company	The Narragansett Electric Company
EFSB	Energy Facility Siting Board
EG-802RI	TNEC's Environmental Guidance document for Rhode Island
EMF	Electric and Magnetic Fields
EPS	Electrical Power System
ER	Environmental Resources
ESA	Endangered Species Act
ESB	TNEC's Electrical Service Bulletin
FEMA	Federal Emergency Management Agency
GA	RI Groundwater Classification – waters known or presumed to be suitable for drinking water use without treatment, and located outside of the three priority areas described under GAA.
GAA	RI Groundwater Classification – waters known or presumed to be suitable for drinking water use without treatment, and located within a major stratified drift aquifer, wellhead protection area or groundwater dependent area.
GB	RI Groundwater Classification – groundwater which may not be suitable for drinking water use without treatment due to known or presumed degradation
GC	RI Groundwater Classification - groundwater classified GC is or may be unsuitable for drinking water use due to certain waste disposal practices
Hz	Hertz
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IEEE	Institute of Electrical and Electronic Engineers
IPaC	Information for Planning and Conservation
ISO-NE	Independent System Operator - New England
kV	kilovolt
kV/M	kilovolts per meter
mG	milliGauss
NEEWS	New England East-West Solutions
NESC	National Electrical Safety Code
NHESP	Natural Heritage Endangered Species Program
NLEB	Northern Long-Eared Bat
NOI	Notice of Intent
NRCS	Natural Resource Conservation Service

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NRHP	National Register of Historic Places
OPGW	fiber optic ground wire
PAL	Public Archaeology Laboratory
PBO	Programmatic Biological Opinion
Project	Thermal upgrade of the K-189 and reconductoring of the G-185N 115 kV transmission lines, owned and operated by TNEC
PV	Photo-voltaic
Report	Siting Report
RI	Rhode Island
RIDEM	Rhode Island Department of Environmental Management
RIDOT	Rhode Island Department of Transportation
RIGIS	Rhode Island Geographic Information System
RIHPHC	Rhode Island Historic Preservation and Heritage Commission
ROW	Right-of-Way
SESC	Soil Erosion and Sediment Control
SHPO	State Historic Preservation Office
TMDL	Total Maximum Daily Load
TNEC	The Narragansett Electric Company
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife
USGS	United States Geological Survey
V/m	volts per meter

1.0 INTRODUCTION

1.1 Project Overview

This Siting Report (the “Report”) has been prepared in accordance with Rule 1.6.F of the Rhode Island Energy Facility Siting Board (“EFSB”) Rules of Practice and Procedure to support a Notice of Intent (“NOI”) for The Narragansett Electric Company’s (“TNEC”) refurbishment of the existing V148S 115 kV Transmission Line (“V148S Line” or “Line”) located in northern Rhode Island (“Project”). The Project includes the entire (approximately 4.8 miles) length of the existing V148S Line. The Project will occur within the existing V148S Line right-of-way (ROW) that runs between the Washington #126 Substation in Lincoln, RI, and the Massachusetts state line. The ROW is located in the towns of Lincoln and Cumberland (please refer to Project Overview Map Figure 1-1).

1.2 Project Team

This Report has been prepared by TNEC employees and consultants retained by TNEC. The description of the affected natural and social environments, and impact analyses were prepared by BSC Group, Inc (“BSC”). Other consultants contributing to the Report include Public Archaeology Laboratories (“PAL”) for cultural resources, Exponent, Inc. for analysis of health effects of electric and magnetic fields (“EMF”), and Gradient Corporation for EMF modeling and calculations. 3Phase Line Construction and TRC Company are responsible for Project engineering and design.

1.3 Compliance with EFSB Requirements

This Report has been prepared in accordance with Rule 1.6(F) of the EFSB Rules of Practice and Procedure to support an NOI. Rule 1.6(F) provides “[i]n the case of the construction of a power line of more than 1000 feet but less than 6000 feet in length with a capacity of 69 kV or more or the modification or relocation of a power line with a capacity of 69 kV or more, a notice of intent for such project shall be filed with the Board and the council of any town or city affected by said construction at least 90 days before commencing construction.” This Report is being submitted to satisfy the applicable requirements of Rhode Island General Laws (R.I.G.L.) 42-98-1 et seq., the Energy Facility Siting Act (the “Act”). It is in compliance with Section 4 of the Energy Facility Siting Act, which states that, “No 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.” Under the Act, transmission lines with a design rating of greater than or equal to 69 kV are classified as major energy facilities. The Report filing requirements and associated procedures for a major generating facility are established in the EFSB’s “Rules of Practice and Procedure” effective November 8, 2018” (the “EFSB Rules”). Although the Project is maintenance work that is not driven by a need to meet anticipated load demands in the area, the normal carrying capacity for the reconducted lines will increase so this maintenance project is therefore jurisdictional to the EFSB.

1.4 Arrangement of the Report

This Report has been prepared in support of an application to the EFSB for construction of jurisdictional facilities and for submission with other state and local applications required for the Project. The 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 Report describes the Project and explains the need for the Project. The Report also discusses the alternatives to the Project that were considered and analyzed, describes the specific natural and social features that have been assessed for the evaluation of impacts, discusses potential impacts, presents a mitigation plan for potential impacts associated with the construction of the Project, and describes permit requirements. The Purpose and Need for the Project is detailed in Section 2.0 of this Report. Section 3.0 provides a detailed description of each of the components of the Project, discusses construction practices, ROW maintenance practices, EMF, 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 these alternatives, is presented in Section 4.0 of this report. 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. The Figures section contains supporting mapping and figures. The Appendices of this Report contain supporting reports and project guidance documents, as applicable.

2.0 PROJECT PURPOSE AND NEED

2.1 Purpose for the Project

The purpose for this Project is to allow TNEC to maintain existing assets to continue to provide reliable delivery of electrical service to the region. The objective of the Project is to improve asset condition and decrease the number of line interruptions. The existing structures were installed in the late 1950s and are a combination of wood and steel lattice structures. Over the years, wood pole deterioration has occurred due to weathering, storm damage, and woodpecker damage. In addition, the existing circuits need to be reconductored, and adapted to provide high-speed communications between substations (installation of fiber optic ground wire (“OPGW”)).

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3.0 PROJECT DESCRIPTION AND PROPOSED ACTION

3.1 Introduction

This section of the Report summarizes: the scope of the Project, the proposed facilities and TNEC's construction practices, estimated Project costs, and the anticipated Project schedule.

3.1.1 V148S Asset Condition Refurbishment Project

The V148S Line is approximately 4.8 miles in length, and passes through the towns of Lincoln and Cumberland, RI. The portion of the Line between Washington #126 and Lincoln Junction was originally constructed in 1914. The portion of the Line between Lincoln Junction and Robinson Avenue Substation was originally constructed in 1923. The portion of the Line between Robinson Avenue and MA state line was originally constructed in 1946. All sections were initially built as 69kV line but were upgraded to 115kV in 1959. In the 1990s, shield wire was added to the section from Lincoln Junction to MA state line, with bayonets supporting it. At this time, the majority of wood crossarms have been replaced with steel.

The Line uses a combination of wood and steel lattice structures to support the conductors. Ground line asset condition inspections, aerial comprehensive inspections, and various other inspections of the V148S Line over the past ten years have identified deteriorated wood pole assets. Over the years, wood pole deterioration has occurred due to weathering, storm damage, and woodpecker damage. In addition, the existing circuits need to be reconducted, and adapted to provide high-speed communications between substations. As such, the Project will utilize 1113kcmil 54/19 ACSR "Finch" conductor to replace the existing circuits and OPGW is proposed to replace the existing shield wires. The proposed refurbishment activities also include structure replacements, overhead maintenance, grading to provide adequate workspace for Project activities for future maintenance, and reestablishing pre-existing access roads where required to safely access the structures.

In total, one (1) new switch structure is proposed, fifty-eight (58) structures will be replaced, and six (6) existing structures will be removed. All replacement structures will be steel davit arm types except for four (4) structures to be replaced with steel H frame structures. The new switch will be a standard horizontal flyover structure.

3.2 Construction and Maintenance Practices

3.2.1 Transmission Line 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 evaluate measures to avoid or minimize environmental impacts.

The transmission line will be constructed in a progression of activities that typically proceed in the sequence and with the equipment described in Table 3-1.

TABLE 3-1: TYPICAL CONSTRUCTION EQUIPMENT

CONSTRUCTION PHASE	TYPICAL EQUIPMENT REQUIRED	
Vegetation Removal and ROW Mowing	<ul style="list-style-type: none"> • Grapple trucks • Track-mounted mowers • Chippers • Brush hogs, skidders • Bucket trucks 	<ul style="list-style-type: none"> • Motorized tree shears • Chain saws • Low-bed trailers, flatbed trucks • Pickup trucks
Soil Erosion/Sediment Controls	<ul style="list-style-type: none"> • Stake body trucks • Pickup and other small trucks 	<ul style="list-style-type: none"> • Small excavators • Trencher
Access Roads Improvement and Maintenance	<ul style="list-style-type: none"> • Dump trucks • Bulldozers • Excavators • Backhoes • Front end loaders • Graders 	<ul style="list-style-type: none"> • Pick-up trucks • Low-bed trailers • Stake body trucks
Removal and Disposal of Existing Transmission Line Components	<ul style="list-style-type: none"> • Cranes • Flatbed trucks • Pullers with take-up reels • Excavators 	<ul style="list-style-type: none"> • Backhoes • Trucks with welding equipment • Dump trucks • Storage containers
Conductor and Shield Wire Installation	<ul style="list-style-type: none"> • Bucket trucks • Puller-tensioners • Conductor reel stands 	<ul style="list-style-type: none"> • Cranes • Flatbed trucks • Pickup trucks • Tracked carriers or skidders
Restoration of the ROW	<ul style="list-style-type: none"> • Pickup and other small trucks • Excavators • Backhoes • Bulldozers 	<ul style="list-style-type: none"> • Dump trucks • Tractor-mounted York rakes • Straw blowers • Hydro-seeders

Removal of Vegetation and ROW Mowing in Advance of Construction

Vegetation mowing together with selective tree trimming and removal may be required to provide access to structure locations to facilitate safe equipment passage, to provide safe work sites for

personnel within the ROW, to facilitate construction equipment access along the ROW and at structure sites, and to maintain safe and reliable clearances between vegetation and transmission line conductors. Prior to vegetation removal and mowing, the boundaries of wetlands will be clearly marked to prevent unauthorized encroachment of equipment into wetland areas. Appropriate forestry techniques will be implemented within wetlands to minimize ground disturbance. Other sensitive resources will be flagged and enclosed with protective fencing prior to removal of vegetation on the ROW. Existing access routes along the ROW will be used by the vegetation removal personnel and equipment to the extent practicable, and road improvements will be kept to a minimum during this phase of the work. The use of temporary swamp mats will be required to gain access to and across wetlands, to minimize wetland disturbance, and to provide a stable platform for safe equipment operation.

Generally, shrubs will be cut close to the ground, leaving the stumps and roots in place to reduce soil disturbance and erosion. If grading is required for access road improvements or at structure sites, stumps will be removed and disposed of off-site. Small trees and shrubs within the ROW will be mowed as necessary with the intent of preserving roots and low-growing vegetation to the extent practical. Brush, limbs, and cleared trees will be chipped or removed from the site.

Installation of Soil Erosion and Sediment Controls

Following vegetation removal activities, TNEC will install proper soil erosion and sediment control devices, such as straw wattles/bales, siltation fencing, and/or chip bales in accordance with approved plans and permit requirements. The soil erosion and sediment control program for the Project will follow the procedures identified in the *Rhode Island Soil Erosion and Sediment Control Handbook*, the *Rhode Island Stormwater Design and Installation Standards Manual*, the Rhode Island Department of Environmental Management's (RIDEM) Wetland Best Management Practices (BMP) Manual: *Techniques for Avoidance and Mitigation*, and TNEC's *ROW Access, Maintenance and Construction Best Management Practices* (EG-303).

The installation of these sediment control devices will be supervised by TNEC's environmental monitor. During construction, these devices will be periodically inspected and monitored by the environmental monitor, and the environmental monitor's findings will be reported regularly to TNEC's Construction Supervisor. The soil erosion and sediment controls will be installed between the work area and environmentally sensitive areas (such as wetlands, streams, drainage courses), roads and adjacent property when work activities will disturb soils and potentially cause soil erosion and sedimentation. The devices will function to mitigate construction-related soil erosion and sedimentation and will also serve as a physical boundary to delineate resource areas and to contain construction activities within approved areas.

Where feasible, staging areas and equipment storage will be situated outside of watershed protection areas, 50-foot perimeter wetlands, and other environmentally sensitive areas. Equipment refueling (except for large, fixed equipment) will occur outside of environmentally sensitive areas (such as waterways, wetlands, and drinking water sources). If extenuating circumstances arise requiring refueling within or in close proximity to sensitive areas, secondary containment devices and other spill prevention BMPs, such as absorbent pads, will be used during refueling.

Swamp mats, soil erosion and sediment controls, and other measures will be implemented as appropriate in accordance with BMPs in resource areas temporarily disturbed by construction. Herbaceous vegetation in disturbed areas will be restored using a native wetland or conservation seed mix. Enhancements proposed as mitigation for important wildlife features lost as a result of tree removal and construction activities may include seeding, planting native shrub species, leaving snags

and placing woody debris and slash or stone piles to create wildlife cover. At the end of construction, swamp mats will be removed and cleaned prior to being moved to another location or off-site.

3.2.1.3 Access Road and Work Pad Maintenance

Access roads are required along the ROW to construct, inspect and maintain the existing and proposed transmission line facilities. Typical access roads are 20 feet wide with a travel lane of approximately 16 feet to accommodate the vehicles and equipment needed for the Project.

TNEC is planning to use the existing network of access roads on the ROW to the greatest extent practicable. Access road improvements are proposed in certain locations to facilitate safe access and construction. For example, clean gravel or trap rock may be necessary to stabilize and level the roads for construction vehicles, and stabilized construction entrances may need to be refreshed where the ROW crosses public roadways.

Access across wetlands and streams, where upland access is not available, will be accomplished by the placement of temporary swamp mats. Such temporary swamp mat access roads will be removed following completion of construction and areas will be restored to re-establish pre-existing topography and hydrology. Swamp mats or similar matting may also be used to cross land in active agricultural use or in other environmentally sensitive areas.

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

Upland work pads will be constructed at structure locations by grading or adding gravel or crushed stone to provide a level work surface for construction equipment and crews. Once construction is complete, the work pads in uplands will remain in place, and will be stabilized with topsoil and mulched to allow vegetation to re-establish. In wetlands, these work pads will be constructed with temporary swamp mats and will be removed after the completion of construction activities.

Removal and Disposal of Existing Transmission Line Components

TNEC proposes to recycle as much of the material generated by construction as possible. Those components not salvaged and any debris that cannot be recycled will be removed from the ROW to an approved off-site facility. Handling of such materials will be performed in compliance with applicable laws and regulations and in accordance with TNEC's policy and procedures.

Installation of Conductor

The existing conductors will be used to pull in the new conductors. The new conductors will be installed using stringing blocks and tensioning equipment. The tensioning equipment is used to pull the conductors through the stringing blocks to achieve the desired sag and tension condition. During the stringing operation, temporary guard structures or boom trucks will be placed at road and highway crossings and at crossings of existing utility lines to ensure the public safety and the continued operation of other utility equipment. To minimize any additional disturbance to soils and vegetation, existing access roads will be used to the fullest extent possible in the placement of pulling and tensioning equipment.

The equipment that will typically be used during the conductor installation operation includes puller-tensioners and conductor reel stands that will be located at the stringing sites. Bucket trucks and platform cranes will be used at non-wetland locations to mount stringing blocks on the structures. To avoid setting temporary poles as guard structures in environmentally sensitive areas, the booms of small cranes and bucket trucks will be used as guard structures in such areas during the stringing operation to prevent the conductors from falling across roads or other utility lines. Pickup trucks will be used to transport work crews and small materials to work sites.

Construction of temporary wire stringing and pulling sites will be required (i) to provide a level workspace for equipment and personnel and (ii) to establish remote wire stringing set-up sites at angle points in the transmission line and at dead-end structures.

Restoration of the ROW

Restoration efforts, including removal of construction debris, final grading, stabilization of disturbed soil, and installation of permanent sediment control devices (water bars/diversion channels/rock fords), will be completed following construction. All disturbed areas around structures and other graded locations will be seeded with an appropriate conservation seed mixture and/or mulched to stabilize the soils in accordance with applicable regulations. Temporary sediment control devices will be removed following the stabilization of disturbed areas. Existing walls and fences will be restored if necessary. Regulated environmental resource areas that are temporarily disturbed by construction will be restored to pre-construction conditions to the extent practicable, in accordance with applicable permit conditions.

3.2.2 Construction Traffic and Mitigation

Construction-related traffic will occur over the duration of construction. The Project may cause intermittent and temporary additional traffic during the construction period. Construction equipment typically will access 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.

TNEC's contractors will coordinate closely with the Rhode Island Department of Transportation ("RIDOT") to develop acceptable traffic management plans for work within state highways. TNEC will coordinate with local authorities in the Towns of Lincoln and Cumberland for work on local streets and roads. At locations where construction equipment must be staged in a public way, the contractors will follow a pre-approved work zone traffic control plan with appropriate police details.

3.2.3 Project 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, when necessary, between 7:00 a.m. and 5:00 p.m. on weekends. Some limited construction may have to occur outside of standard work hours when needed to complete certain activities. For example, once started, some work tasks such as installing reels of conductor must be continued through to completion and may go beyond normal work hours.

In addition, the nature of transmission line construction requires line outages for certain procedures such as transmission line connections, equipment cutovers, or stringing under or over other

transmission lines. Availability of these outages, which is dictated by the ISO-NE based on regional system load and weather conditions, can be very 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 Towns' Department of Public Works and Police and Fire Chiefs of the details of planned construction including the normal work hours and any extended work hours.

3.2.4 Environmental Compliance Monitoring

Throughout the 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 soil erosion and sediment controls and other BMPs to ensure compliance with all federal, state and local permit commitments. Prior to the start of construction, all Project personnel will be trained on Project environmental requirements and permit conditions, including environmental, 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 contractor's awareness of these issues. Pre-construction "look-ahead meetings" will take place in the field with appropriate Project personnel. The environmental monitor will attend these meetings to provide feedback on environmental requirements and compliance to construction personnel.

During the construction process, the environmental monitor 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.

In addition to retaining the services of an environmental monitor, TNEC will require the construction contractor 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.

3.3 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 National Electric Safety Code ("NESC"). The facilities will be designed in accordance with sound engineering practices using established design codes and guides published by, among others, the Institute of Electrical and Electronic Engineers ("IEEE"), the American Society of Civil Engineers ("ASCE"), the American Concrete Institute ("ACI"), and the American National Standards Institute ("ANSI"). The practices that TNEC will use to protect the public during construction include, but are not limited to, establishing traffic control plans for construction traffic on busy streets to maintain safe driving conditions; restricting public access to potentially hazardous work areas; use of temporary guard structures at road and electric line crossings to prevent accidental contact with conductors during installation; noise and dust control management; and coordination with the Towns of Lincoln and Cumberland and RIDOT during construction.

A report discussing the current status of the health research relevant to exposure to EMF was prepared by Exponent and is attached as Appendix A.

3.4 Public Outreach

The Company believes in and has committed to a fully open, transparent, and regular two-way dialogue with project stakeholders throughout the life of its projects. The Company will launch - and has already begun 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. This multi-faceted campaign includes:

- 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.

3.4.1 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. To date, the Project team has met with the Towns of Cumberland and Lincoln, RI, as well as the City of Attleboro, MA 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.

3.4.2 Open Houses/Community Outreach

The Company 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.

3.4.3 Project Website

A Project website will be developed. This website provides Project information, including background, updates, and contact resources. The Company 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.

3.4.4 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 the Company pledges to respond no later than the next business day to all inquiries – most often on the same business day whenever practical.

3.4.5 Abutter Communications

The Company 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.

3.4.6 Door-to-Door Outreach

The Company 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, the Company representative will leave Project-related information at the door. A similar effort will be undertaken with affected businesses along the project route.

3.4.7 Construction Communication Plan

Building off the existing outreach and communications plan, the Company 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.

The Company'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.

3.4.8 Advertising

The Company 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, all advertising will be placed in the *Valley Breeze*, the community newspaper of record and other publications, as needed, to ensure maximum visibility in the community.

3.4.9 Project Collateral

The Company 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.

3.5 Estimated Project Costs

TNEC has prepared conceptual level estimates for the Project (Table 3-2).

TABLE 3-2: ESTIMATED PROJECT COSTS

PROJECT COMPONENTS	ESTIMATED COST (\$M)
Transmission Line Facilities V148S	\$41.8 +/- 10%

¹ Annual operation and maintenance activities for transmission lines include periodic ROW vegetation management, helicopter patrol, and miscellaneous route inspections.

3.6 Project Schedule

TNEC has developed a preliminary schedule based on time estimates for planning and engineering, permitting and licensing, and construction (Table 3-3). The Project is expected to be completed and in-service by the summer of 2023.

TABLE 3-3: PROJECT SCHEDULE

ACTIVITY	ESTIMATED START DATE	ESTIMATED COMPLETION DATE
Planning and Engineering	November 2020	March 2022
Permitting and Licensing	October 2020	May 2022
Construction	August 2022	May 2023
Facilities In-Service		May 2023
Final Restoration		July 2023

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4.0 PROJECT ALTERNATIVES

4.1 Introduction

This section describes the alternatives to the Project that were considered to address the need for general maintenance and system improvement activities along the existing V148S Transmission Line. These include the replacement of deteriorated wood pole assets and re-conductoring of the existing circuits to provide continued, reliable, electrical service across the region, and to improve high-speed communication between substations.

Selecting a preferred design option involves evaluating a suite of comparable and feasible project alternatives, analyzing the alternative routes and configurations, general ranking of alternatives and identification of initial recommendations in the selection of a preferred solution. TNEC's overriding goal has been to select the alternative that best meets the Project need, with a minimum impact on the natural and social environment, at the lowest possible cost.

Section 4.2 describes the no-action alternative, Section 4.3 describes the partial upgrade with in-kind wood poles alternative, and Section 4.4 describes the Preferred Alternative (the Project).

4.2 No-Action Alternative

Due to the deteriorated condition of numerous assets along the Line, failure to replace these structures could result in major damage to the lines, and dangerous loss of clearance beneath the lines. In summary, this alternative was dismissed as it would not address the need to upgrade the existing electrical transmission system to avoid overloading conductors and provide reliable service to customers.

4.3 Partial Upgrade – Repair Existing Assets

TNEC considered a partial upgrade Project alternative, where existing steel lattice structures would be reinforced. These existing structures were installed between 1917 and 1959, and are considered vintage assets. Due to the condition of these existing assets and current clearance requirements for the current voltage, it was determined that the existing structures would not support new conductor without substantial modifications (height, support arms etc). Therefore, reinforcement or repair of existing assets alternative would not address the need to upgrade the existing electrical transmission system to avoid overloading conductors and provide reliable service to customers.

4.4 V148S Line Asset Condition Refurbishment and OPGW Installation Project

TNEC concluded that the proposed Asset Condition Refurbishment and OPGW Installation Project along the V148S Line on the existing ROW is the preferred option. The preferred alternative will result in lower total impacts on the natural and social environment than the Partial Upgrade alternative (due to the longer lifespan of steel structures, reduced need for repeated future maintenance, and improved reliability of the new conductor and the two OPGW lines), while addressing the Project need for improved system reliability. As a result, the Project costs are estimated to be lower in the long-term than any alternative that involves partial and repeated maintenance along the Line. The preferred

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alternative meets the need for the Project and will reinforce the reliability of the V148S Line between the Washington #126 Substation in Lincoln and the Read Street #9 Substation in Attleboro, MA.

5.0 DESCRIPTION OF AFFECTED NATURAL ENVIRONMENT

This section of the Report describes the existing natural environment that may be affected by the Project, both within and surrounding the Project ROW. As required by the EFSB Rules, a detailed description of environmental characteristics within and immediately surrounding the Project is provided below. This section describes the specific natural features that were evaluated using published resource information, the Rhode Island Geographic System (“RIGIS”) database, various state and local agency databases, and field investigations of the Project ROW.

The Project involves work activities on an existing 115 kV transmission line with an established and maintained ROW, therefore the Project is anticipated to have only negligible impacts on the geology, surficial geology, air quality, population trends, and employment and labor force. For this reason, these environmental characteristics are not included in the below assessment.

5.1 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 determined to allow for a detailed desktop analysis of existing conditions within and adjacent to the Project ROW (Figure 5-1).

5.2 Soils

Detailed information concerning the physical properties, classification, agricultural suitability, and erodibility of soils in the vicinity of the Study Area were obtained from the Natural Resource Conservation Service (NRCS, 2019). 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. Table 5-1 lists the characteristics of the soil phases (lower taxonomic units than series) found within the Study Area. 93.3% of the Study Area is in Rhode Island and 6.7% of the Study Area is in Bristol County, Massachusetts (and therefore not included in this assessment). Study Area hydric soil status is depicted on Figure 5-2.

TABLE 5-1: CHARACTERISTICS OF SOIL PHASES WITHIN THE STUDY AREA

Map unit symbol	Map unit name	Drainage Class	Depth to Bedrock (cm)	Acres in AOI	Percent of AOI
CaC	Canton-Charlton-Rock outcrop complex, 3 to 15 percent slopes	Well drained	> 6 ft.	17.2	0.5%
CaD	Canton-Charlton-Rock outcrop complex, 15 to 35 percent slopes, very stony	Well drained	> 6 ft.	15.3	0.5%
CB	Canton-Urban land complex	Well drained	> 6 ft.	277.5	8.2%
CC	Canton-Urban land complex, very rocky	Well drained	> 6 ft.	27.4	0.8%
CdA	Canton and Charlton fine sandy loams, 0 to 3 percent slopes	Well drained	> 6 ft.	58.4	1.7%
CdB	Canton and Charlton fine sandy loams, 3 to 8 percent slopes	Well drained	> 6 ft.	220.9	6.5%
CdC	Canton and Charlton fine sandy loams, 8 to 15 percent slopes	Well drained	> 6 ft.	145.3	4.3%

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Map unit symbol	Map unit name	Drainage Class	Depth to Bedrock (cm)	Acres in AOI	Percent of AOI
CeC	Canton and Charlton fine sandy loams, 3 to 15 percent slopes, very rocky	Well drained	> 6 ft.	520.3	15.4%
ChB	Canton and Charlton fine sandy loams, 0 to 8 percent slopes, very stony	Well drained	> 6 ft.	307.7	9.1%
ChC	Canton and Charlton fine sandy loams, 8 to 15 percent slopes, very stony	Well drained	> 6 ft.	11.4	0.3%
ChD	Canton and Charlton very stony fine sandy loams, 15 to 25 percent slopes	Well drained	> 6 ft.	5.2	0.2%
CkC	Canton and Charlton fine sandy loams, 3 to 15 percent slopes, extremely stony	Well drained	> 6 ft.	7.8	0.2%
Dc	Deerfield loamy fine sand, 0 to 3 percent slopes	Well drained	1.5 - 3.5 ft	12.1	0.4%
Du	Dumps	Moderately well drained	Variable	47.7	1.4%
FeA	Freetown muck, 0 to 1 percent slopes	Very poorly drained	0 - 1.5 ft.	18.5	0.5%
HkC	Hinckley loamy sand, 8 to 15 percent slopes	Excessively drained	> 6 ft.	151.2	4.5%
MmB	Merrimac fine sandy loam, 3 to 8 percent slopes	Somewhat excessively drained	> 6 ft.	58.4	1.7%
MU	Merrimac-Urban land complex, 0 to 8 percent slopes	Well drained	> 6 ft.	116.0	3.4%
NaA	Narragansett silt loam, 0 to 3 percent slopes	Well drained	> 6 ft.	11.4	0.3%
NaB	Narragansett silt loam, 3 to 8 percent slopes	Well drained	> 6 ft.	2.6	0.1%
NbC	Narragansett very stony silt loam, 8 to 15 percent slopes	Well drained	> 6 ft.	6.5	0.2%
NeB	Newport silt loam, 3 to 8 percent slopes	Well drained	2 - 4 ft.	17.5	0.5%
Nt	Ninigret fine sandy loam, 0 to 3 percent slopes	Moderately well drained	1.5 - 3.5 ft	7.8	0.2%
PaB	Paxton fine sandy loam, 3 to 8 percent slopes	Well drained	2 - 4 ft.	15.2	0.4%
Pg	Pits, gravel	Variable	Variable	101.7	3.0%
Pk	Pits, quarries	Variable	Variable	13.8	0.4%
Pp	Pootatuck fine sandy loam	Moderately well drained	1.5 - 3.5 ft	66.5	2.0%
Rc	Raypol silt loam	Poorly drained	0 - 1.5 ft.	2.5	0.1%
Re	Ridgebury fine sandy loam, 0 to 3 percent slopes	Poorly drained	0 - 1.5 ft.	64.8	1.9%
Rf	Ridgebury, Leicester, and Whitman soils, 0 to 8 percent slopes, extremely stony	Poorly drained	0 - 1.5 ft.	204.1	6.0%

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Map unit symbol	Map unit name	Drainage Class	Depth to Bedrock (cm)	Acres in AOI	Percent of AOI
Ru	Rippowam fine sandy loam	Poorly drained	0 - 1.5 ft.	23.3	0.7%
Sb	Scarboro mucky fine sandy loam, 0 to 3 percent slopes	Very poorly drained	0 - 1.5 ft.	40.1	1.2%
StA	Sutton fine sandy loam, 0 to 3 percent slopes	Moderately well drained	1.5 - 3.5 ft	30.9	0.9%
StB	Sutton fine sandy loam, 3 to 8 percent slopes	Moderately well drained	1.5 - 3.5 ft	27.2	0.8%
SuB	Sutton fine sandy loam, 0 to 8 percent slopes, very stony	Moderately well drained	1.5 - 3.5 ft	39.1	1.2%
SwA	Swansea muck, 0 to 1 percent slopes	Very poorly drained	0 - 1.5 ft.	25.3	0.8%
UD	Udorthents-Urban land complex	Variable	Variable	177.0	5.2%
Ur	Urban land	Variable	Variable	74.2	2.2%
W	Water	Subaquatic	Water	69.9	2.1%
Wa	Walpole sandy loam, 0 to 3 percent slopes	Poorly drained	0 - 1.5 ft.,	7.8	0.2%
WbA	Wapping silt loam, 0 to 3 percent slopes	Moderately well drained	1.5 - 3.5 ft	21.4	0.6%
WbB	Wapping silt loam, 3 to 8 percent slopes	Moderately well drained	1.5 - 3.5 ft	49.4	1.5%
WgB	Windsor loamy sand, 3 to 8 percent slopes	Moderately well drained	> 6 ft.	10.5	0.3%
WhB	Woodbridge fine sandy loam, 3 to 8 percent slopes	Moderately well drained	1.5 - 3.5 ft	20.3	0.6%
Subtotals for Area of Interest in Rhode Island				3148.9	93%
Totals for Area of Interest				3374.7	100%

Source: (NRCS, 2019).

5.2.1 Soil Series

The soil series detailed in the following subsections were identified within the Study Area. The following classifications are as published online (NRCS, 2019).

Canton and Charlton Series: The Canton series consists of very deep, well drained soils formed in a loamy mantle underlain by sandy till. They are on nearly level to very steep moraines, hills, and ridges. Slope ranges from 0 to 45 percent. Saturated hydraulic conductivity is moderately high or high in the solum and high or very high in the substratum. The Charlton series consists of very deep, well drained soils formed in loamy melt-out till. They are nearly level to very steep soils on moraines, hills, and ridges. Slope ranges from 0 to 60 percent. Saturated hydraulic conductivity is moderately high or high.

Canton-Urban Land Complex: This complex consists of well drained Canton soils and areas of Urban land. The complex is on side slopes and crests of glacial upland hills in the more densely populated areas of the State. Areas are irregular in shape and mostly range from 10 to 200 acres. Slopes are commonly about six percent but range from 0 to 15 percent. The complex is approximately 40 percent Canton soils, 30 percent

Urban land, and 30 percent other soils. The areas are in such an intricate pattern that it was not practical to map them separately.

Deerfield Series: The Deerfield series consists of very deep, moderately well drained soils formed in glaciofluvial deposits. They are nearly level to strongly sloping soils on terraces, deltas, and outwash plains. Slope ranges from 0 to 15 percent. Saturated hydraulic conductivity is high or very high. Mean annual temperature is about 9 degrees C. and mean annual precipitation is about 1194 mm.

Freetown muck: The Freetown series consists of very deep, very poorly drained organic soils formed in more than 130 centimeters of highly decomposed organic material. They are commonly in depressions or on level uplands and alluvial plains. Slope ranges from 0 to 2 percent. Saturated hydraulic conductivity is moderately high or high. The mean annual temperature is about 9 degrees Celsius and mean annual precipitation is about 1205 millimeters.

Hinckley Series: The Hinckley series consists of very deep, excessively drained soils formed in glaciofluvial materials. They are nearly level through very steep soils on outwash terraces, outwash plains, outwash deltas, kames, kame terraces, and eskers. Saturated hydraulic conductivity is high or very high. Slope ranges from 0 to 60 percent.

Merrimac Series: The Merrimac series consists of very deep, somewhat excessively drained soils formed in outwash. They are nearly level through very steep soils on outwash terraces and plains and other glaciofluvial landforms. Slope ranges from 0 through 35 percent. Saturated hydraulic conductivity is high or very high. Mean annual temperature is about 48 degrees F. (9 degrees C.) and mean annual precipitation is about 42 inches (1067 millimeters).

Narragansett Series: The Narragansett series consists of very deep, well drained loamy soils formed in a mantle of medium-textured deposits overlying till. They are nearly level to moderately steep soils on till plains, low ridges and hills. Slope ranges from 0 to 25 percent. Permeability is moderate in the surface layer and subsoil and moderately rapid or rapid in the substratum. Mean annual temperature is about 50 degrees F. and the mean annual precipitation is about 47 inches.

Newport Series: The Newport series consists of well drained loamy soils formed in lodgement till derived mainly from dark sandstone, conglomerate, argillite, and phyllite. The soils are very deep to bedrock and moderately deep to a densic contact. They are nearly level through moderately steep soils on till plains, low ridges, hills and drumlins. Slope ranges from 0 through 35 percent. Saturated hydraulic conductivity is moderately high or high in the surface layer and subsoil and low or moderately high in the dense substratum. Mean annual temperature is 49 degrees F. (9 degrees C.) and mean annual precipitation is 48 inches (1219 mm).

Ninigret Series: The Ninigret series consists of very deep, moderately well drained soils formed in loamy over sandy and gravelly glacial outwash. They are nearly level to strongly sloping soils on glaciofluvial landforms, typically in slight depressions and broad drainage ways. Slope ranges from 0 through 15 percent. Saturated hydraulic conductivity is moderately high or high in the solum and high or very high in the substratum. Mean annual temperature is about 49 degrees F. and mean annual precipitation is about 48 inches.

Paxton Series: The Paxton series consists of well drained loamy soils formed in lodgment till. The soils are very deep to bedrock and moderately deep to a densic contact. They are nearly level to steep soils on hills, drumlins, till plains, and ground moraines. Slope ranges from 0 to 45 percent. Saturated hydraulic conductivity is moderately high or high in the surface layer and subsoil and low or moderately low in the

substratum. Mean annual temperature is about 10 degrees C., and mean annual precipitation is about 1194 mm.

Pootatuck Series: The Pootatuck series consists of very deep, moderately well drained loamy soils formed in alluvial sediments. They are nearly level soils on floodplains subject to frequent to occasional flooding. Slope ranges from 0 to 3 percent. Saturated hydraulic conductivity is moderately high or high in the loamy upper layers and high or very high in the sandy substratum. Mean annual temperature is about 10 degrees Celsius, and mean annual precipitation is about 1190 millimeters.

Raypol Series: The Raypol series consists of very deep, poorly drained soils formed in loamy over sandy and gravelly outwash. They are nearly level to gently sloping soils in shallow drainageways and low-lying positions on terraces and plains. Slope ranges from 0 to 5 percent. The soils have a water table at or near the surface much of the year. Permeability of the Raypol soils is moderate in the surface layer and subsoil and rapid or very rapid in the substratum. Mean annual temperature is about 50 degrees F., and mean annual precipitation is about 47 inches.

Ridgebury, Leicester and Whitman Series: The Ridgebury series consists of very deep, somewhat poorly and poorly drained soils formed in lodgment till derived mainly from granite, gneiss and/or schist. They are commonly shallow to a densic contact. They are nearly level to gently sloping soils in depressions in uplands. They also occur in drainage ways in uplands, in toeslope positions of hills, drumlins, and ground moraines, and in till plains. Slope ranges from 0 to 15 percent. Saturated hydraulic conductivity is moderately high or high in the solum and very low to moderately low in the substratum.

The Leicester series consists of very deep, poorly drained soils formed in coarse-loamy till. They are nearly level or gently sloping soils in drainageways and low-lying positions on hills. Slope ranges from 0 to 8 percent. Permeability is moderate or moderately rapid in the surface layer and subsoil and moderate to rapid in the substratum.

The Whitman series consists of very deep, very poorly drained soils formed in lodgment till derived mainly from granite, gneiss, and schist. They are shallow to a densic contact. These soils are nearly level or gently sloping soils in depressions and drainageways on uplands. Saturated hydraulic conductivity is moderately high or high in the solum and very low to moderately low in the substratum.

Rippowam Series: The Rippowam series consists of very deep, poorly drained loamy soils formed in alluvial sediments. They are nearly level soils on flood plains subject to frequent flooding. Slope ranges from 0 to 3 percent. Saturated hydraulic conductivity ranges from moderately high or high in the loamy upper part and high or very high in the underlying sandy materials. Mean annual temperature is about 50 degrees F., and mean annual precipitation is about 47 inches.

Scarboro Series: The Scarboro series consists of very deep, very poorly drained soils in sandy glaciofluvial deposits on outwash plains, deltas, and terraces. They are nearly level soils in depressions. Slope ranges from 0 through 3 percent. Saturated hydraulic conductivity is high or very high. Mean annual temperature is about 49 degrees F. (9 degrees C.) and the mean annual precipitation is about 44 inches (1118 millimeters).

Sutton Series: The Sutton series consists of very deep, moderately well drained loamy soils formed in melt-out till. They are nearly level to strongly sloping soils on hills, low ridges, and ground moraines, typically on footslopes, lower backslopes and in slight depressions. Slope ranges from 0 to 15 percent. Saturated hydraulic conductivity is moderately high or high throughout.

Swansea Series: The Swansea series consists of very poorly drained organic soils. They formed in 40 to 130 centimeters of highly decomposed organic material over sandy mineral. These soils are in depressions or on flat level areas on uplands and outwash plains. Saturated hydraulic conductivity is moderately high or high in the organic material and very high in the substratum. The mean annual temperature is about 9 degrees Celsius and the mean annual precipitation is about 1143 millimeters.

Udorthents – Urban Land Complex: This complex consists of moderately well drained to excessively drained soils that have been disturbed by capping or filling, and areas that are covered by buildings and pavement. The areas are mostly larger than five acres. The complex is about 70 percent Udorthents, 20 percent Urban land, and 10 percent other soils.

Walpole Series: The Walpole Series consists of very deep, poorly drained sandy soils formed in outwash and stratified drift. They are nearly level to gently sloping soils in low-lying positions on terraces and plains. Slope ranges from 0 to 8 percent. Saturated hydraulic conductivity is moderately high or high in the surface layer and subsoil, and high or very high in the substratum. Mean annual temperature is about 48 degrees F., and mean annual precipitation is about 43 inches.

Wapping Series: The Wapping series consists of very deep, moderately well drained loamy soils formed in silty mantled friable or firm till on uplands. They are nearly level to gently sloping soils on till plains, low ridges and hills, typically on lower slopes and in slight depressions. Slope ranges from 0 to 8 percent. Saturated hydraulic conductivity is moderately high or high in the surface layer and subsoil and high or very high in the substratum. Mean annual temperature is about 48 degrees F. and mean annual precipitation is 45 inches.

Windsor Series: The Windsor series consists of very deep, excessively drained soils formed in sandy outwash or eolian deposits. They are nearly level through very steep soils on glaciofluvial landforms. Slope ranges from 0 through 60 percent. Saturated hydraulic conductivity is high or very high. Mean annual temperature is about 10 degrees C and mean annual precipitation is about 1092 mm

5.2.2 Prime Farmland Soils

Prime farmland, as defined by the United States Department of Agriculture (USDA Soil Survey Staff, n.d.), 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 yield of crops when it is treated and managed using acceptable farming methods. Urbanized land and water are exempt from consideration as prime farmland. Table 5-2 lists the prime farmland soil units within the Study Area. The Project ROW crosses 12 areas of prime farmland, including areas of fine sand loams, silt loam and sandy loam.

TABLE 5-2: USDA PRIME FARMLAND SOILS WITHIN STUDY AREA

SOIL MAP UNIT SYMBOL	MAP UNIT NAME	PERCENT SLOPE
CdA	Canton and Charlton fine sandy loams	0-3%
CdB	Canton and Charlton fine sandy loams	3-8%
Mmb	Merrimac sandy loam	3-8%
NaA	Narragansett silt loam	0-3%
NaB	Narragansett very stony silt loam	8-15%

SOIL MAP UNIT SYMBOL	MAP UNIT NAME	PERCENT SLOPE
NeB	Newport silt loam	3-8%
Nt	Ninigret fine sand loam	N/A
PaB	Paxton fine sandy loam	3-8%
Pp	Pootatuck fine sandy loam	N/A
WbA	Wapping silt loam	0-3%
WbB	Wapping silt loam	3-8%
WhB	Woodbridge fine sandy loam	3-8%

5.2.3 Farmland of Statewide Importance

Farmland of statewide importance is land that is designated by the Rhode Island Department of Administration Division of Planning to be statewide importance for the production of food, feed, fiber, storage, and oilseed crops. Generally, farmlands of statewide importance include those lands that do not meet the requirements to be considered prime farmland, but that economically produce high crop yields when treated and managed with modern farming methods. Some may produce as high a yield as prime farmland if conditions are favorable.

To extend the additional protection of state regulation to prime farmland, the state of Rhode Island has expanded its definition of farmland of stateside importance to include all prime farmland areas. Therefore, in Rhode Island all USDA-designated prime farmland soils are also farmland of statewide importance.

Table 5-3 lists soil units designated as farmland soils of statewide importance that are found within the Study Area. The Project ROW crosses nine areas of farmland soils of statewide importance, including soils identified as fine sandy loams, fine sands, loamy sands, and sandy loams.

TABLE 5-3: FARMLAND SOILS OF STATEWIDE IMPORTANCE WITHIN THE STUDY AREA

SOIL MAP UNIT SYMBOL	MAP UNIT NAME	PERCENT SLOPE
CdC	Canton and Charlton fine sandy loam	8-15%
Dc	Deerfield loamy fine sand	0-3%
HkC	Hinckley loamy sand	8-15%
MmB	Merrimac fine sandy loam	3-8%
Rc	Raypol silt loam	0-3%
Re	Ridgebury fine sandy loam	0-3%
Ru	Rippowam fine sandy loam	0-3%
Wa	Walpole sandy loam	0-3%
WgB	Windsor loamy sand	3-8%

5.2.4 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 in Rhode Island range from 0.10 to 0.64 and vary throughout the depth of the soil profile with changes in soil texture. K values aid in determining locations where soil erosion and sediment controls may be necessary. Very poorly drained soils and certain floodplain soil 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 described as strongly sloping or rolling may include areas with slopes greater than eight percent. Soil map units with assigned K values within the project study area, are listed in Table 5-4.

TABLE 5-4: STUDY AREA POTENTIALLY HIGHLY ERODIBLE SOIL MAPPING UNITS

SOIL MAP UNIT SYMBOL	MAP UNIT NAME	PERCENT SLOPE	SURFACE K VALUES
EXAMPLES: CeC	Canton and Charlton fine sandy loams, very rocky	3-15	0.43
ChD	Canton and Charlton very stony fine sandy loams	15-25	0.43
HkC	Hinckley loamy sand	8-15	0.17
MmB	Merrimac fine sandy loam	3-8	0.28
NaB	Narragansett very stony silt loam	8-15	0.43
NeB	Newport silt loam	3-8	0.43
SuB	Sutton very stony fine sandy loam	0-8	0.43
WbB	Wapping silt loam	3-8	0.64
WcB	Wapping very stony silt loam	0-8	0.64
WhB	Woodbridge fine sandy loam	3-8%	0.43

Source: (NRCS, 2019)

USDA Erodibility Values (K) and Texture of the B and C Horizons of Soils in Rhode Island
([https://efotg.sc.egov.usda.gov/references/public/RI/section7\(USLE\).pdf](https://efotg.sc.egov.usda.gov/references/public/RI/section7(USLE).pdf))

5.3 Surface Water

The Study Area is drained by waterways in the Moshassuck River, Abbott Run and Peters River – Blackstone River Watersheds. Waterways generally flow south. The major surface water resources and classifications within the Study Area are listed in Table 5-5. Most of these major watercourses cross the Project ROW. 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 courses that follow.

TABLE 5-5: MAJOR SURFACE WATER RESOURCES WITHIN THE STUDY AREA

WATER BODY NAME	CLASSIFICATION/ USE	FISHERY DESIGNATION	IMPAIRMENT CATEGORY	WATER BODY CROSSED BY PROJECT
Moshassuck River	B	Cold	5	Yes
Blackstone River	B/B1	Warm	5	Yes
Blackstone Canal	B1	Warm	5	Yes
Monastery Brook	B	Warm	5	Yes
Scott Brook	A	Unassigned	5	No
Millers River	AA	Cold	5	Yes
Abbott Run Brook	AA	Warm	5	Yes

Source: Rhode Island Department of Environmental Management Environmental Resource Map:
<http://ridemgis.maps.arcgis.com/apps/webappviewer/index.html>

Most surface waters within the Study Area are classified as “B” or “B1”, which provides fish and wildlife habitat and primary and secondary contact recreational activities. Class B waters are suitable for compatible industrial processes and cooling, hydropower, aquaculture uses, navigation, and irrigation and other agricultural uses. Class B waters should have good aesthetic value. Two surface waters (Millers River and Abbott Run Brook) are classified as “AA”, which are public drinking water supply waterbodies. Class AA waters may be subject to restricted recreational use by State and local authorities.

Pursuant to the requirements of Section 305(b) of the Federal Clean Water Act, water bodies that don’t support 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. All seven major surface waters within the Study Area are not meeting their designated uses, with impairments due to *Enterococcus* bacteria, fecal coliform, cadmium, lead, iron, PCBs in fish tissue, mercury in fish tissue, non-native aquatic plants, and benthic macroinvertebrate bioassessments.

5.4 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, whereas groundwater classified as GB and

GC is known or presumed to be unsuitable for drinking water use without treatment. 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 in the study area are predominantly protected to maintain drinking water quality and are roughly equally split between those classified by the RIDEM as GA (~50% the study area), and those classified as GAA (~43% the Study Area).

5.5 Vegetation

The Study Area contains a variety of vegetative cover typical of Southern New England (DeGraaf & Yamasaki, 2001). These include oak/pine forest, pine/oak/maple forest, old field, and managed lawn. This section of the report focuses on upland communities. Wetland communities are discussed in Section 5.6 of this report. The Project occurs within existing ROWs maintained by TNEC as low-growth vegetative communities that are typical along overhead transmission line facilities.

5.5.1 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.

5.5.2 White Pine/Northern Red Oak/Red Maple Forest

Portions of the Study Area are typically dominated by Oaks, white pine and red maple (*Acer rubrum*) forest. Other common associated tree species include paper (*Betula papyrifera*), yellow (*B. alleghaniensis*), sweet birches (*B. lenta*), American beech (*Fagus grandifolia*), eastern hemlock (*Tsuga canadensis*), and black cherry (*Prunus serotina*). This forested community type occurs across southern New England to elevation of 1,500 feet, generally on deep, well-drained fertile soils. This type is common in the transition between northern hardwoods and oak types in southern New England. Common understory shrubs include witch-hazel (*Hamamelis virginiana*), alternate-leaf dogwood (*Cornus alterniflora*), maple-leaved viburnum (*Viburnum acerifolium*), and mountain laurel (*Kalmia latifolia*).

5.5.3 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.), aster (*Aster* sp.), pokeweed (*Phytolacca americana*), and mullein (*Verbascum thapsus*) are also common.

5.5.4 Upland Low Shrub Land Community

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*), and northern arrowwood (*Viburnum recognitum*) 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 (*Juniperus virginiana*). Mature forest containing northern red oak (*Quercus rubra*) and red maple (*Acer rubrum*) are also present along the corridor, and saplings of these species are occasionally found in the ROW.

5.5.5 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 these areas.

5.6 Wetlands

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 percent) 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.

Federal and State-regulated freshwater wetlands and/or streams were identified and delineated within the Project ROW during the summer of 2019. Wetlands were re-delineated and wetland boundaries confirmed during the spring and autumn of 2021. 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 ROWs. Wetlands outside the ROW within the Study Area were identified based on a desktop review of RIGIS wetlands data (RIGIS 2019). Figure 5-3 depicts wetland resources within the Study Area, based on the results of this desktop analysis.

In total, 40 waterbodies (including 29 lakes/ponds, and 11 marsh/swamps), were mapped within the Study Area, as well as 212 freshwater wetlands, 29 perennial streams, and 1 intermittent stream. Of these wetlands and waterways, field investigations identified 15 wetlands, nine perennial streams and one intermittent stream within the Project ROW.

In accordance with the provisions of the Rhode Island Fresh Water Wetlands Act and Rules (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. **Swamps** are defined as wetlands dominated by woody species and are three acres in size, or greater. **Marshes** are at least one acre in size and contain standing or running water during the growing season. Marsh plant species include grasses (*Gramineae*), sedges (*Cyperaceae*), rushes (*Juncaceae*) and other non-woody species. **Bogs** are wetlands dominated by “bog” species, which generally prefer acidic conditions, such as blueberries and cranberries (*Vaccinium* sp.), leatherleaf (*Chamaedaphne calyculata*), and sedges (*Carex* spp.). Generally, over 50 percent of the ground or water surface within a bog is covered with sphagnum moss (*Sphagnum* sp.). Bogs have no minimum size criteria. **Emergent wetland** communities are areas similar to marshes in vegetation composition; however, they are less than one acre in size. **Forested and shrub wetlands** are similar to swamps, but do not meet the three-acre size criteria. The upland area within 50 feet of the edge of a swamp, marsh, or bog is regulated as the 50-foot Perimeter Wetland under the Rules. Emergent wetland communities, forested wetlands, and shrub wetlands do not merit a 50-foot Perimeter Wetland according to the Rules.

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. A river is any perennial stream indicated by a 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. A pond is an area of open standing or slow-moving water present for six or more months during the year and at least one quarter of an acre in size. Ponds have a 50-foot perimeter wetland associated with their boundary. ASSF are defined as a body of flowing water as identified by a scoured channel or change in vegetative composition or density that conveys storm runoff into or out of a wetland. ASSF include drainage swales and channels that lead into, out of, pass through, or connect other freshwater wetlands or coastal wetlands, and that carry flows resulting from storm events, but may remain relatively dry at other times. ASF include, but are not limited to, floodplains, depressions or low-lying areas flooded by rivers, streams, intermittent streams, or areas subject to storm flowage, which collect, hold, or meter out storm and flood waters. ASSF and ASF are not assigned perimeter or riverbank wetlands.

5.6.1 Freshwater Pond

A “pond” is defined by the R.I. Gen. Laws § 2-1-20(12), as “a place, natural or manmade...where open standing or slowly moving water shall be present for at least six (6) months a year. For the purpose of these Rules, ponds exclude those places within the State of Rhode Island that meet the definition of vernal pool”. The boundary of a pond is determined by the extent of water which is delineated and surveyed. There are 52 unnamed ponds within the Study Area (refer to Figure 5-3) (*RIDEM Environmental Resource Map*, n.d.). There are no ponds or open waterbodies on the Project ROW.

5.6.2 Swamp

Swamps are defined as areas where groundwater shall be near or at the surface of the ground for a significant part of the growing season, or where runoff water from surface drainage shall collect frequently, and/or where a vegetational community shall be made up of species including (but not limited to) red maple (*Acer rubrum*), elm (*Ulmus americana*), black spruce (*Picea mariana*), white cedar (*Chamaecyparis thyoides*), ashes (*Fraxinus*), poison sumac (*Rhus vernix*), larch (*Larix laricina*), spice bush (*Lindera benzoin*), alders (*Alnus*), skunk cabbage (*Symplocarpus foetidus*), hellebore (*Veratrum viride*), hemlock (*Tsuga canadensis*), sphagnums (*Sphagnum*), azaleas (*Rhododendron*), black alder (*Ilex verticillata*), coast pepperbush (*Clethra alnifolia*), marsh marigold (*Caltha palustris*), blueberries (*Vaccinium*), buttonbush (*Cephalanthus occidentalis*), willow (*Salicaceae*), water willow (*Decodon verticillatus*), tupelo (*Nyssa sylvatica*), laurels (*Kalmia*), swamp white oak (*Quercus bicolor*), or species indicative of marsh. For purposes of this definition, “significant part of the growing season” means that period of the growing season when water is present long enough to support a plant community of predominantly hydrophytic vegetation.

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 swamp transitions into off-ROW forested swamp. Vegetation in a forested swamp includes predominantly red maple, willow, alder, silky dogwood, coast pepperbush, winterberry, and sphagnums.

In total, there are 78 forested swamps within the Study Area (*RIDEM Environmental Resource Map*, n.d.).

5.6.3 Marsh / Emergent Plant Community

Marshes are wetlands where a vegetational community shall exist in standing or running water during the growing season and/or shall be made up of one (1) or more of, but not limited to nor necessarily including all of the following plants or groups of plants: hydrophytic reeds (*Phragmites*), grasses (*Gramineae*), mannagrasses (*Glyceria*), cutgrasses (*Leersia*), pickerelweeds (*Pontederiaceae*), sedges (*Cyperaceae*), rushes (*Juncaceae*), cattails (*Typha*), water plantains (*Alismataceae*), bur-reeds (*Sparganiaceae*), pondweeds (*Zosteraceae*), frog's bits (*Hydrocharitaceae*), arums (*Araceae*), duckweeds (*Lemnaceae*), water lilies (*Nymphaeaceae*), water-milfoils (*Haloragaceae*), water-starworts (*Callitrichaceae*), bladderworts (*Utricularia*), pipeworts (*Eriocaulon*), sweet gale (*Myrica gale*), and buttonbush (*Cephalanthus occidentalis*). An “Emergent plant community” means a freshwater wetland characterized by erect, rooted, herbaceous hydrophytic vegetation that is present for most of the growing season in most years, and that may be persistent or non-persistent in nature

Within the Study Area there are fifteen wetlands that are identified as marsh/emergent wetlands or wet meadows, with an approximate area of 24 acres (*RIDEM Environmental Resource Map*, n.d.)

5.6.4 River / Perennial Stream

A river is typically a named body of water designated as a perennial stream by United States Geological Survey (“USGS”) (a blue line stream on a USGS topographic map). A perennial stream maintains flow year-round. There are 29 rivers / perennial streams located within the Study Area, of which nine cross the Project ROW. These include the Blackstone River, Blackstone Canal, Abbott Brook, Millers River and unnamed perennial tributaries.

5.6.5 Stream / Intermittent Stream

A stream means any flowing body of water or watercourse other than a river that flows long enough each year to develop and maintain a channel and that may carry groundwater discharge or surface runoff. Such watercourses may not have flowing water during extended dry periods but may contain isolated pools or standing water. There is 1 stream / intermittent stream located within the Study Area, which also crosses the Project ROW.

The Project has been designed to avoid impacts to the perennial and intermittent streams in proximity to the ROW. Some streams within the Project area are culverted and therefore will not be impacted by Project activities. Those streams that cannot be avoided will be bridged/spanned. Construction mats will be placed forming a bridge for vehicular and equipment access while avoiding impacts to the stream bed and only temporarily impacting the bank.

5.6.6 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. There are 78 forested and shrub wetlands within the Study Area (*RIDEM Environmental Resource Map*, n.d.), with an approximate area of 143 acres.

5.6.7 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 (“FEMA”) (RIGIS 2017). There are 12 areas of 100-year floodplain located within the Study Area, of which two extend into the Project ROW – these are associated with the Blackstone River and Abbott Run Brook.

5.6.8 Area Subject to Storm Flowage (“ASSF”)

ASSFs 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. There are no mapped ASSFs within the Study Area.

5.6.9 Special Aquatic Site – Vernal Pools

A vernal pool is a type of special aquatic site that is generally defined as a contained basin that generally lacks a permanent above-ground outlet. It fills with water between late fall and spring from rising

groundwater, or with the meltwater and runoff of winter and spring snow and rain (RIDEM 2016). 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.”

No impacts to vernal pools will occur because of Project activities.

5.7 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. A list of amphibians, reptiles, birds, and mammals expected to occur within a given habitat are provided in Table 5-6. It should be noted that individual species may not occur in any one particular area but may be found throughout the general Study Area. This information is based on geographical distribution and habitat preferences as described in *New England Wildlife: Habitat, Natural History and Distribution* (DeGraaf and Yamasaki 2001).

5.7.1 Fisheries

There are two Designated Trout Waters within the Study Area (Blackstone River and Abbott Run). Millers River (which is not listed as a designated trout water), is however listed as a cold water fishery. Typical fish species found in coldwater water fisheries include: brook trout (*Salvenius fontinails*), brown trout (*Salmo trutta*), yellow perch (*Perca flavescens*), bluegill (*Lepomis macrochirus*), and a variety of minnow and other species.

TABLE 5-6: EXPECTED WILDLIFE SPECIES WITHIN THE STUDY AREA

	TERRESTRIAL HABITATS				AQUATIC HABITATS					
	OAK/PIN E FOREST	WHITE PINE/NORTHERN RED OAK/RED MAPLE FOREST	OLD FIELD COMMUNIT Y†	UPLAND LOW SHRUB LAND COMMUNITY†	POND	SHALLO W MARSH†	SHRUB SWAM P†	FORESTE D WETLAND †	RIVE R	STREA M†
Amphibians & Reptiles										
American Bullfrog					X	X	X		X	X
American Toad	X	X	X	X	X	X	X	X		
Black Rat Snake	X	X	X	X				X		
Blanding's Turtle			X	X						
Blue-spotted Salamander	X	X			X	X	X	X		
Common Garter Snake	X	X	X	X	X	X	X	X		X
Common Musk Turtle			X		X	X	X		X	X
Common Snapping Turtle	X	X	X	X	X	X	X		X	X
Eastern Box Turtle	X	X	X	X		X	X	X		
Eastern Hognose Snake	X	X	X	X		X		X		
Eastern Milk Snake	X	X	X	X				X		
Eastern Smooth Green Snake	X	X	X	X		X	X	X		
Eastern Worm Snake	X	X	X	X						
Four-toed Salamander	X	X				X	X	X		X
Fowler's Toad	X	X	X	X	X	X	X	X		
Green Frog					X	X	X	X	X	X
Gray Treefrog	X	X			X	X	X	X		
Marbled Salamander	X	X			X		X	X		

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	TERRESTRIAL HABITATS				AQUATIC HABITATS					
	OAK/PIN E FOREST	WHITE PINE/NORTHERN RED OAK/RED MAPLE FOREST	OLD FIELD COMMUNIT Y†	UPLAND LOW SHRUB LAND COMMUNITY†	POND	SHALLO W MARSH†	SHRUB SWAM P†	FORESTE D WETLAND †	RIVE R	STREA M†
Northern Black Racer	X	X	X	X		X	X	X		
Northern Brown Snake	X	X	X	X		X	X	X		
Northern Dusky Salamander	X	X						X		X
Northern Redback Salamander	X	X				X		X		
Northern Redbelly Snake	X	X	X	X			X	X		
Northern Ringneck Snake	X	X						X		
Northern Spring Peeper	X	X			X	X	X	X		
Northern Two-lined Salamander	X	X						X		X
Northern Water Snake					X	X	X		X	X
Painted Turtle			X	X						
Pickerel Frog					X	X		X		X
Red-spotted Newt	X	X			X	X	X	X		X
Ribbon Snake	X	X			X	X	X	X		X
Spotted Salamander	X	X			X	X	X	X		
Spotted Turtle	X	X	X	X	X	X	X	X		
Wood Frog	X	X				X	X	X		
Wood Turtle	X	X	X	X	X	X	X	X	X	X
Birds										
American Black Duck					X	X	X	X	X	X
Acadian Flycatcher	X	X						X		

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	TERRESTRIAL HABITATS				AQUATIC HABITATS					
	OAK/PINE FOREST	WHITE PINE/NORTHERN RED OAK/RED MAPLE FOREST	OLD FIELD COMMUNITY†	UPLAND LOW SHRUB LAND COMMUNITY†	POND	SHALLOW MARSH†	SHRUB SWAMP†	FORESTED WETLAND†	RIVER	STREAM†
American Crow	X	X	X	X				X		
American Goldfinch	X	X	X	X		X	X	X		
American Kestrel	X	X	X	X		X		X		
American Redstart	X	X						X		
American Robin*	X	X	X				X	X		
American Tree Sparrow	X	X	X	X		X	X	X		
American Woodcock	X	X	X	X			X	X		
Baltimore Oriole	X	X	X				X	X		
Bank Swallow	X	X	X	X	X	X		X	X	X
Barn Owl										
Barn Swallow	X	X	X	X	X	X		X	X	X
Barred Owl	X	X	X	X				X		
Belted Kingfisher					X				X	X
Black & White Warbler	X	X						X		
Black-billed Cuckoo			X	X				X		
Black-capped Chickadee	X	X	X	X			X	X		
Black-throated Green Warbler	X	X						X		
Blue-gray Gnatcatcher	X	X	X	X			X	X		
Blue-headed Vireo	X	X						X		
Blue Jay	X	X	X					X		
Blue-winged Warbler	X	X	X	X			X	X		

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	OAK/PIN E FOREST	WHITE PINE/NORTHERN RED OAK/RED MAPLE FOREST	OLD FIELD COMMUNIT Y†	UPLAND LOW SHRUB LAND COMMUNITY†	POND	SHALLO W MARSH†	SHRUB SWAM P†	FORESTE D WETLAND †	RIVE R	STREA M†
Bobolink						X				
Broad-winged Hawk	X	X						X		
Brown Creeper	X	X						X		
Brown Thrasher	X	X	X	X				X		
Brown-headed Cowbird	X	X	X	X		X		X		
Bufflehead									X	X
Canada Goose					X	X	X		X	X
Canada Warbler	X	X					X	X		
Carolina Wren	X	X	X	X				X		
Cedar Waxwing	X	X	X	X			X	X		
Chestnut-sided Warbler			X	X			X	X		
Chimney Swift			X	X						
Chipping Sparrow	X	X						X		
Common Nighthawk	X	X	X	X				X		
Common Grackle	X	X				X	X	X		
Common Merganser	X	X			X			X	X	X
Common Redpoll	X	X	X	X		X	X			
Common Yellowthroat	X	X	X	X	X	X	X	X		
Cooper's Hawk	X	X	X	X				X		
Dark-eyed Junco	X	X	X	X				X		
Downy Woodpecker	X	X	X					X		

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Eastern Bluebird	X	X	X	X			X	X		
Eastern Kingbird	X	X	X	X		X	X	X	X	
Eastern Meadowlark					X					
Eastern Phoebe	X	X	X				X	X		
Eastern Screech Owl	X	X	X	X		X		X		
Eastern Towhee	X	X	X	X				X		
Eastern Wood-Pewee	X	X	X				X	X		
European Starling	X	X	X					X		
Evening Grosbeak	X	X						X		
Field Sparrow	X	X	X	X				X		
Fish Crow					X	X			X	X
Fox Sparrow	X	X	X	X				X		
Grasshopper Sparrow										
Golden-crowned Kinglet	X	X					X	X		
Golden-winged Warbler	X	X	X	X				X		
Gray Catbird	X	X	X	X			X	X		
Great Black-backed Gull										
Great Blue Heron	X	X			X	X	X	X	X	X
Great Crested Flycatcher	X	X	X					X		
Great Horned Owl	X	X	X	X		X	X	X		
Green Heron	X	X			X	X	X	X	X	X

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Hairy Woodpecker	X	X						X		
Hermit Thrush	X	X	X	X			X	X		
Herring Gull									X	
Hoary Redpoll			X	X		X	X	X		
Hooded Merganser	X	X			X			X	X	X
Hooded Warbler	X	X	X	X			X	X		
Horned Lark										
House Wren	X	X	X	X			X	X		
House Finch	X	X								
House Sparrow										
Indigo Bunting	X	X	X	X				X		
Killdeer										
Lapland Longspur										
Least Bittern						X				
Least Flycatcher	X	X						X		
Louisiana Waterthrush	X	X						X		X
Mallard					X	X	X		X	X
Mourning Dove	X	X	X	X				X		
Mute Swan					X	X	X		X	X
Nashville Warbler	X	X					X	X		
Northern Bobwhite	X	X	X	X						

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Northern Cardinal	X	X	X	X			X	X		
Northern Flicker	X	X	X					X		
Northern Goshawk	X	X	X	X				X		
Northern Mockingbird	X	X	X	X			X	X		
Northern Rough- winged Swallow	X	X	X	X	X	X		X		X
Northern Saw-whet Owl	X	X						X		
Northern Shrike	X	X	X	X		X		X		
Northern Waterthrush	X	X					X	X		
Orchard Oriole	X	X						X		
Ovenbird	X	X						X		
Pine Grosbeak	X	X						X		
Pine Siskin	X	X	X	X			X	X		
Pine Warbler	X	X								
Prairie Warbler	X	X	X	X						
Purple Finch	X	X	X	X				X		
Purple Martin			X	X	X	X		X		
Red-bellied Woodpecker	X	X						X	X	X
Red-breasted Nuthatch	X	X								
Red-eyed Vireo	X	X						X		
Red-shouldered Hawk	X	X					X	X		
Red-tailed Hawk	X	X	X	X			X	X		

	TERRESTRIAL HABITATS				AQUATIC HABITATS					
	OAK/PINE FOREST	WHITE PINE/NORTHERN RED OAK/RED MAPLE FOREST	OLD FIELD COMMUNITY†	UPLAND LOW SHRUB LAND COMMUNITY†	POND	SHALLOW MARSH†	SHRUB SWAMP†	FORESTED WETLAND†	RIVER	STREAM†
Ring-necked Pheasant			X	X			X			
Rose-breasted Grosbeak	X	X	X	X			X	X		
Red-winged Blackbird					X	X		X		
Rock Dove							X			
Rough-legged Hawk			X	X		X				
Ruby-crowned Kinglet	X	X								
Ruby-throated Hummingbird	X	X	X	X				X		
Ruffed Grouse	X	X	X	X				X		
Rusty Blackbird								X		
Savannah Sparrow						X				
Scarlet Tanager	X	X						X		
Sharp-shinned Hawk	X	X						X	X	
Snow Bunting						X				
Solitary Sandpiper						X	X			
Song Sparrow	X	X	X	X		X	X	X		
Sora Rail					X	X				
Spotted Sandpiper					X		X		X	X
Swamp Sparrow					X	X	X	X		
Tree Swallow	X	X	X	X	X	X	X	X	X	X
Tufted Titmouse	X	X	X				X	X		
Turkey Vulture	X	X	X		X		X	X		

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	OAK/PINE FOREST	WHITE PINE/NORTHERN RED OAK/RED MAPLE FOREST	OLD FIELD COMMUNITY†	UPLAND LOW SHRUB LAND COMMUNITY†	POND	SHALLOW MARSH†	SHRUB SWAMP†	FORESTED WETLAND†	RIVER	STREAM†
Veery	X	X						X		
Virginia Rail						X				
Warbling Vireo	X	X	X							
Whip-poor-will	X	X	X	X				X		
White-breasted Nuthatch	X	X	X					X		
White-eyed Vireo	X	X	X	X			X	X		
White-throated Sparrow	X	X	X	X				X		
Wild Turkey	X	X	X	X				X		
Willow Flycatcher	X	X	X	X				X		
Wilson's (Common) Snipe			X			X	X			
Winter Wren	X	X					X	X		
Wood Duck	X	X			X	X	X	X	X	X
Wood Thrush	X	X						X		
Worm-eating Warbler	X	X								
Yellow-bellied Sapsucker	X	X						X		
Yellow-billed Cuckoo	X	X	X	X			X	X		
Yellow-throated Vireo	X	X						X		
Yellow Warbler	X	X	X	X			X	X		
Mammals										
Beaver	X	X			X	X	X	X	X	X
Big Brown Bat	X	X	X	X	X	X	X	X	X	X

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	OAK/PIN E FOREST	WHITE PINE/NORTHERN RED OAK/RED MAPLE FOREST	OLD FIELD COMMUNIT Y†	UPLAND LOW SHRUB LAND COMMUNITY†	POND	SHALLO W MARSH†	SHRUB SWAM P†	FORESTE D WETLAND †	RIVE R	STREA M†
Black Bear	X	X	X	X	X	X	X	X	X	X
Bobcat	X	X	X	X			X	X		
Coyote	X	X	X	X		X	X	X		X
Deer Mouse	X	X	X	X				X		
Eastern Chipmunk	X	X	X	X				X		
Eastern Cottontail	X	X	X	X		X	X	X		X
Eastern Mole	X	X	X	X				X		
Eastern Pipistrelle	X	X	X	X	X	X	X	X	X	X
Ermine	X	X	X	X		X	X	X		X
Fisher	X	X	X	X				X		
Gray Fox	X	X	X	X		X	X	X		X
Gray Squirrel	X	X						X		X
Hairy-tailed Mole	X	X	X	X				X		
Hoary Bat	X	X	X	X	X	X	X	X	X	X
House Mouse			X	X						
Little Brown Myotis	X	X	X	X	X	X	X	X	X	X
Long-tailed Weasel	X	X	X	X		X	X	X		X
Meadow Jumping Mouse	X	X	X	X		X	X	X		X
Meadow Vole	X	X	X	X		X	X	X		X
Masked Shrew	X	X	X	X		X	X	X		X
Mink	X	X			X	X	X	X	X	X

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	OAK/PINE FOREST	WHITE PINE/NORTHERN RED OAK/RED MAPLE FOREST	OLD FIELD COMMUNITY†	UPLAND LOW SHRUB LAND COMMUNITY†	POND	SHALLOW MARSH†	SHRUB SWAMP†	FORESTED WETLAND†	RIVER	STREAM†
Muskrat					X	X	X		X	X
New England Cottontail	X	X	X	X		X	X	X		X
Northern Flying Squirrel	X	X								
Northern Myotis	X	X	X	X	X	X	X	X	X	X
Northern Short-tailed Shrew	X	X	X	X		X	X	X		X
Norway Rat			X	X						
Porcupine	X	X	X	X				X		
Raccoon	X	X	X	X		X	X	X		X
Red Bat	X	X	X	X	X	X	X	X	X	X
Southern Flying Squirrel	X	X						X		
Red Fox	X	X	X	X		X	X	X		X
Red Squirrel	X	X						X		
River Otter	X	X			X	X	X	X	X	X
Silver-haired Bat	X	X	X	X	X	X	X	X	X	X
Smoky Shrew	X	X					X	X		X
Snowshoe Hare	X	X	X	X		X		X		
Southern Bog Lemming	X	X	X	X		X		X		X
Southern Red-backed Vole	X	X	X	X				X		X
Star-nosed Mole					X	X	X	X	X	X
Striped Skunk	X	X	X	X		X	X	X		X

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	OAK/PINE FOREST	WHITE PINE/NORTHERN RED OAK/RED MAPLE FOREST	OLD FIELD COMMUNITY†	UPLAND LOW SHRUB LAND COMMUNITY†	POND	SHALLOW MARSH†	SHRUB SWAMP†	FORESTED WETLAND†	RIVER	STREAM†
Virginia Opossum	X	X	X	X		X	X	X		X
Water Shrew	X	X			X	X	X	X	X	X
White-footed mouse	X	X	X	X			X	X		X
White-tailed Deer	X	X	X	X		X	X	X		X
Woodchuck	X	X	X	X				X		
Woodland Vole	X	X	X	X			X	X		

Legend: X = Expected Source: DeGraaf and Yamasaki 2001. † Habitat type crossed by Project ROW

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5.7.2 Rare and Endangered Species

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

Federal-Listed Species

To assess the potential for state or federally-listed, endangered, threatened, and/or special concern plant and/or animal species along the Project route, BSC reviewed the RIDEM 2018 and 2021 Natural Heritage datalayers, solicited database information from RIDEM, and followed the U.S. Fish and Wildlife Service (USFWS) Endangered Species Consultation Procedure available on their website.

As a result of the USFWS Endangered Species Consultation Procedure, it was determined that the federally listed northern long-eared bat (*Myotis septentrionalis*) may be present within the Project area. However, no known hibernaculum, maternity roost trees, or potential roost trees are located within the Project area. Additionally, only minimal tree removal is proposed as a part of this project. In accordance with 4(d) Rule for Non-Federal activities, a permit is not required for the Project. No federally-designated Critical Habitat occurs in the Project ROW. Species descriptions and habitat requirements for NLEB are described below.

Northern Long-eared Bat

The NLEB is a medium-sized bat in the Family Vespertilionidae with distinguishing long ears. Their body lengths range from 3.0 to 3.7 inches with a wingspan of 9.0 to 10 inches. Fur color ranges from medium to dark brown on the back and tawny to pale-brown on the underside. The NLEB has both a winter and summer habitat. During winter, these bats hibernate in natural caves and abandoned mines (known as hibernacula) which have high humidity, constant temperatures, and no air currents (NHESP, 2019). NLEB will share caves and mines with other wildlife species, but hibernate singly or in small groups within deep crevices or cracks of the caves and mines. 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/Fish and Wildlife, n.d.). During the summer, NLEB 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. The estimated maximum lifespan of the NLEB is up to 18.5 years. NLEB feed at dusk and eat a variety of insects such as flies, leafhoppers, caddisflies, beetles, and moths. The greatest threat to the NLEB is white-nose syndrome, which is spreading from the Northeast to the Midwest and Southeast United States. The NLEB is federally listed as a threatened species under the Endangered Species Act (ESA) (U.S. Fish & Wildlife, 2015).

In accordance with the final 4(d) Rule for the NLEB, a verification letter for the Project was submitted to the US Fish & Wildlife Service on May 6, 2021. Based upon the IPaC submission, a determination was made that the action “may affect” NLEB. The verification letter from US Fish & Wildlife Service verifies that the PBO satisfies and concludes responsibilities for the Action under ESA Section 7(a)(2) with respect to NLEB.

State-Listed Species

Based on correspondence with the RIDEM in March 2019, two state-listed plant species were identified which may be present within the Project ROW (see Appendix B, Agency Correspondence). These were the daisy-leaved moonwort (*Botrychium matricariifolium*) and orange fruited horse-gentian (*Triosteum aurantiacum*). Based on data obtained from RIDEM, BSC conducted field surveys of the known plant

locations within the ROW. A survey for *T. aurantiacum* was completed between Structure 224 easterly towards Structure 6 on October 2, 2019 and on July 10, 2020. A survey for *B. matricarifolium* was completed between Structures 214 and 222 on July 10, 2020. Surveys were conducted across the full cleared width of ROW, in the vicinity of proposed work areas only.

Surveys for *B. matricariifolium* and *T. aurantiacum* did not result in any observations of either species. However, the State-listed Species of Concern slender-leaved agalinis (*Agalinis tenuifolia*) was observed in October 2019, between Structures 5 and 6.

Based on the findings of the field surveys, BSC Wildlife Biologists recommend the following precautions during construction:

- For construction, it is recommended that the proposed access between Structures 5 and 6 avoid the two populations of slender-leaved agalinis. Prior to construction, this species should be clearly marked with survey tape for avoidance. There is a possibility that population size and distribution changes and access may need to be adjusted for avoidance.
- For construction in moonwort habitat (Structures 214-222), it is recommended that habitat, regardless of the presence/absence of moonwort during field surveys, be protected to the greatest extent possible. Since this species exists underground, impacts to the ground surface in supporting habitat should be reduced where possible. It is recommended that work areas be minimized to the extent practicable. Soil disturbance should be limited to work areas and access.

6.0 DESCRIPTION OF AFFECTED SOCIAL ENVIRONMENT

Per the EFSB Rules, this section provides a detailed description of all environmental characteristics of the proposed site including the physical and social environment on and off site.

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. Land use along within the Study Area includes a mix of residential, commercial, institutional, transportation, recreational, and agricultural land uses as shown in Figure 6-1. Natural open-water areas in the Study Area include the Blackstone River and Abbott Run Brook, and their associated backwater/impounded areas, New Pond and Robbin Hollow Pond. The dominant land use in the Study Area is deciduous forest (33%), followed by residential land use (31%). Of the residential land use, the majority is medium to high density.

6.1.1 Open Space and Recreation

Open space, characterized by brushland/areas of reforestation, hardwood and softwood forest, recreation land, transitional areas, vacant land, water, and wetlands comprises approximately 40% of the Study Area. Most of the open space within the study area is dominated by undeveloped forest land and open pasture and agricultural land. The Project ROW also crosses the Blackstone River Bike Trail, which is maintained by the RIDEM Division of Parks and Recreation.

6.1.2 Residential

Residential development is the second-most dominant land use type within the Study Area. Approximately 31% of the Study Area is characterized by residential development ranging from low to high levels of density. Of the 1,037 acres dedicated to residential development within the Study Area, approximately 18.4 acres is characterized as Low (>2 acre lots) density, 58.9 acres as Medium-Low (1 – 2 acre lots) density, 381.5 acres as Medium (0.25 - 1 acre lots) density, 552.4 acres as Medium-High (0.25 - 0.125 acre lots) density, and 26.4 acres as High (<0.125 acre lots) density.

Residential neighborhoods are located throughout the Study Area, but are particularly dominant in the southeast portion of the Study Area between Route 122 and Curran Road in Cumberland, RI. High densities of residential development are also associated with Route 116 and Route 126 in Lincoln, RI.

6.1.3 Commercial Business

Commercial business within the Project Study Area is characterized by commercial and industrial mixed development. Commercial development within the Study Area is predominantly located in the north of the Study Area, along Route 116. This includes buildings associated with medical centers, utility companies, dentists, insurance companies, and a pre-school. A second area of industrial/commercial mixed development are located along the east bank of the Blackstone River, including manufacturing and distribution companies, construction companies, as well as various shops and bars/restaurants.

6.1.4 Institutions

Institutional land use identified as churches, municipal buildings (e.g., Schools, fire stations), and hospitals exists within the Study Area. The majority of institutional land use within the Study Area is associated with schools - Lincoln High School is located to the northeast of the Study Area, and Central Elementary School is located just south of the Project ROW, within the central Study Area.

6.1.5 Agricultural

Agricultural land use within the Study Area includes 2.2 acres of orchards, groves and nurseries, 0.7 acres of idle agriculture (abandoned fields and orchards), and 118.8 acres of pasture (agricultural land not suitable for tillage).

6.1.6 Future Land Use

A zoning analysis was completed to assess future land use in the Study Area. Typically, towns and cities manage future growth through zoning regulations. The majority of the Study Area in Lincoln is zoned for Residential/Agricultural Use, with some areas of Residential Limited and Residential Single-Family use to the east (near the Blackstone River). Within Cumberland, the majority of the Study Area is zoned as Low to Medium density Residential, with a small area of Light Industrial along the east bank of the Blackstone River.

Both Cumberland and Lincoln have Comprehensive Plans, dated 2016 (Cumberland) and 2003 (updated from the 1992 Plan – Lincoln). While there is no mention of electric transmission lines in the Cumberland Comprehensive Plan, the Plan outlines sustainability efforts to fund renewable energy Projects in the future. Maintaining and improving existing electrical transmission infrastructure will be important for the future transition to new, renewable, energy sources. There is no mention of electric transmission or energy supply in the 2003 Lincoln Comprehensive Plan.

6.2 Visual Resources

The Project is within an existing maintained ROW. Although the Project will require a height increase for structures, the height increase does not represent a dramatic change in the visual appearance of the transmission line facilities. On average, the steel structures replacing the wood structures will be taller than current conditions due to the switch from the horizontal alignment to the vertical alignment (existing range is 40-95 ft., and the proposed range is 40-110 ft.). The range of change in structure heights is -20 to +40-ft. Although structures will be slightly taller, the difference in appearance when viewed from the ground will be negligible.

6.3 Noise

Environmental sound levels are quantified using a variety of parameters and metrics. This section introduces general concepts and terminology related to acoustics and environmental noise.

Sound energy is physically characterized by amplitude and frequency. Sound amplitude is measured in decibels (dB) as the logarithmic ratio of a sound pressure to a reference sound pressure which corresponds to the typical threshold of human hearing. Generally, the average listener considers a 1.0 dB change in a constant broadband noise “imperceptible” and a 3.0 dB change “just barely perceptible.” Similarly, a 5.0 dB change is generally considered “clearly noticeable” and a 10 dB change is generally considered a

doubling (or halving) of the apparent loudness. Frequency is measured in hertz (Hz), which is the number of cycles per second. The typical human ear can hear frequencies ranging from approximately 20 Hz to 20,000 Hz. Typically, the human ear is most sensitive to sounds in the middle frequencies (1,000 Hz to 8,000 Hz) and is less sensitive to sounds in the low and high frequencies. As such, the A-weighted scale was developed to simulate the frequency response of the human ear to sounds at typical environmental levels. The A-weighted scale emphasizes sounds in the middle frequencies and de-emphasizes sounds in the low and high frequencies. Any sound level to which the A-weighted scale has been applied is expressed in A-weighted decibels, dBA. For reference, the A-weighted sound pressure levels associated with some common noise sources are shown in Table 6-1 below.

TABLE 6-1: TYPICAL SOUND PRESSURE LEVELS ASSOCIATED WITH COMMON NOISE SOURCES

SOUND PRESSURE LEVEL (dBA)	SUBJECTIVE EVALUATION	ENVIRONMENT	
		OUTDOOR	INDOOR
140	Deafening	Jet aircraft takeoff at 75 feet	
130	Threshold of pain	Jet aircraft takeoff at 300 feet	
120	Threshold of feeling	Elevated train	Rock band concert
110	Extremely loud	Jet flyover at 1,000 feet	Inside propeller plane
100	Very loud	Motorcycle at 25 feet, auto horn at 10 feet, crowd noise at football game	
90	Very loud	Propeller plane flyover at 1,000 feet, noisy urban street	Full symphony or band, food blender, noisy factory
80	Moderately loud	Diesel truck (40 mph) at 50 feet	Inside auto at high speed, garbage disposal, dishwasher
70	Loud	B-757 cabin during flight	Close conversation, vacuum cleaner, electric typewriter
60	Moderate	Air-conditioner condenser at 15 feet, near highway traffic	General office
50	Quiet		Private office
40	Quiet	Farm field with light breeze, birdcalls, soft stereo music in residence	Bedroom, average residence (without television and stereo)
30	Very quiet	Quiet residential neighborhood	
20	Very quiet	Rustling leaves	Quiet theater, whisper
10	Just audible		Human breathing
0	Threshold of hearing		

Source: Adapted from Architectural Acoustics, M. David Egan 1988 and Architectural Graphic Standards, Ramsey and Sleeper 1994, as referenced in the Environmental Noise Assessment prepared for the Southern Rhode Island Transmission Project by Black & Veatch Corporation.

Within Lincoln, the Study Area closely follows the Route 116 and Route 126 corridors (>60dB), before entering quieter residential environments (with moderate density development), to the east of Lincoln and through most of Cumberland (~40-50 dB). 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 residences, hospitals and designated recreational areas.

6.4 Cultural and Historic Resources

TNEC's cultural resource consultant, The Public Archaeology Laboratory, Inc. (PAL), completed a cultural resources due diligence review of the Project from 2019 through 2021. The purpose of this review was to identify historic architectural properties, archaeological sites, and other cultural resources within the vicinity of the Project, and to make recommendations regarding consultation with the Rhode Island Historic Preservation and Heritage Commission ("RIHPHC"), office of the State Historic Preservation Officer (SHPO), and any appropriate additional cultural resource investigations.

Historic properties were identified through a search of the RIHPHC's archaeological, National Register of Historic Places ("NRHP") and architectural survey files, cultural resource fieldwork, and consultation with RIHPHC and Tribal Historic Preservation Office ("THPO") representatives from the Wampanoag Tribe of Gay Head (Aquinnah), the Mashpee Wampanoag Tribe, and the Narragansett Indian Tribe. PAL initiated consultation with the RIHPHC and Tribes in 2019, prior to the commencement of cultural resource fieldwork. TNEC and PAL will continue to consult with the RIHPHC, and the Tribes throughout the Project permitting process. Additional details on the consultation with RIHPHC and the Tribes is included in Section 7.12 below.

For archaeological resources, the initial due diligence study area to identify previously-recorded archaeological sites encompassed 0.5 mile on either side of the Project centerline for a total width of one mile. For historic architectural properties, the initial due diligence study area was established at 0.25 mile on either side of the Project centerline. The area of potential effects ("APE") for archaeological sites is defined as any area of ground disturbances that may occur because of the Project, including the relocation or replacement of existing structures, access roads, and staging areas. The APE for historic architectural properties includes the construction area and areas adjacent to the ROW where visual impacts may occur.

Section 106 of the National Historic Preservation Act of 1966 requires federal agencies to review federally funded or permitted projects for their potential impacts to historic and cultural resources. Potential resources addressed under this review include known and unknown properties that are listed or are determined eligible for listing on the NRHP. Once a review has been initiated, the agency, in consultation with the SHPO and appropriate Tribal authorities, must identify historic properties, assess whether effects to the properties will be adverse, and then work to minimize, resolve, or mitigate those adverse effects.

Eligibility for inclusion on the NRHP is based on four criteria, at least one of which must be met (36 Code of Federal Regulations [CFR] Part 60). To be eligible, cultural resources must:

- a) be "associated with events that have made a significant contribution to the broad patterns of our history,"
- b) be "associated with the lives of persons significant in our past,"
- c) "embody the distinctive characteristics of a type, period, or method of construction, or ... represent a master, or ... possess high artistic values, or ... represent a significant and distinguishable entity whose components may lack individual distinction," or
- d) "have yielded, or may be likely to yield, information important in prehistory or history[.]

In addition to meeting at least one of these four criteria, an eligible property must retain integrity in its location, design, setting, materials, workmanship, feeling, and/or association. Resources can include both above-ground/architectural resources and archaeological sites; NRHP criteria and standards of integrity are

applied to both types of resources. In Rhode Island, State Review process follows that of Section 106 and is conducted by the SHPO at the RIHPHC as per R.I.G.L. 42-45 et seq.

6.5 Transportation

The Study Area is served by a limited network of state and local roads and highways. The major north/south routes in the area are Route 146 and Route 126. The major east/west route is Route 116, which the V148S Line crosses between Structures 213 and 213A. The Project ROW also crosses a railroad to the east of the Blackstone River (within Cumberland, RI).

6.6 Electric and Magnetic Fields

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

Power-frequency EMFs are present wherever electricity is used. This includes utility transmission lines, distribution lines, and substations. It also includes electrical wiring in homes, offices, and schools. Appliances and machinery that use electricity will also generate electric and magnetic fields.

Electric fields exist whenever voltages are present on transmission conductors and 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 = 1,000 V.

Magnetic fields are present whenever current flows in a conductor and 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

THE NARRAGANSETT ELECTRIC COMPANY
Rhode Island Energy Facility Siting Board – Siting Report

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. The EMF guidelines identified in Table 6-3 were developed by the identified organizations to be protective against adverse health effects from EMF. They should not be viewed as representing EMF levels that have been proven as safe versus levels that are un-safe; the values shown are simply guidelines based on current knowledge.

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 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>

7.0 IMPACT ANALYSIS

This section presents an analysis of the potential impacts of the Project on the existing natural and social environments within the Study Area. As with any construction project, potential adverse impacts can be associated with the construction, operation, or maintenance of an electric transmission line. These impacts will be minimized to the greatest extent feasible through thoughtful design and 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 operational-related (permanent) impacts. Examples of potential temporary construction-related impacts include traffic impacts, temporary use of areas to stage construction equipment and supplies, and short-term 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. Design and construction mitigation measures will be implemented so that construction-related environmental impacts are minimized.

7.1 Summary of Environmental Effects and Mitigation

The Project will occur within the existing ROW, thereby minimizing adverse environmental impacts. No long-term impacts to soil, bedrock, vegetation, surface water, groundwater, wetland resources or air quality will occur. Any potential sedimentation impacts, and other short-term construction impacts to wetlands and surface waters, will be mitigated through the use of soil erosion and sediment control BMPs and equipment access mats (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, and no permanent alteration of the existing habitat is proposed. As part of the Project, 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 the refurbishment of an existing transmission line within an existing ROW. 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. Minimal visual impacts will result from the Project (associated with the slight increase in height of transmission line structures). The Project will improve the reliability of the electric supply and as such will have a positive effect for the area. Traffic controls plans will be employed as necessary, and as required at the ROW access points off local and state roads. The Project will not adversely impact the social and economic conditions in the Project area.

7.3 Soils

Construction activities which expose unprotected soils have the potential to increase 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- or long-term impacts due to construction activity. These include the installation of straw bales, siltation fencing, water bars,

diversion channels, the use of dust control measures, and the reestablishment of vegetation post-construction. Sediment and erosion control devices will be inspected by TNEC's environmental monitor frequently during construction and repaired or replaced if necessary. The Applicant will develop and implement a Soil Erosion and Sediment Control Plan ("SESC Plan:), which will detail BMPs and inspection protocols.

Highly erodible soils 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.

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 (EG-303).

Temporary soil erosion controls listed below 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 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 Surface Water Resources

Any impact of the Project upon surface waters will be minor and temporary. Rivers and streams within the Project ROW are spanned by existing transmission lines. 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. In addition, construction equipment will not cross the stream along the construction corridor without the use of temporary swamp mat bridges. Emphasis has been placed on using existing gravel roadways within the Project ROW and seeking access points that avoid crossing wetlands and surface waters to the extent possible.

There are several surface water features within the Study Area. Temporary swamp mats will be used to access structure locations within or adjacent to surface water features as conditions warrant. Access to most structure locations adjacent to these watercourses will be provided without impacting the channels either by using alternate upland access on the Project ROW or by spanning the areas using temporary swamp mats during construction. Sedimentation and turbidity within these watercourses will be minimized through the implementation of BMPs prior to construction activities.

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. Soil erosion and sediment controls are intended to effectively minimize the potential for this situation to occur. The implementation and maintenance of stringent soil erosion and sediment control BMPs will limit the levels of Project related sedimentation and will minimize adverse impacts to surface waters.

7.4.1 Water Quality

The primary potential impact to water quality from any construction project is the increase in turbidity of surface waters in the vicinity of construction resulting from soil erosion and sedimentation from the impacted site. A second potential impact is the spillage of petroleum, hydraulic fluid, or other products near waterways. Impacts to previously undisturbed areas on the ROW will be minimized using existing access roads. Further, equipment (with exceptions for equipment that is not readily mobile) will not be refueled or maintained near wetland or surface water resources. The contractors will respond to an inadvertent release or spill of soil or other hazardous materials in accordance with Rhode Island State and TNEC requirements. Pre-construction environmental training of contractors will reinforce this obligation. TNEC has company procedures to minimize risks and provide procedural requirements to be followed in the event of an inadvertent release. Therefore, it is anticipated that any adverse impacts to water resources resulting from construction of the Project will be negligible.

7.4.2 Hydrology

Some minor, temporary impacts to surface drainage can be expected during construction on the transmission lines. These impacts will be associated with access road and work pad improvements. TNEC will employ soil erosion and sediment controls prior to the initiation of soil disturbing activities to protect adjacent surface waters where necessary. Following construction, temporarily disturbed areas will be restored to pre-construction conditions to the extent practicable. Features that will permanently remain on the Project ROW (such as improved access roads), will be stabilized.

The hydrology of surface waters will not be significantly affected during or after construction since temporary wooden mat bridges will be constructed across stream channels to allow for the staging of equipment without disturbing the stream or its channel substrate.

7.4.3 Floodplain

Project activities located within Floodplain are limited to the replacement of structures, temporary access roads and construction matting. No other impacts are proposed within Floodplain.

7.5 Groundwater Resources

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. Refueling 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. Following construction, the normal operation and maintenance of the transmission line facilities will have no impact on groundwater resources.

7.6 Vegetation

TNEC's vegetation management program maintains safe access to transmission line facilities and promotes the growth of vegetative communities along ROWs that are compatible with transmission line operation and in accordance with federal and state standards. TNEC has conducted vegetation management within its ROWs as a matter of good utility practice since the late 1980s. TNEC's vegetation management program is designed to allow the safe operation of transmission lines by preventing the growth of incompatible vegetation that may interfere with the transmission facilities or access along its ROW. As a result, the vegetation within the maintained portions of the TNEC ROW typically consists of low-growing shrubs, herbaceous species, and other low-growing species. Portions of the ROW that are not proximate to an existing line may support taller vegetation, if it will not conflict with the construction or operation of the lines.

To stabilize impacted sites after the work on the transmission facilities, TNEC will 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. 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. Select tree removal along the ROW is required as part of the proposed Project.

7.7 Wetlands

Construction of the Project will result in temporary and secondary impacts to wetland resources. The following section describes the impacts associated with construction of the Project. Table 7-1 summarizes the potential impacts of the Project on wetlands, based on preliminary design data.

TABLE 7-1: SUMMARY OF POTENTIAL IMPACTS ON WETLANDS AND WATERCOURSES

TEMPORARY IMPACTS	APPROXIMATE IMPACT
Swamp Mats for Access and Work Pads	1.79 acres

All temporary matting used for access and work pads in wetlands and over watercourses will be removed after the completion of the Project.

7.8 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 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 reconductoring of the transmission line are expected to be limited in number. Effects will be localized to the immediate area of construction around structure locations and along existing access roads. However, this is anticipated to be a temporary effect as it is expected that existing wildlife use patterns will resume, and population sizes will recover, once work activities are completed. Any wildlife displacement will be negligible and temporary, since no permanent alteration of the existing habitat is proposed. No long-term impacts to wildlife are expected to result from the Project.

7.9 Social and Economic

Based on the proposed location of the Project, the greatest potential for social impact is the interaction of construction and future maintenance activities on current and future land uses abutting the Project ROW.

7.9.1 Social Impacts

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 3.0, the proposed work will be located entirely within an existing cleared transmission line.

7.10 Land Use

The following section addresses the compatibility of the Project with various land uses along the proposed route. Because the Project will occupy areas dedicated to use for electrical facilities, it will not displace any existing residential uses, nor will it affect any future development proposals that meet local zoning requirements. Short-term land use impacts may occur during the construction phase of the Project. Impacts associated with the construction phase of the Project will be temporary, and most present land uses within the existing ROW could resume following construction.

The construction of the Project in the ROW will be consistent with the established land use and therefore, will not present long-term land use impacts. Generally, existing land uses within and adjacent to the Project ROW will be allowed to continue following construction. The encroachment, installation or construction of buildings, pools or other non-transmission related facilities is not allowed with the transmission line easement.

7.10.1 Residential

Several residential areas are in proximity to the Project ROW. No significant tree clearing or widening of the ROW is required for the Project. The existing vegetative visual buffers will continue to provide visual screening of the facilities from residences.

7.10.2 Agriculture

The Project will not impact agricultural land use within the ROW or wider Study Area.

7.10.3 Institutions

The Project is not anticipated to impact the institutions located within the Study Area. The only institution adjacent to the Project ROW is the Central Elementary School in Lincoln.

7.10.4 Recreation

No existing recreational uses or trails will be displaced long-term by the Project. Impacts to existing parks and recreational areas from the construction of the Project will be minimal and short-term. Since the Project is located within existing maintained ROW, potential long-term impacts will be avoided. TNEC will coordinate with the RIDEM for access along the Blackstone River Bike Trail.

7.11 Visual Resources

The Project involves replacing conductors and upgrades to existing structures, which will involve a slight increase in structure heights (with ranges of -20 to +40-ft). The structures will be replaced along the same alignment and in roughly the same location. No significant impacts to visual resources are anticipated because of the Project.

7.12 Cultural and Historic Resources

PAL has conducted extensive fieldwork within the ROW. All work was completed in a manner consistent with the standardized procedures for conducting archaeological field investigations per the Secretary of the Interior's Standards and Guidelines for Archeology and Historic Preservations (4716-44742, NPS 1983), the MHC's Public Planning and Environmental Review: Archeology and Historic Preservation (1979), the RIHPHC's Performance Standards and Guidelines for Archaeology in Rhode Island (2015), and the guidelines established by the National Park Service in the Recovery of Scientific, Prehistoric, Historic, and Archeological Data (36 CFR 66, Appendix A).

As part of the V148S Transmission Line permitting process, historic and archaeological resources within the ROW were evaluated to assist the USACE to comply with Section 106 of the National Historic Preservation Act of 1966, as amended ("NHPA"), and in accordance with historic preservation laws in Rhode Island. PAL initiated communications with the Rhode Island SHPO and provided information to the above-referenced THPOs and other interested stakeholders. On September 24, 2019, PAL submitted a Cultural Resource Due Diligence Report and an application for a Permit to conduct a Phase I intensive archaeological survey for proposed structure replacements; the THPOs were copied on all correspondence to the Rhode Island SHPO and were provided the same information that was submitted to the SHPO. On October 11, 2019, the Rhode Island SHPO issued Permit #19-24 to PAL to conduct the archaeological

survey. On January 28, 2020, PAL submitted correspondence to the Rhode Island SHPO, requesting that Permit #19-24 be amended to include all access roads along the Project corridor, and on February 11, 2020, the SHPO amended the Permit.

On October 2, 2019, the USACE notified the THPOs to initiate the Section 106 Consultation process. The letter also attempted to seek input about areas of concern and provide the Tribes with a schedule for the archaeological survey. On March 3, 2020, the USACE sent a follow-up letter to the THPOs to provide cultural resource reporting prepared by PAL, with a request for review by the THPOs and to ask if they would like to monitor any further archaeological work on the Project, or if they would like to schedule a site walk of the Permit Areas.

PAL conducted the Phase I intensive archaeological survey fieldwork between October 2019 and January 2020. Five archaeological resources were identified within the Project APE in Rhode Island: the Logan Drive Find Spot and the Limerock and Simon Sayles Road sites in Lincoln and the Millers River East and Stateline sites in Cumberland. PAL also conducted an historic architectural reconnaissance survey of the Project area, recommending that the Project would not have any adverse effects on any aboveground historic architectural properties, including the Blackstone Canal Historic District which is listed in the National Register. Of the archaeological resources identified during the Phase I intensive survey, PAL recommended that the Simon Sayles Road, Millers River East, and Stateline sites were potentially eligible for listing in the National Register of Historic Places under Criteria A and D. PAL further recommended that TNEC should assess alternatives to avoid these sites, but if avoidance was not possible, PAL recommended the sites be subject to Phase II archaeological site examination investigations. PAL noted in the report recommendations that no testing was conducted at Structure 11 within the Blackstone Canal Historic District because the work area is within the Peterson/Puritan, Inc. Superfund Site.

On March 24, 2020, the USACE hosted a virtual WebEx meeting for PAL to provide an overview of the results of the Phase I intensive archaeological survey conducted in Rhode Island. PAL conducted a virtual page turn and debriefed the THPOs on the survey results and answered questions about the results of the survey, resources identified, and proposed Phase II archaeological site examination investigations. The THPOs communicated that they concurred with PAL's recommendations and next steps for the Phase II archaeological site examination investigations.

On April 9, 2020, PAL submitted the Phase I intensive archaeological survey and historic architectural reconnaissance survey reports to the Rhode Island SHPO, copying the above-referenced THPOs, as well as the Blackstone River Heritage Corridor, Inc.; the submittal package also included an application for a Permit to conduct Phase II archaeological site examination investigations of three sites that were recommended by PAL as potentially meeting the criteria of eligibility for listing in the National Register of Historic Places (National Register). On May 13, 2020, the Rhode Island SHPO concurred with the recommendations in the Phase I intensive archaeological survey and historic architectural reconnaissance survey reports and issued Permit #20-09 to PAL to perform the Phase II archaeological site examination investigations.

PAL conducted the Phase II archaeological site examination investigation fieldwork between May and July 2020. The Phase II archaeological site examination investigations were conducted to evaluate the eligibility of the three sites for listing in the National Register. Site significance was assessed by evaluating each site's size, age, archaeological content, and ability to contribute new information on pre-contact Native American settlement and land use in northeastern Rhode Island. PAL recommended that the Millers River East and Stateline sites are eligible for listing in the National Register under Criteria A and D; PAL recommended that the Simon Sayles Road Site does not meet the criteria for listing in the National Register. PAL further recommended that NEP avoid impacting the sites through redesign or the implementation of engineering controls that will prevent or reduce the amount of ground disturbance.

On November 17, 2020, PAL submitted the Phase II archaeological site examination report to the Rhode Island SHPO, copying the above-referenced THPOs and the Blackstone River Heritage Corridor, Inc. On January 12, 2021, the USACE hosted a virtual WebEx meeting for PAL to provide an overview of the results of the Phase II archaeological site examination investigations conducted in Rhode Island. PAL conducted a virtual page turn and debriefed the THPOs on the results of the Phase II archaeological site examination investigations. The THPOs communicated that they concurred with PAL's recommendations for the Millers River East and Stateline sites, TNEC and PAL plan to develop an archaeological site avoidance and protection plan ("ASAPP").

On February 9, 2021, PAL submitted documentation to the Rhode Island SHPO, THPOs, and Blackstone River Heritage Corridor, Inc. related to the V148S Transmission Line Geotechnical Soil Boring Project (USACE File #NAE-2021-00639), recommending that ASAPP measures be implemented for that separate undertaking along the V148S Line ROW; the package also included an archaeological assessment of the proposed work pad and access to Structure 11, recommending that soils at that location were disturbed and no further archaeological investigation is warranted. On March 12, 2021, Rhode Island SHPO responded, concurring with the recommendations in the Phase II archaeological site examination report. On March 12, 2021, the Rhode Island SHPO also concurred with PAL's recommendation to implement the ASAPP for soil boring work at Structure 46 where the Millers River East and Stateline Sites are located; the Rhode Island SHPO also concurred that the proposed boring activities at Structure 11 would have no adverse effect on the Blackstone River and Canal Historic District and that the remaining borings along TNEC facilities will have no effect on significant cultural resources.

On August 11, 2021, PAL submitted a draft ASAPP and a request to amend Permit #20-09 to conduct supplemental Phase II archaeological site examination investigations at the Stateline Site. The ASAPP and supplemental Phase II site examination investigations are proposed to avoid and minimize any potential effects the proposed Project may have on historic properties, including significant archaeological sites, within the Project's APE. PAL plans to conduct the supplemental archaeological site examination investigations in the first and second quarters of 2022, and TNEC plans to implement the ASAPP measures during construction of the Project. On September 21, 2021, the RIHPHC responded, concurring with the ASAPP and extended Permit #20-09 to conduct supplemental Phase II investigation of the Stateline Site. On December 3, 2021, PAL sent correspondence to the Rhode Island SHPO, making a recommendation that the Project will have no adverse effects on the Blackstone River and Canal Historic District, which is listed in the National Register, and the Millers River East and Stateline Sites, which are eligible for listing in the National Register. PAL requested the Rhode Island SHPO's concurrence that TNEC's implementation of the ASAPP will result in no adverse effect to the Millers River East and Stateline Sites.

TNEC and PAL will continue to communicate with the Rhode Island SHPO, THPOs, and other interested stakeholders to develop acceptable protocols to avoid, minimize, and/or mitigate any adverse effects the proposed Project may have on historic properties to assist the USACE in complying with Section 106 of the NHPA and the Rhode Island Antiquities Act.

7.13 Noise

Noise impacts are expected to be negligible. Temporary, minor construction noise may be generated by the Project that will occur predominantly during normal daytime working hours. Proper mufflers will be required to control noise levels generated by construction equipment. Noise impacts are expected to be negligible.

7.14 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. These limited periods of traffic are not expected to result in any additional congestion or change in operating conditions on any of the roadways along the ROW. TNEC will coordinate closely with RIDOT to develop acceptable traffic management plans for work within state highway ROWs. At all locations where access to the ROW intersects a public way, the contractor 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 require maintenance. As a result, the construction and operation of the transmission line will have minimal impact on the traffic of the surrounding area roadways. No long-term impacts to traffic flow or roadways are expected.

7.15 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 using existing gates and/or barriers at entrances from public roads.

7.15.1 Electric and Magnetic Fields

Gradient performed an independent assessment of the electric and magnetic field (EMF) levels associated with the proposed TNEC V148S Asset Condition Replacement (ACR) Project, involving the replacement of the 115-kV overhead V148S line. For this assessment, EMF modeling was conducted at a height of 1 meter (3.28 feet) above the ground surface at two representative right-of-way (ROW) cross sections along the Project route. Pre-Project and post-Project modeled electric field values at the ROW edges are well below the ICNIRP health-based guideline of 4.2 kV/m for all modeled cases, and modeling analysis indicates that the Project will result in small decreases to electric fields at the ROW edges.

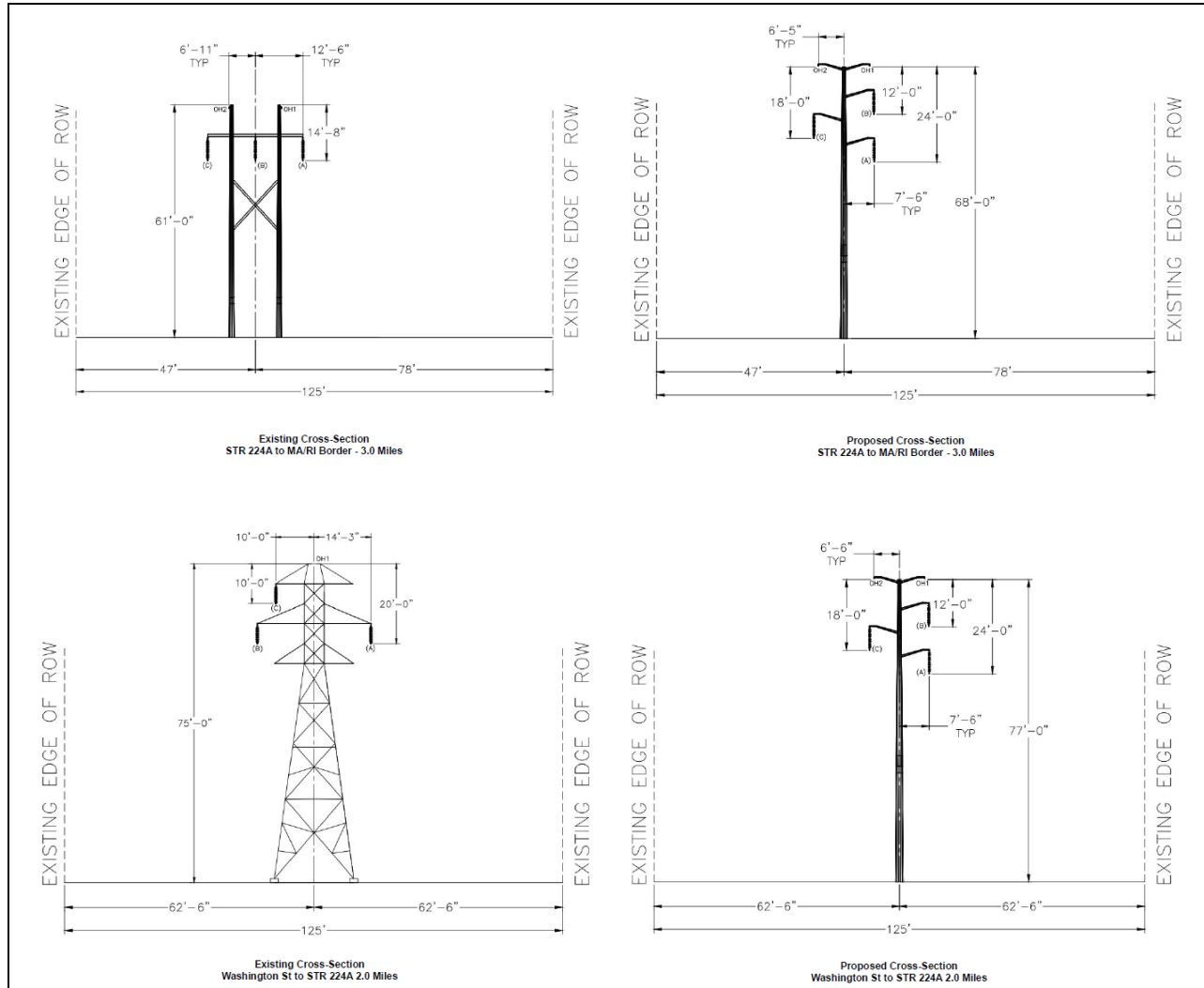


FIGURE 7-1 CONCEPTUAL DRAWING OF THE STRUCTURES ON THE ROW (VIEW FACING TOWARDS NORTH).

The V148S Line is constructed on a combination of wood H-frame structures centered ~47-ft from the existing edge of ROW, and steel lattice structures centered ~62'6" from the edge of ROW. Replacement structures will be installed in approximately the same locations as existing structures and maintain the same distance from the edge of ROW. Because the proposed upgrades to the electrical facilities will be designed, built and maintained in accordance with the standards and codes as discussed in Section 6.6, public health and safety will be protected.

7.15.2 Electric Fields

The pre-Project and post-Project modeled electric field vales at the ROW edges are well below health-based guidelines of 4.2 kV/m for all modeled cases. The modeling analysis indicates that the Project will result in small decreases to electric fields at the ROW edges. The calculations of the electric field levels at the edge of the ROW are summarized in Table 7-2.

TABLE 7-2: ANNUAL AVERAGE ELECTRIC FIELD LEVELS (KV/M)

SECTION	CONFIGURATION	-ROW EDGE	+ROW EDGE
D-13870-NE: Washington St. to STR 224A	Existing (2022)	0.24	0.27
	Proposed (2023)	0.20	0.16
D-13871-NE: STR 224A to RI/MA Border	Existing (2022)	0.47	0.15
	Proposed (2023)	0.34	0.10

7.15.3 Magnetic Fields

Calculations indicate that the magnetic field levels after the reconductoring of the Project will decrease slightly at the ROW edges, due to greater MF cancellation achieved by the delta configuration of the Project conductors in both representative cross-sections, and for the D-13870-NE cross section from the Washington #126 Substation to Structures 224A, the greater midspan heights of the Project conductors at the location of lowest conductor sag that was modeled. On the northern edge of ROW between Washington St. and Structure 224A, the magnetic field at average loading is calculated to change between +0.1 mG and -5.4mG compared to existing conditions.

Calculations of the magnetic field levels at the edges of the ROW are summarized in Table 7-3.

TABLE 7-3: MAGNETIC-FIELD LEVEL (MG) AT AVERAGE LOADING AND PEAK LOADING

			MAGNETIC FIELD (MG)	
			NORTHERN ROW EDGE	SOUTHERN ROW EDGE
D-13870-NE: Washington St. to STR 224A	Annual Average	Pre-Project	21.8	22.0
		Post-Project 2023	11.8	12.8
		Post-Project 2028	11.8	12.8
D-13871-NE: STR 224A to RI/MA Border	Annual Average	Pre-Project	24.4	10.3
		Post-Project 2023	18.7	8.9
		Post-Project 2028	18.7	8.9

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8.0 MITIGATION MEASURES

The Project is not anticipated to have any long-term impacts to the natural or social environment of the Study Area. 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 structure replacements and the reconductoring of the existing V148S Line in an existing ROW. As described in Chapter 6.0, there are no long-term impacts to mitigate because of the Project. Therefore, mitigation efforts are focused on the construction phase.

8.1 Construction Phase

Construction for this Project will require only minor temporary disturbances to the surrounding natural environment. Mitigation measures will be implemented during construction to effectively minimize Project impacts on the natural and social environments. These mitigation measures include the use of existing access roads and structure pads where possible to minimize disturbed areas, installation of erosion and sedimentation controls, and supervision and inspection of construction activities within resource areas by an environmental monitor. The following section details various mitigation measures which will be implemented to minimize construction related impacts.

8.1.1 Mitigation of Natural Resource Impacts

When the existing transmission lines were constructed, 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 to the existing structure locations will be provided using swamp mats from the existing maintained portion of the ROW. Construction access will be limited to the existing structure locations and proposed access routes, which will be bordered by erosion and sedimentation control BMPs, where needed. Following overhead reconductoring and thermal upgrade activities along the Lines, all disturbed areas will be stabilized and restored.

Vegetation management operations will be confined to the existing ROW. Vegetation mowing adjacent to wetland areas is of particular concern due to the potential for erosion, and therefore, specific mitigation measures will be implemented to minimize this potential where needed. These measures will include the installation of straw wattle or compost mulch tube diversion berms across the slope, to intercept storm water runoff, which will be directed through straw wattle or silt fence to remove suspended sediment. These structures will be maintained until vegetative cover is reestablished. In addition, straw wattle and/or erosion control blankets will be installed across disturbed slopes adjacent to wetland areas in accordance with an erosion and sediment control plan. Excavated soils will be stockpiled and spread in approved soil areas well outside all biological wetland areas in such a manner that general drainage patterns will not be affected.

Where possible, existing vegetation will be retained at all road crossings and areas subject to public view to maintain a visual buffer to the ROW. Stream crossings will be located perpendicular to the channel to the extent possible to reduce the crossing length and reduce the potential for disturbance to the water body. Design and implementation of all stream crossing structures (i.e., temporary mat bridges) will comply with standards and specifications as outlined in the *Rhode Island Soil Erosion and Sediment Control Handbook* and TNEC's EG303. Temporary access is used where the substrate is sufficiently firm or level to support equipment without creating a disturbance to the soil substrate.

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. Construction crews will be responsible for conducting daily inspections and identifying erosion controls that must be maintained or replaced as necessary. Erosion and sedimentation controls will be installed and maintained in accordance with the *Rhode Island Soil Erosion and Sediment Control Handbook* and TNEC's Environmental Guidance Policies for ROW Access, Maintenance and Construction Best Management Practices for New England (EG-303).

8.1.3 Supervision and Monitoring

Throughout the entire construction process, TNEC will retain the services of an environmental monitor who will oversee the implementation and maintenance of BMPs and soil erosion and sediment controls on a routine basis to ensure compliance with all federal and state permit requirements and TNEC environmental guidance and policy. The environmental monitor will be a trained environmental scientist, who will be responsible for supervising construction activities relative to environmental issues. The environmental monitor will be experienced in soil erosion and sediment control management and the project's environmental resources

During periods of prolonged precipitation, the monitor will inspect all locations to confirm environmental controls are functioning properly. In addition to retaining the services of an environmental monitor, TNEC will require the contractor 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 contractor's awareness of these issues and make corrective actions.

8.1.4 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. 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. During earth disturbing activities, the contractor will deploy dust mitigation measures as described in TNEC'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 its contractor'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 R.I.G.L.s § 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 contractor is responsible for

complying with the state regulatory requirements along with the TNEC Environmental Guidance (EG-802RI) Vehicle Idling – Rhode Island.

Construction generated noise will be limited using 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 and street sweeping. TNEC will minimize the potential for disturbance from the construction by notifying the City 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 line in a timely fashion, TNEC will keep these impacts to a minimum. TNEC will prepare a traffic management plan for approval by the RIDOT, which will minimize impacts associated with increased construction traffic on local roadways.

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 Mitigation 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 do not interfere with utility line safety or maintenance, but help inhibit soil erosion, and provide habitat for certain wildlife species.,

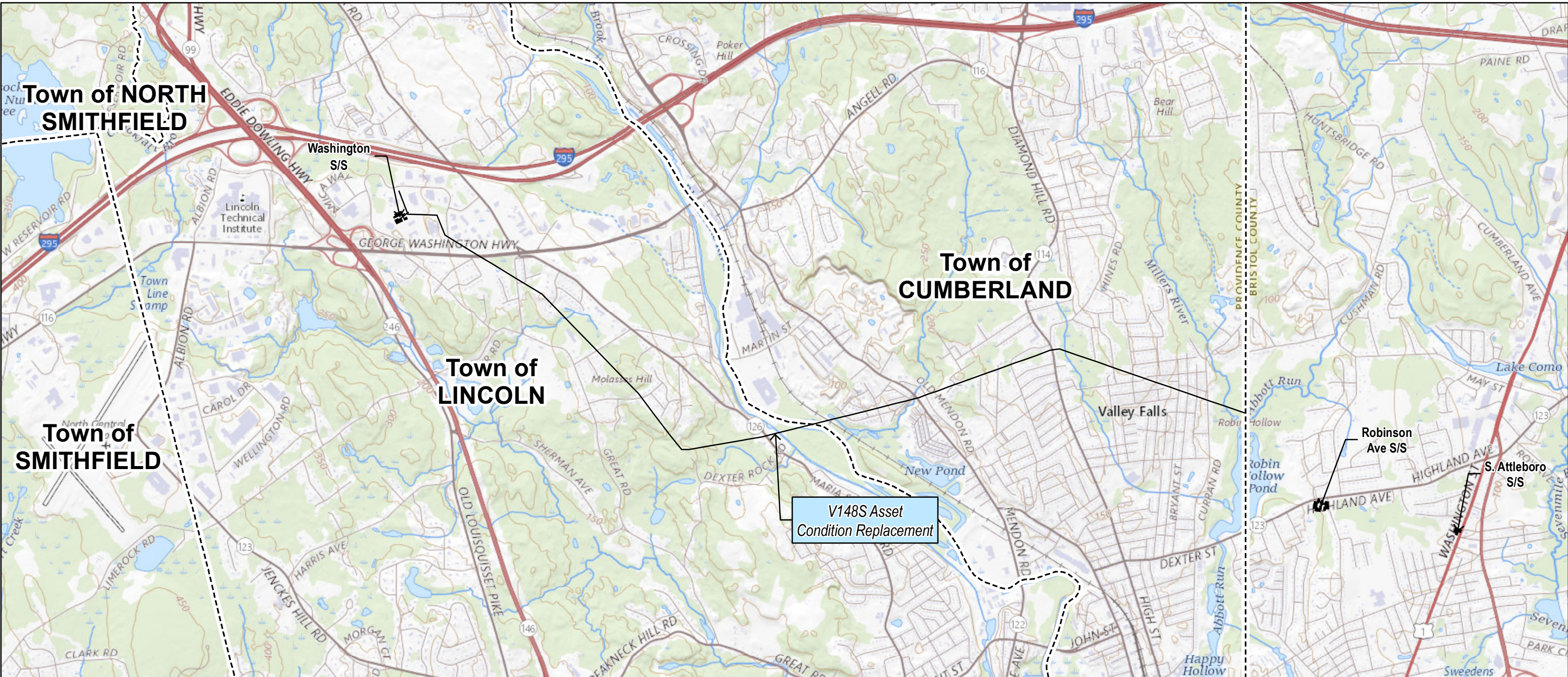
8.2.2 Mitigation of Social Resource Impacts

Where possible, TNEC will limit access to the ROW by installing permanent gates and barriers where access roads enter the ROW from public ways. Select areas may be visually screened with landscaping and/or grading, as appropriate.

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9.0 REFERENCES

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Project Vicinity

NORTH SMITHFIELD CUMBERLAND
SMITHFIELD LINCOLN
CENTRAL FALLS PAWTUCKET

Legend

- Project Transmission Line
- Existing Power Facility
- Town Boundary

V148S ACR Project

Figure 1-1
Project Overview Map

State of Rhode Island
Providence County:
Cities of Lincoln & Cumberland

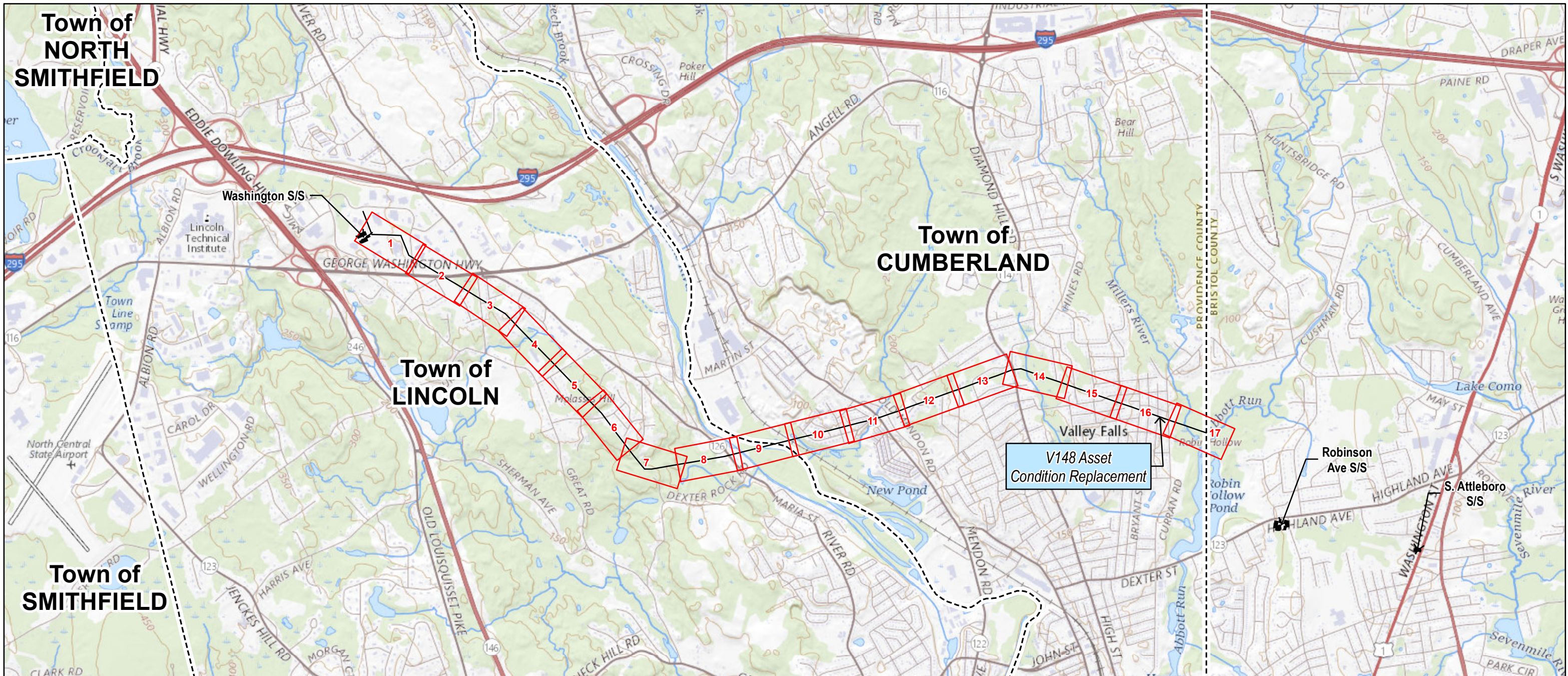
NAD 1983 2011 StatePlane Rhode Island FIPS 3800 Ft US

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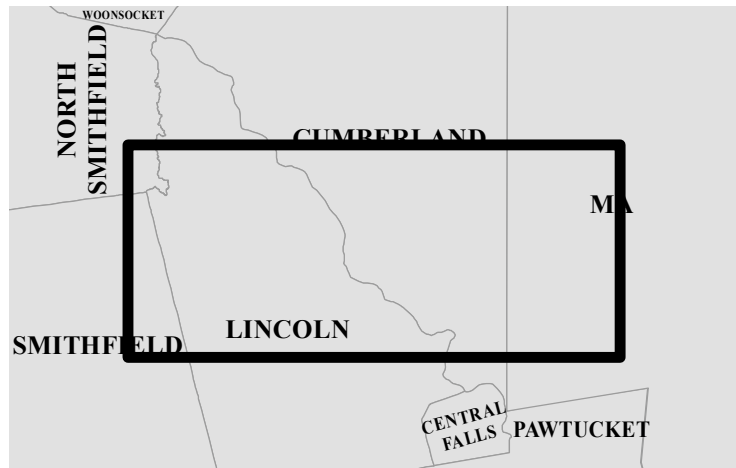
1" = 2,500'

NOT FOR CONSTRUCTION

AUTHOR: LSTANLEY



Project Vicinity



Legend

- Project Transmission Line
- Existing Power Facility
- Town Boundary

V148S ACR Project

Figure 3-1 Project Alignment Drawings Index Map

State of Rhode Island
Providence County:
Cities of Lincoln & Cumberland



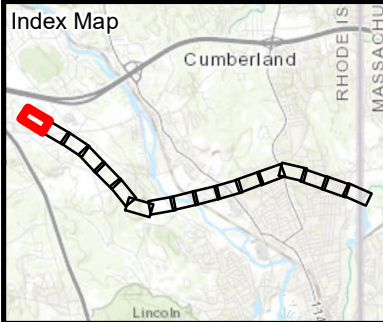
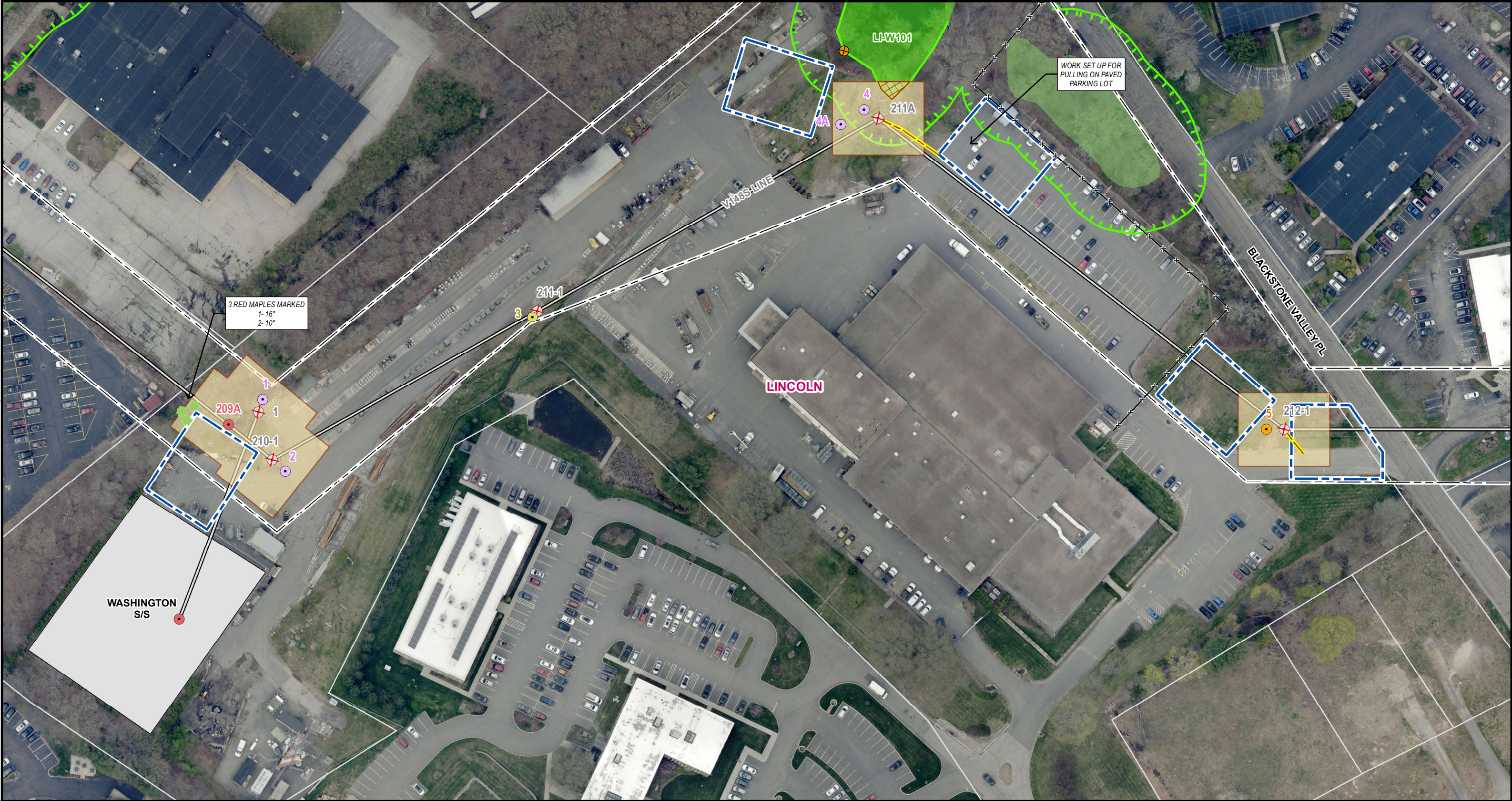
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1" = 2,500'

NOT FOR
CONSTRUCTION

DATE: 11/17/2021

AUTHOR: LSTANLEY



Legend

- Existing Structure
- Install Structure
- Install Structure with Concrete Caisson (1)
- Install Structure with Concrete Caisson (2)
- Remove Structure
- V148S OH Line
- Approx. Edge of ROW
- Preferred Access Road
- Access Road to be Improved
- Refresh with Stone
- Off ROW Access Road
- Alternate Access Road
- Construction Mats
- Work Envelope*
- Graded Work Envelope*
- Guard Structure
- Pull Pad
- Graded Pull Pad
- Field Delineated Intermittent Stream
- Field Delineated Perennial Stream/Bank
- Field Delineated Streams*
- Field Delineated Wetland Lines
- Field Delineated Wetlands*
- Wetland Replication Area*
- MADEP Hydrologic Connections
- USFWS Wetlands*
- Estimated Wetlands
- 50ft Perimeter Wetland
- 100ft Riverbank Wetland
- 200ft Riverbank Wetland/
- FEMA 100yr Floodplain*
- Water Bar
- Hazardous Material Site
- Leaking Underground Storage
- Surface Water Protection Area
- Ground Water Compliance Boundary
- Zone II Wellhead Protection Area
- Community Wellhead Protection Area/Outstanding Resource Water
- Natural Heritage Area
- NHESP Priority & Estimated Habitats
- State-Listed Species Habitat
- Conservation Land*
- Soil Stockpile
- Town Boundary
- Parcel Boundary
- Approximate Pipeline
- Access Gate
- Culverts
- Catch Basin
- Bike Path
- Stonewall
- Fence
- Guardrail
- Superfund Site Boundary
- Tree to be Removed

***Indicates Layers Set to Transparency**

1 inch = 100 feet

0 50 100 Feet

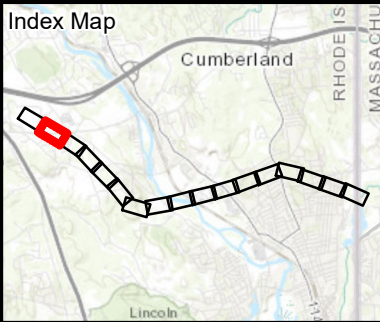
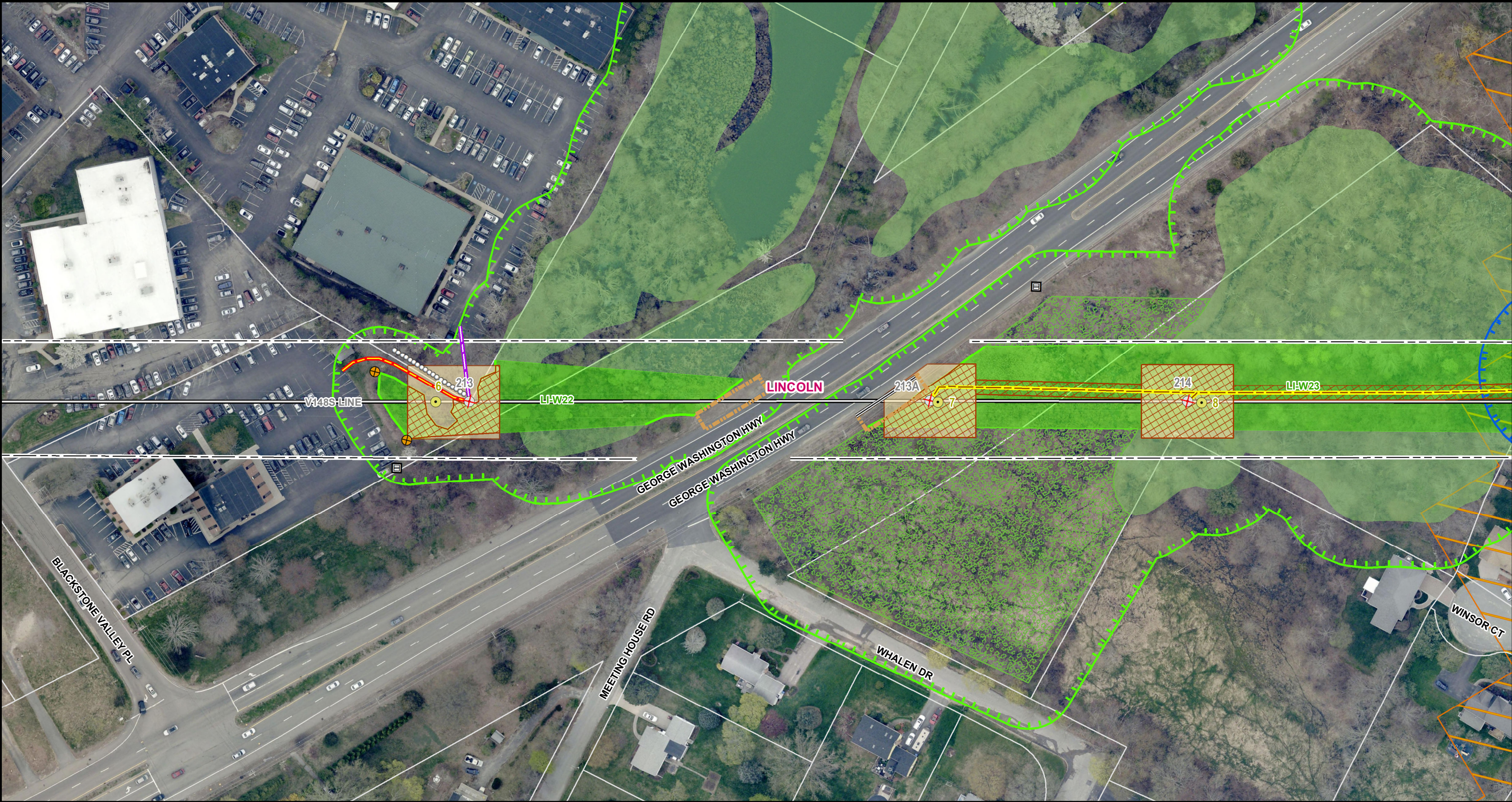
**V148S LINE ASSET CONDITION
REFURBISHMENT PROJECT**

Figure 3-1
Project Alignment Drawings

City of Lincoln, RI
Page 1 of 17

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

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Legend

- Existing Structure
- Install Structure
- Install Structure with Concrete Caisson (1)
- Install Structure with Concrete Caisson (2)
- Remove Structure
- V148S OH Line
- Approx. Edge of ROW
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- Access Road to be Improved
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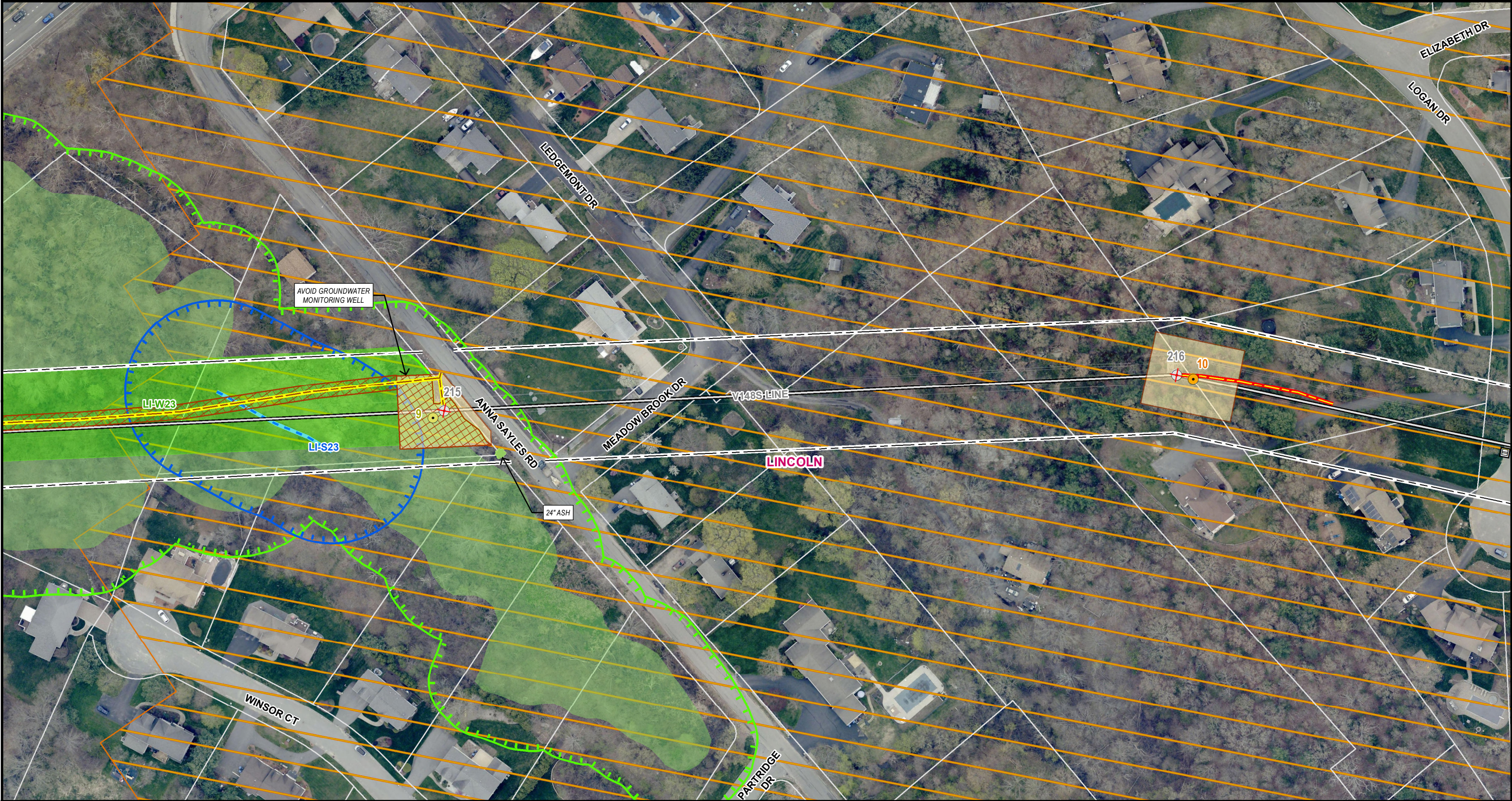
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City of Lincoln, RI
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Index Map

Legend

Existing Structure	Off ROW Access Road	Field Delineated Wetland Lines	Hazardous Material Site
Install Structure	Alternate Access Road	Field Delineated Wetlands*	Leaking Underground Storage
Install Structure with Concrete Caisson (1)	Construction Mats	Wetland Replication Area*	Surface Water Protection Area
Install Structure with Concrete Caisson (2)	Work Envelope*	MADEP Hydrologic Connections	Ground Water Compliance Boundary
Remove Structure	Graded Work Envelope*	USFWS Wetlands*	Zone II Wellhead Protection Area
V148S OH Line	Guard Structure	Estimated Wetlands	Community Wellhead Protection Area/Outstanding Resource Water
Approx. Edge of ROW	Pull Pad	50ft Perimeter Wetland	Natural Heritage Area
Preferred Access Road	Graded Pull Pad	100ft Riverbank Wetland	NHESP Priority & Estimated Habitats
Access Road to be Improved	Field Delineated Intermittent Stream	200ft Riverbank Wetland/	State-Listed Species Habitat
Refresh with Stone	Field Delineated Perennial Stream/Bank	FEMA 100yr Floodplain*	Conservation Land*
	Field Delineated Streams*	Water Bar	

***Indicates Layers Set to Transparency**

Soil Stockpile	Guardrail
Town Boundary	Superfund Site Boundary
Parcel Boundary	Tree to be Removed
Approximate Pipeline	
Access Gate	
Culverts	
Catch Basin	
Bike Path	
Stonewall	
Fence	

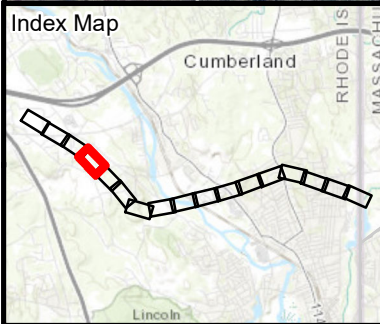
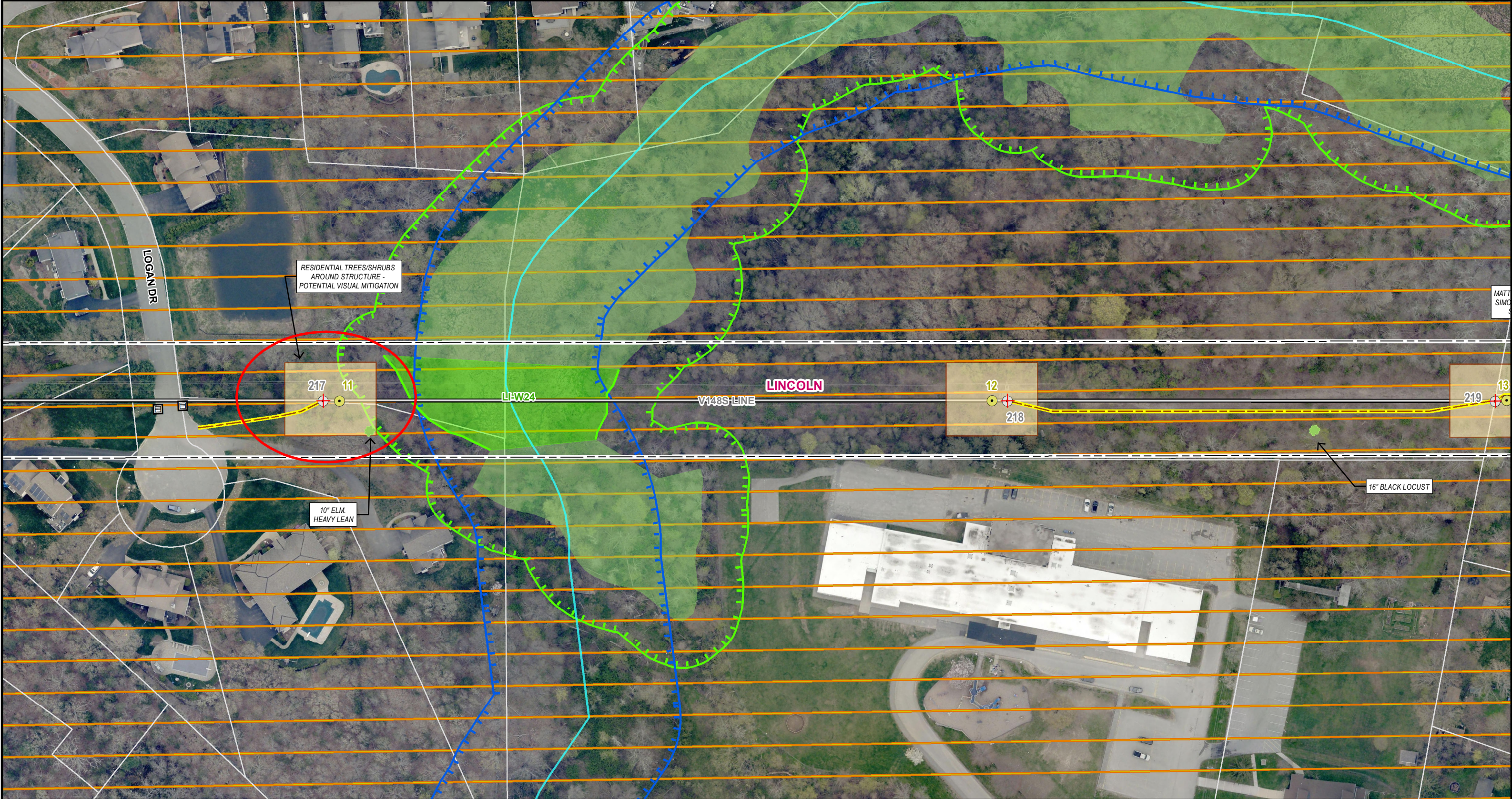
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City of Lincoln, RI
Page 3 of 17

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Legend

Existing Structure	Off ROW Access Road	Field Delineated Wetland Lines	Hazardous Material Site	Soil Stockpile	Guardrail
Install Structure	Alternate Access Road	Field Delineated Wetlands*	Leaking Underground Storage	Town Boundary	Superfund Site Boundary
Install Structure with Concrete Caisson (1)	Construction Mats	Wetland Replication Area*	Surface Water Protection Area	Parcel Boundary	Tree to be Removed
Install Structure with Concrete Caisson (2)	Work Envelope*	MADEP Hydrologic Connections	Ground Water Compliance Boundary	Approximate Pipeline	
Remove Structure	Graded Work Envelope*	USFWS Wetlands*	Zone II Wellhead Protection Area	Access Gate	
V148S OH Line	Guard Structure	Estimated Wetlands	Community Wellhead Protection Area/Outstanding Resource Water	Culverts	
Approx. Edge of ROW	Pull Pad	50ft Perimeter Wetland	Natural Heritage Area	Catch Basin	
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	Field Delineated Streams*	Water Bar			

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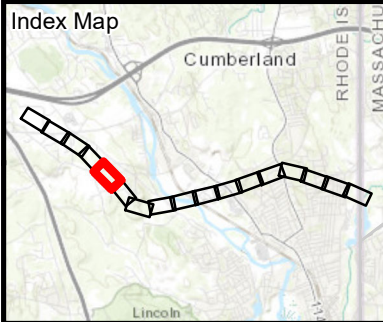
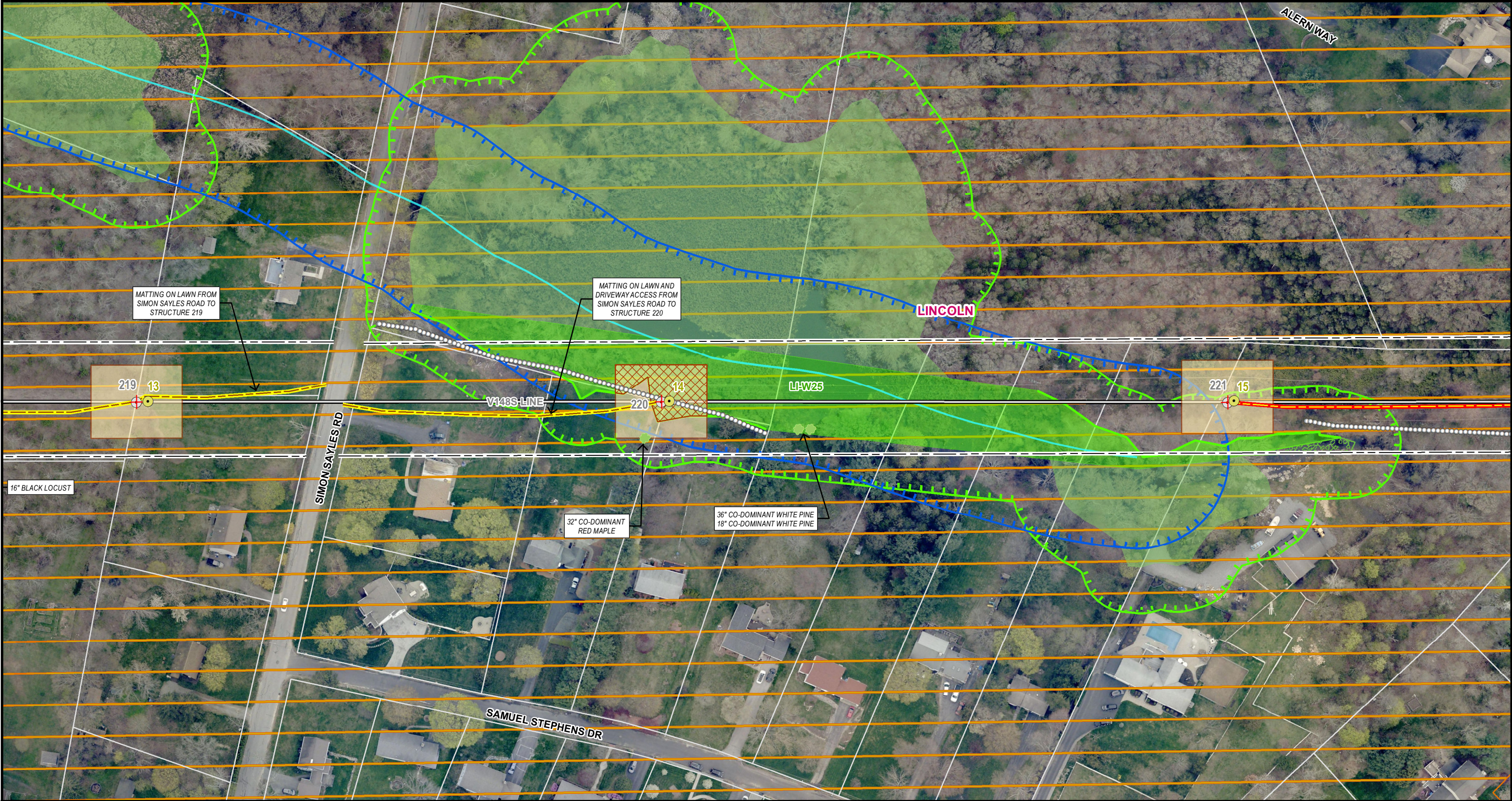
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City of Lincoln, RI
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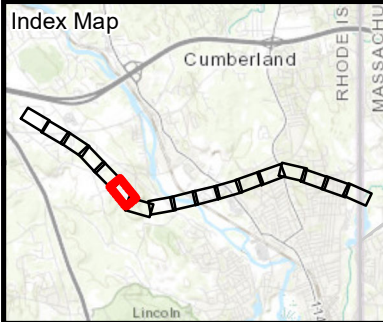
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City of Lincoln, RI
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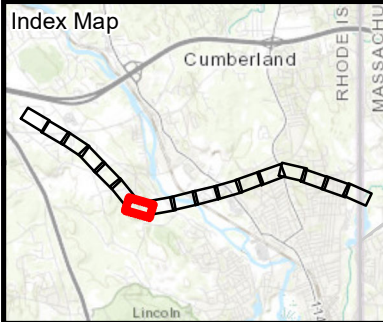
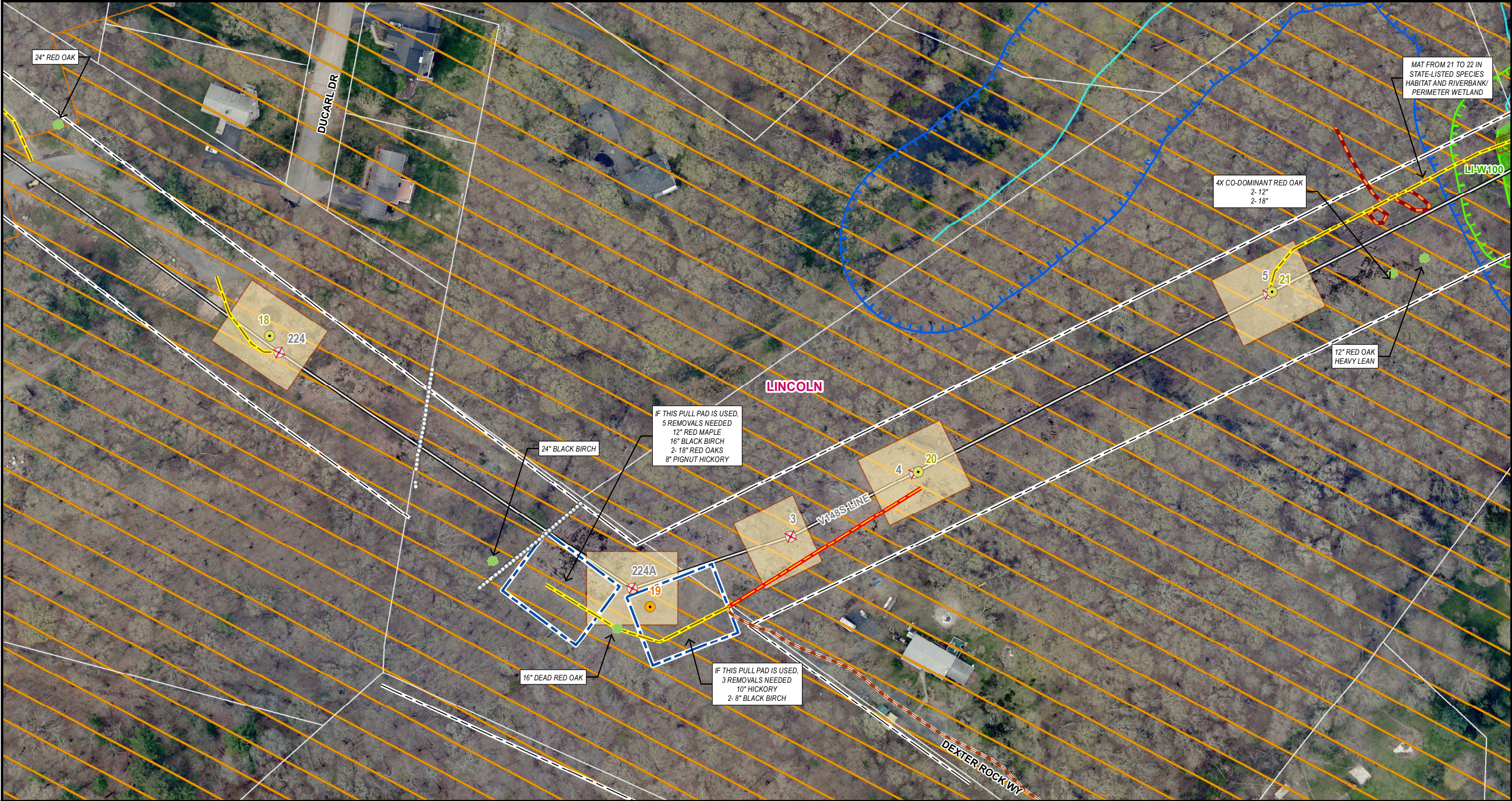
**V148S LINE ASSET CONDITION
REFURBISHMENT PROJECT**

Figure 3-1
Project Alignment Drawings

City of Lincoln, RI
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- NHESP Priority & Estimated Habitats
- State-Listed Species Habitat
- Conservation Land*
- Soil Stockpile
- Town Boundary
- Parcel Boundary
- Approximate Pipeline
- Access Gate
- Culverts
- Catch Basin
- Bike Path
- Stonewall
- Fence
- Guardrail
- Superfund Site Boundary
- Tree to be Removed

***Indicates Layers Set to Transparency**

- Soil Stockpile
- Town Boundary
- Parcel Boundary
- Approximate Pipeline
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- Culverts
- Catch Basin
- Bike Path
- Stonewall
- Fence
- Guardrail
- Superfund Site Boundary
- Tree to be Removed

1 inch = 100 feet

0 50 100

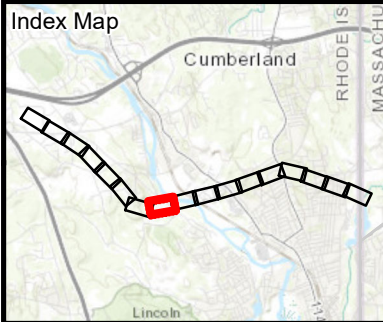
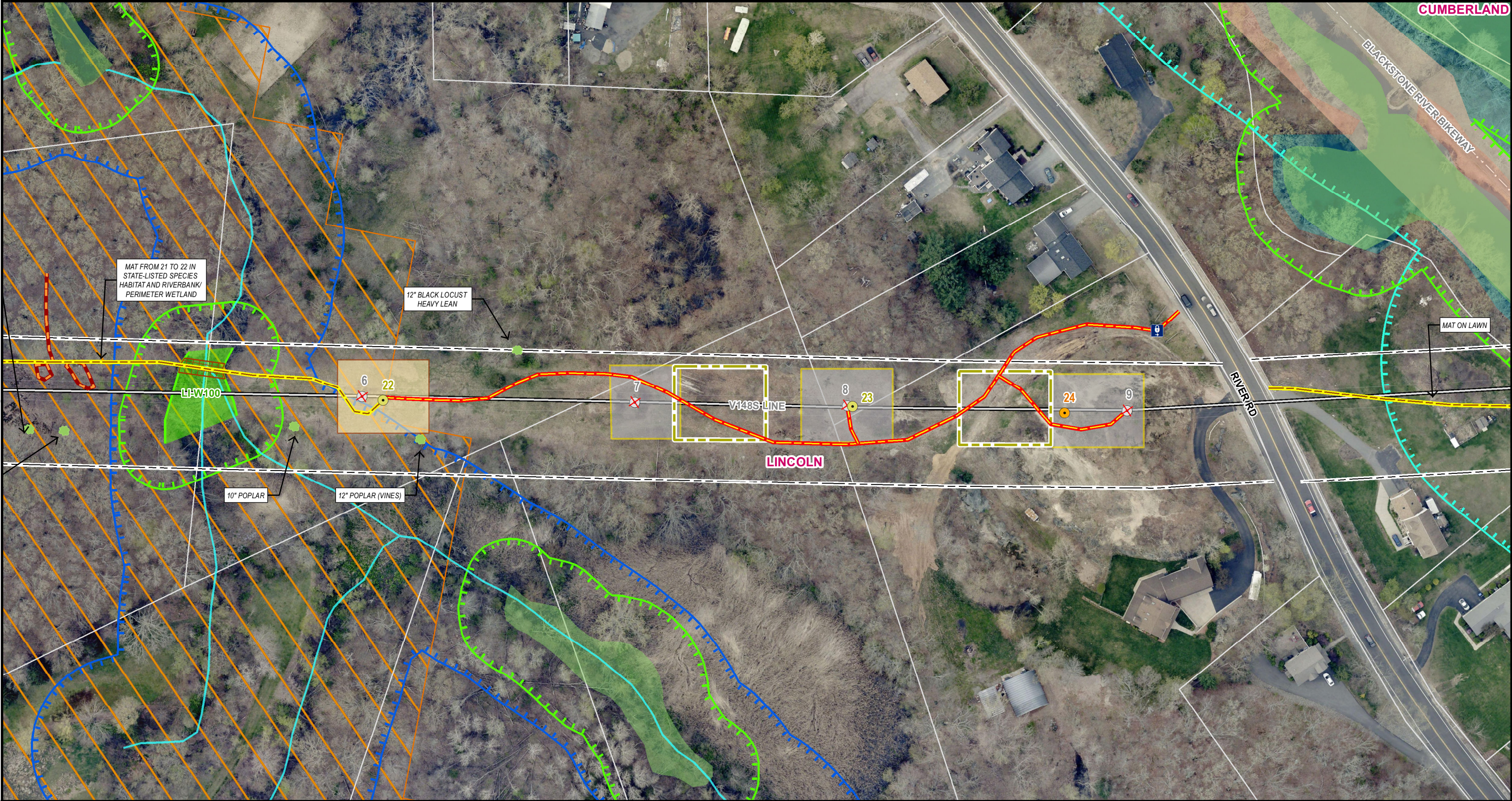
Feet

**V148S LINE ASSET CONDITION
REFURBISHMENT PROJECT**

Figure 3-1
Project Alignment Drawings

City of Lincoln, RI
Page 7 of 17

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community



Legend

- Existing Structure
- Install Structure
- Install Structure with Concrete Caisson (1)
- Install Structure with Concrete Caisson (2)
- Remove Structure
- V148S OH Line
- Approx. Edge of ROW
- Preferred Access Road
- Access Road to be Improved
- Refresh with Stone
- Off ROW Access Road
- Alternate Access Road
- Construction Mats
- Work Envelope*
- Graded Work Envelope*
- Guard Structure
- Pull Pad
- Graded Pull Pad
- Field Delineated Intermittent Stream
- Field Delineated Perennial Stream/Bank
- Field Delineated Streams*
- Field Delineated Wetland Lines
- Field Delineated Wetlands*
- Wetland Replication Area*
- MADEP Hydrologic Connections
- USFWS Wetlands*
- Estimated Wetlands
- 50ft Perimeter Wetland
- 100ft Riverbank Wetland
- 200ft Riverbank Wetland/
- FEMA 100yr Floodplain*
- Water Bar
- Hazardous Material Site
- Leaking Underground Storage
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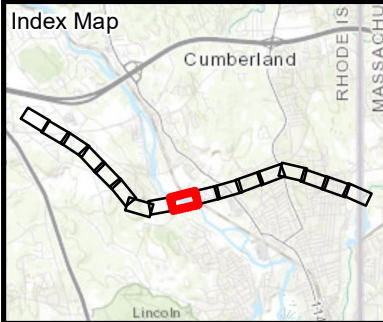
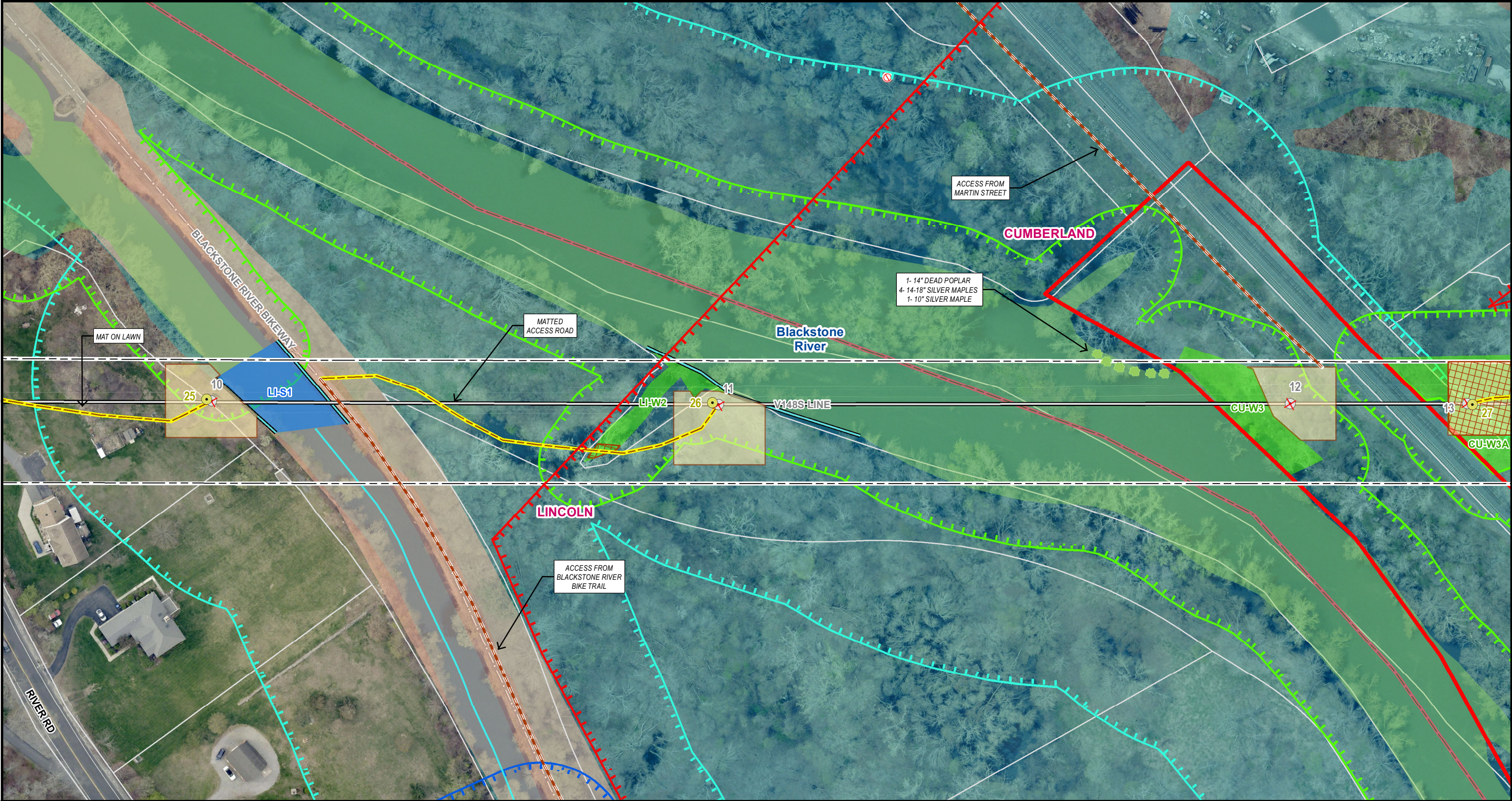
**V148S LINE ASSET CONDITION
REFURBISHMENT PROJECT**

Figure 3-1
Project Alignment Drawings

City of Lincoln, RI
Page 8 of 17

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- Superfund Site Boundary
- Tree to be Removed

**Indicates Layers Set to Transparency*

1 inch = 100 feet

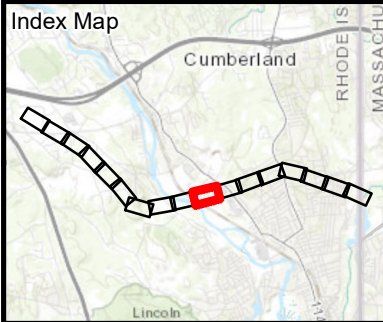
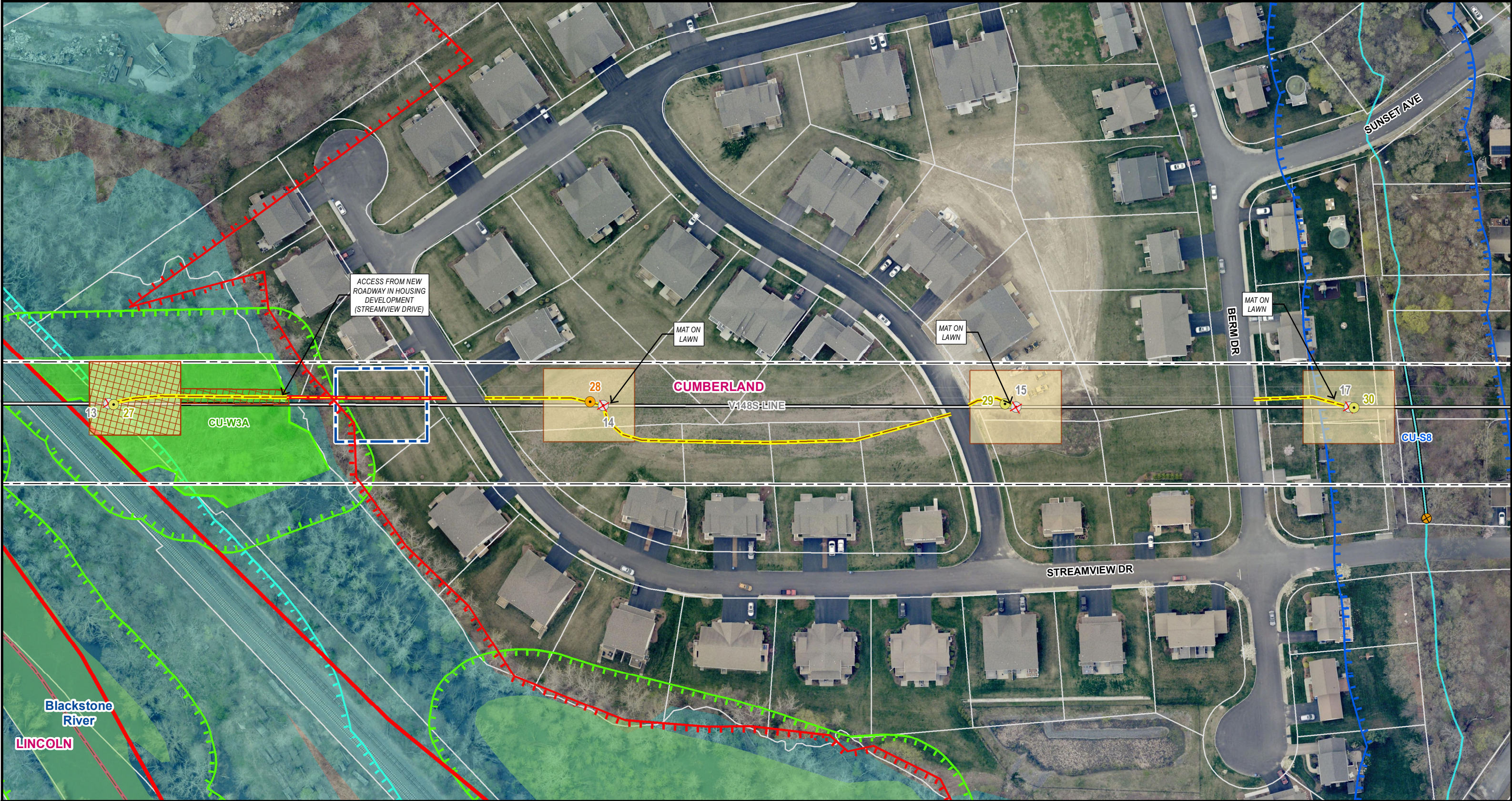
0 50 100 Feet

**V148S LINE ASSET CONDITION
REFURBISHMENT PROJECT**

Figure 3-1
Project Alignment Drawings
City of Lincoln & Cumberland, RI
Page 9 of 17

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

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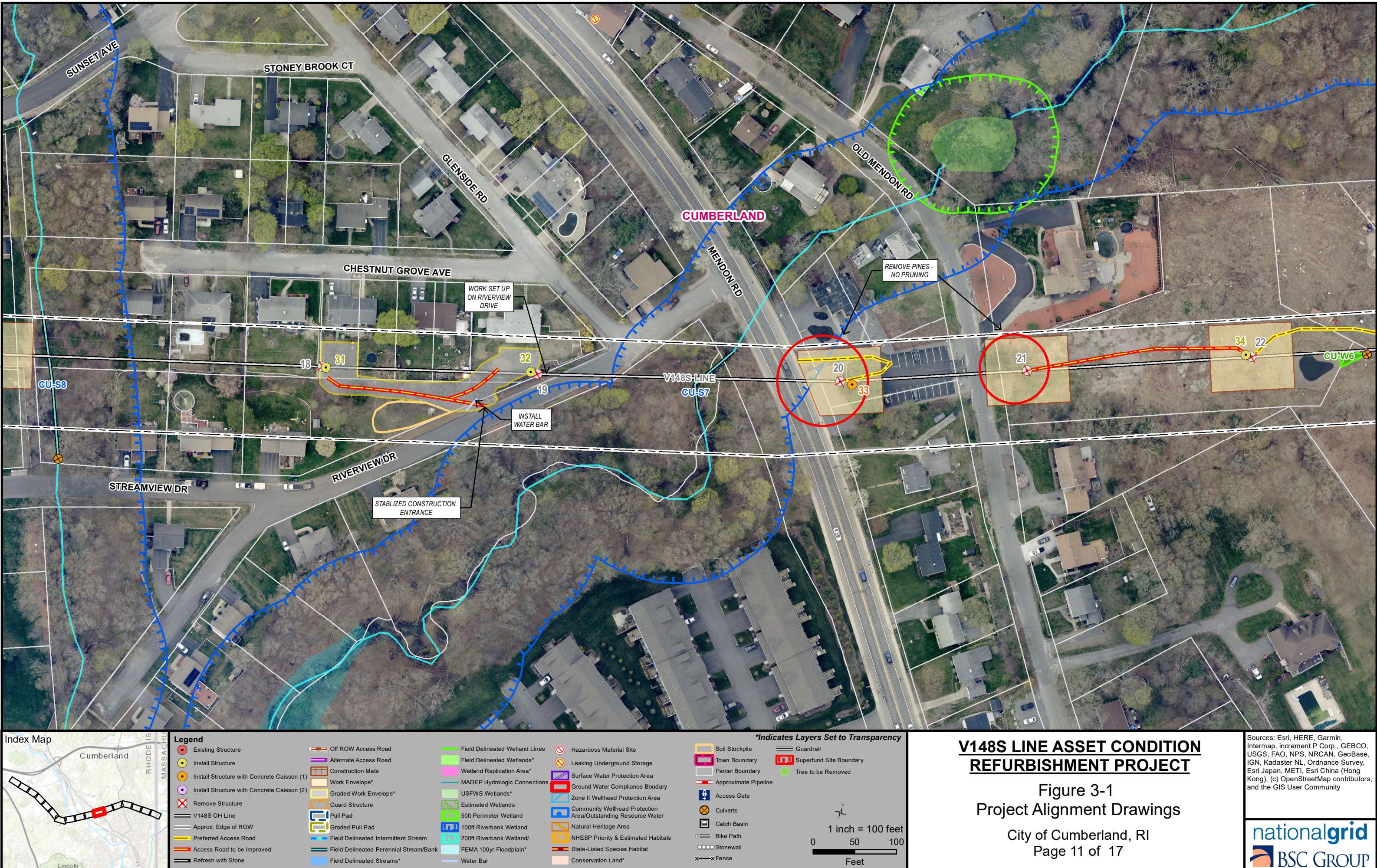
1 inch = 100 feet

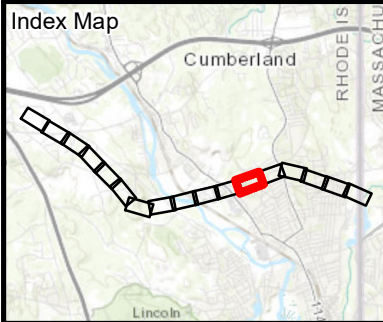
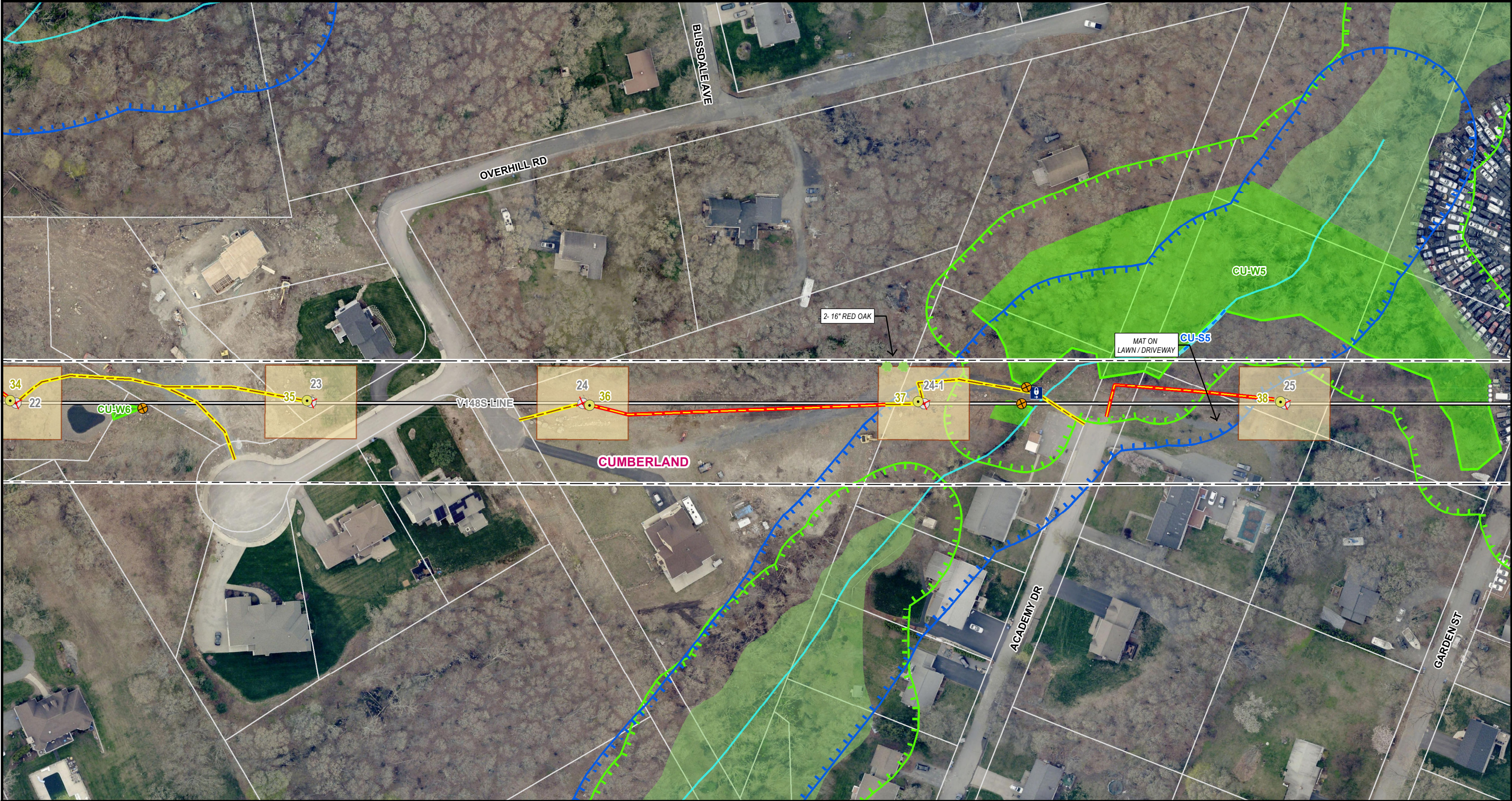
0 50 100

Feet

V148S LINE ASSET CONDITION REFURBISHMENT PROJECT

Figure 3-1
Project Alignment Drawings
City of Lincoln & Cumberland, RI
Page 10 of 17





Legend

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0 50 100

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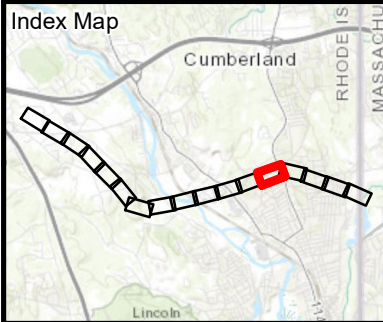
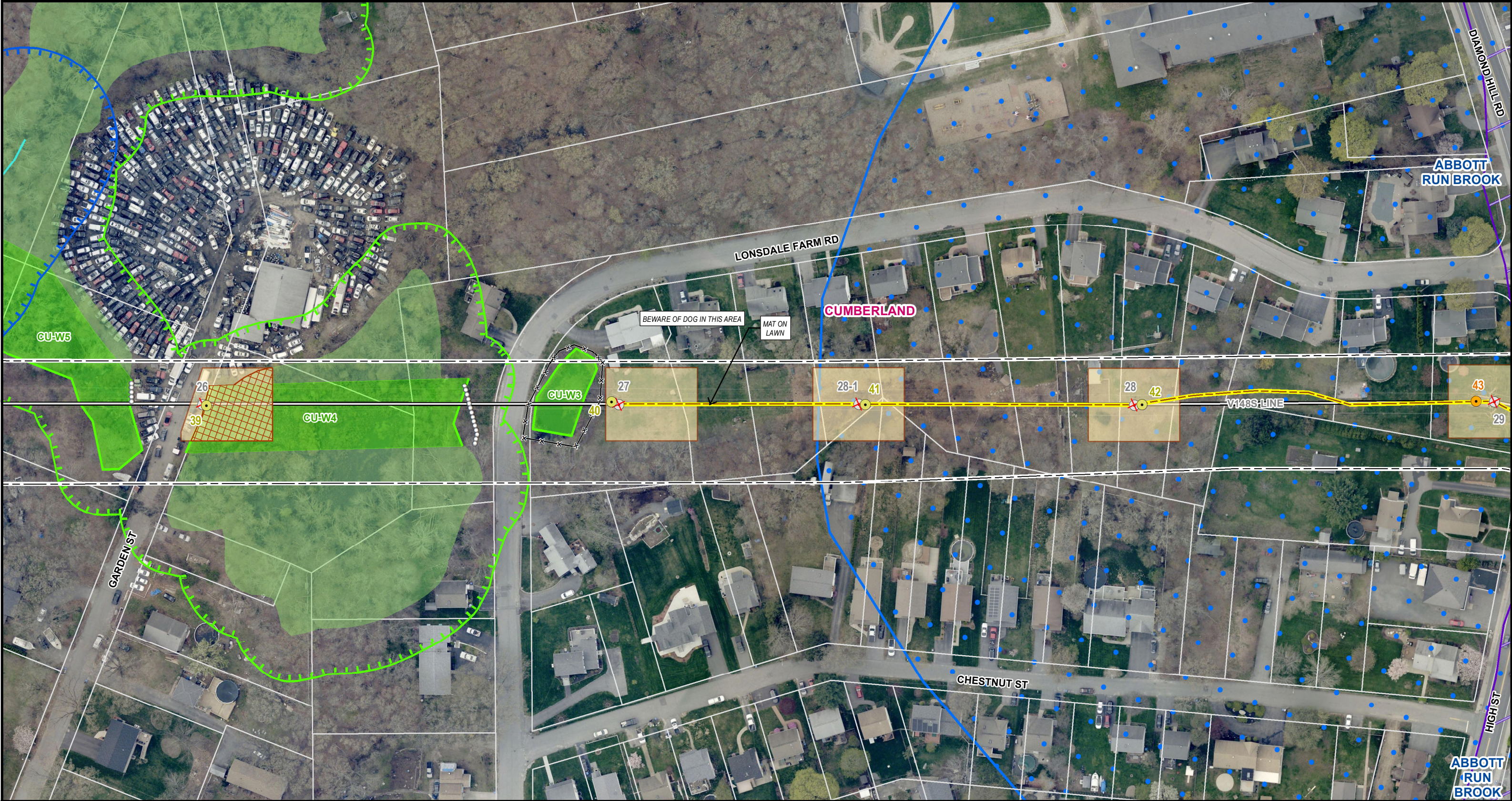
**V148S LINE ASSET CONDITION
REFURBISHMENT PROJECT**

Figure 3-1
Project Alignment Drawings

City of Cumberland, RI
Page 12 of 17

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

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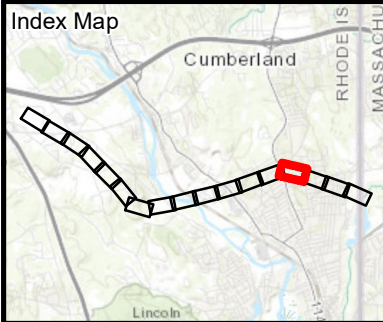
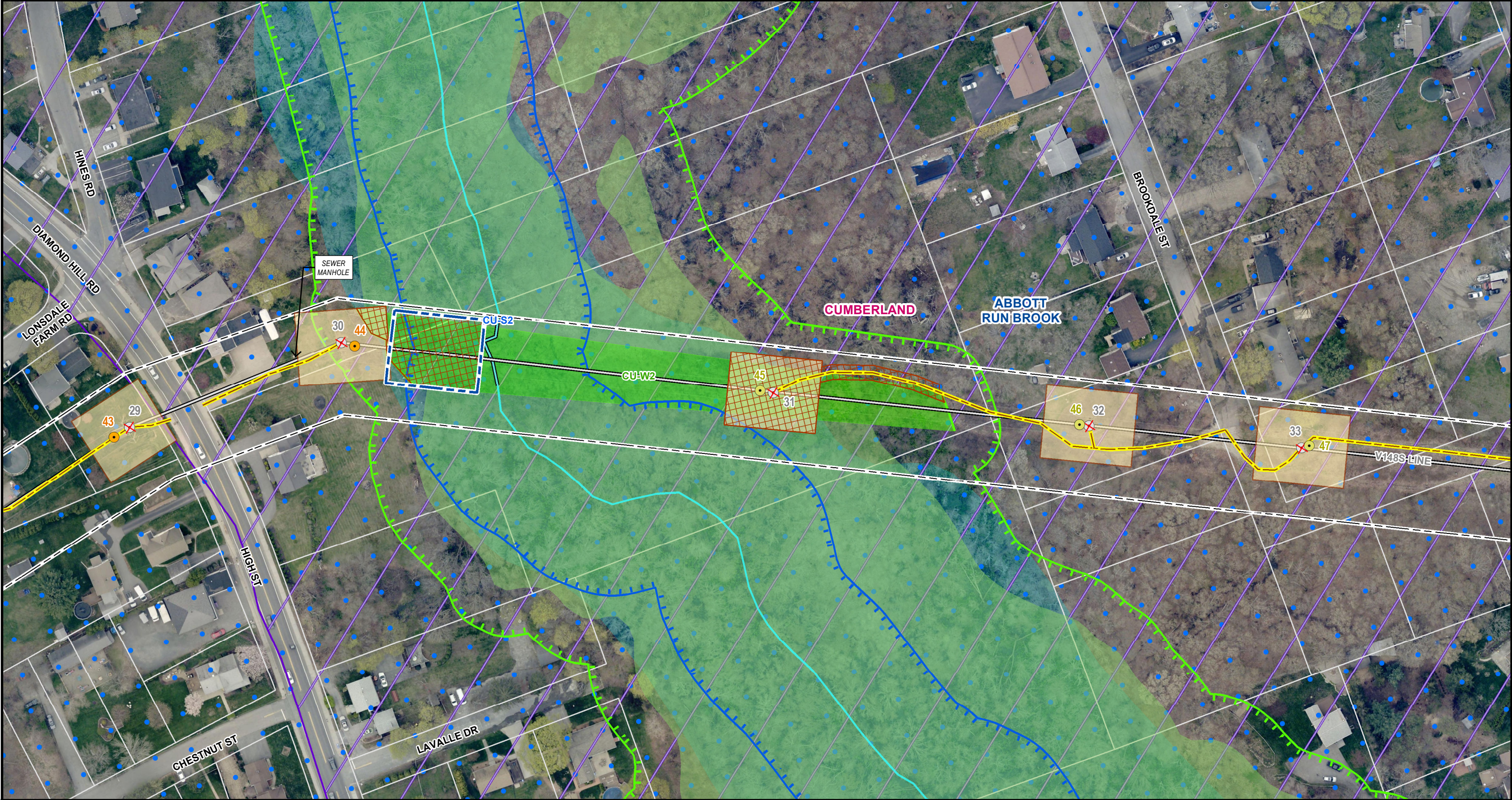
**V148S LINE ASSET CONDITION
REFURBISHMENT PROJECT**

Figure 3-1
Project Alignment Drawings

City of Cumberland, RI
Page 13 of 17

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0 50 100

Feet

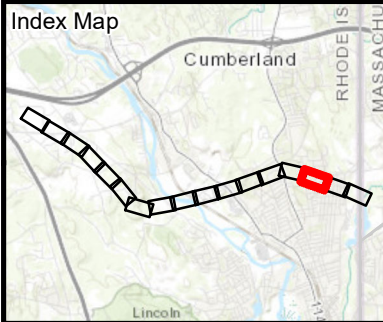
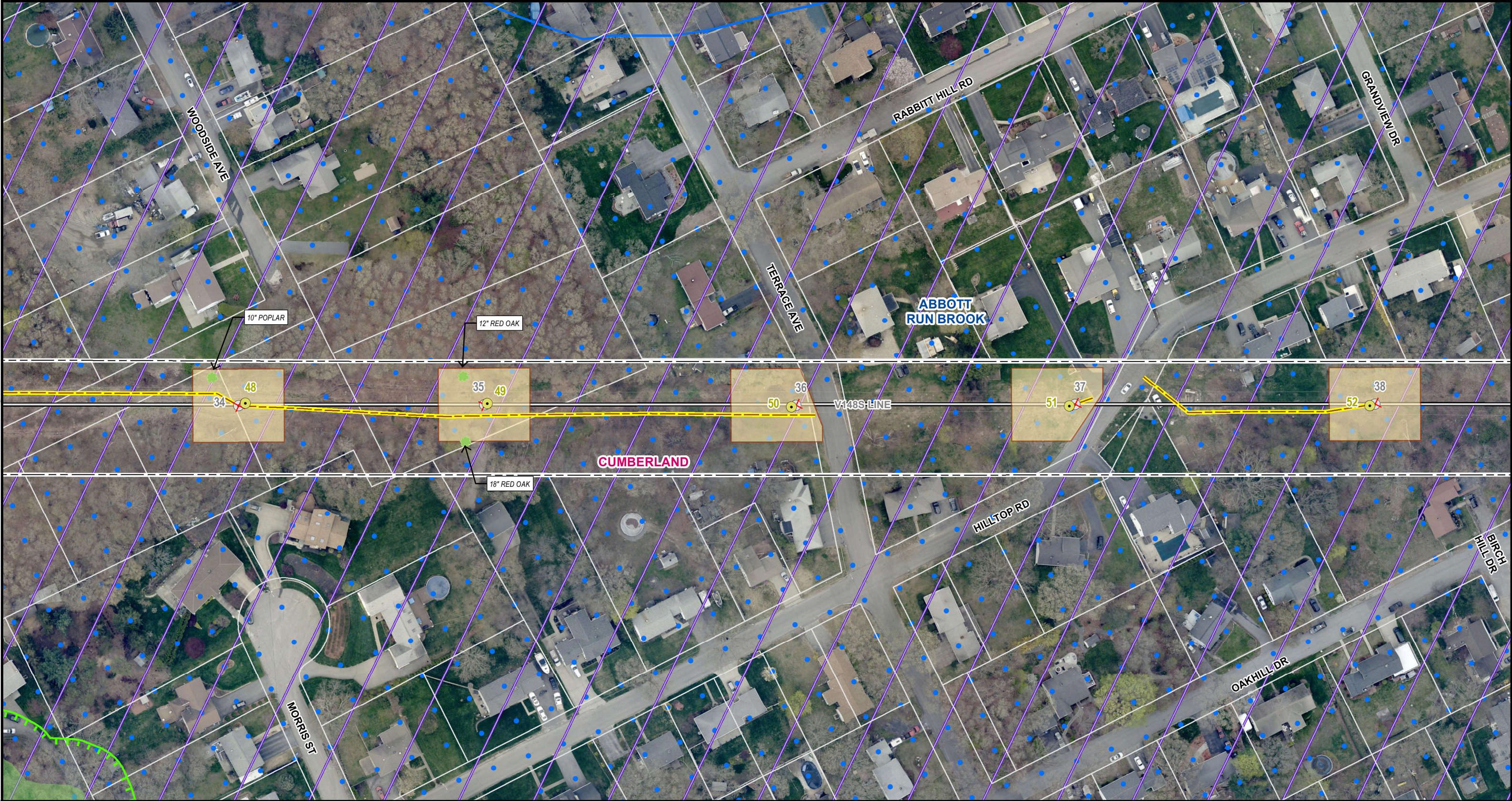
**V148S LINE ASSET CONDITION
REFURBISHMENT PROJECT**

Figure 3-1
Project Alignment Drawings

City of Cumberland, RI
Page 14 of 17

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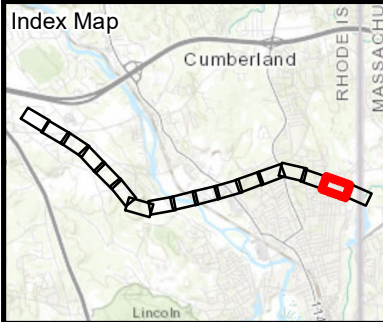
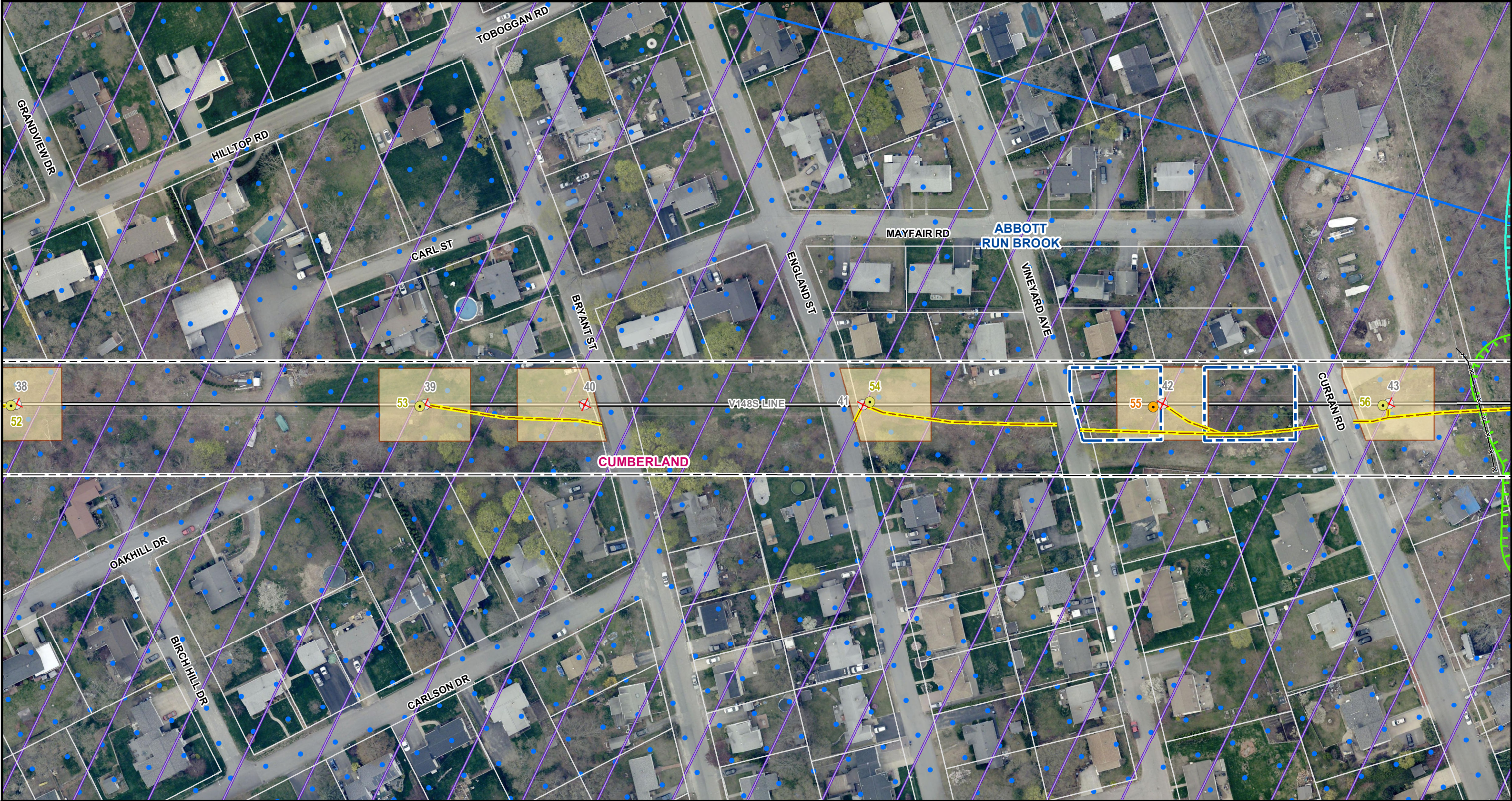
**V148S LINE ASSET CONDITION
REFURBISHMENT PROJECT**

Figure 3-1
Project Alignment Drawings

City of Cumberland, RI
Page 15 of 17

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

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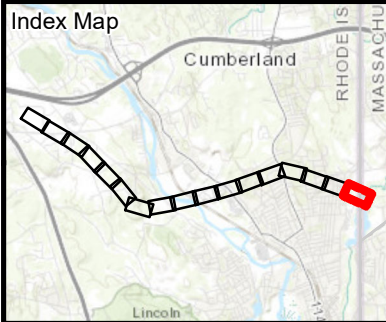
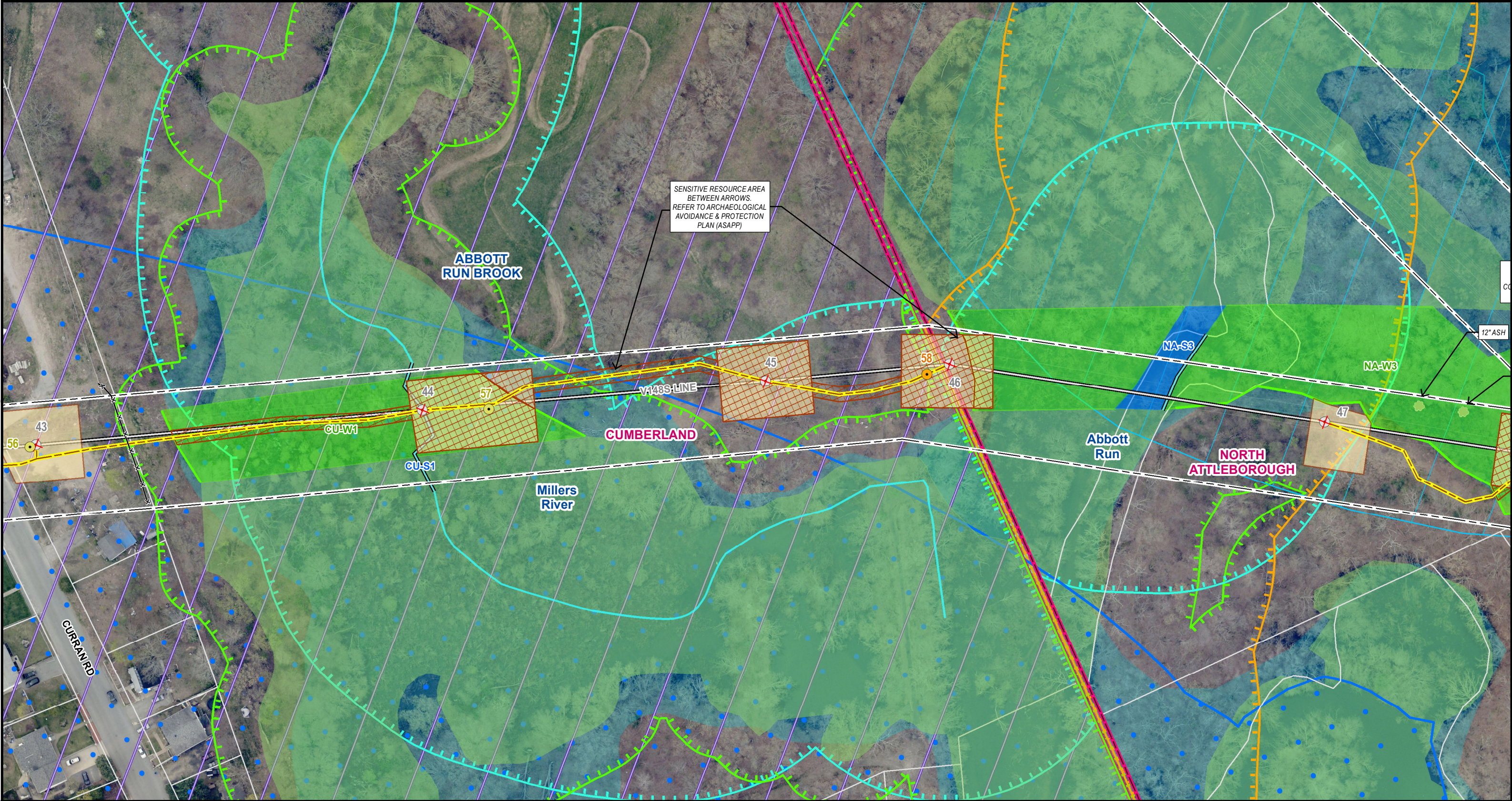
**V148S LINE ASSET CONDITION
REFURBISHMENT PROJECT**

Figure 3-1
Project Alignment Drawings

City of Cumberland, RI
Page 16 of 17

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

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Legend

<ul style="list-style-type: none">Existing StructureInstall StructureInstall Structure with Concrete Caisson (1)Install Structure with Concrete Caisson (2)Remove StructureV148S OH LineApprox. Edge of ROWPreferred Access RoadAccess Road to be ImprovedRefresh with Stone	<ul style="list-style-type: none">Off ROW Access RoadAlternate Access RoadConstruction MatsWork Envelope*Graded Work Envelope*Guard StructurePull PadGraded Pull PadField Delineated Intermittent StreamField Delineated Perennial Stream/BankField Delineated Streams*	<ul style="list-style-type: none">Field Delineated Wetland LinesField Delineated Wetlands*Wetland Replication Area*MADEP Hydrologic ConnectionsUSFWS Wetlands*Estimated Wetlands50ft Perimeter Wetland100ft Riverbank Wetland200ft Riverbank Wetland/FEMA 100yr Floodplain*Water Bar	<ul style="list-style-type: none">Hazardous Material SiteLeaking Underground StorageSurface Water Protection AreaGround Water Compliance BoundaryZone II Wellhead Protection AreaCommunity Wellhead Protection Area/Outstanding Resource WaterNatural Heritage AreaNHESP Priority & Estimated HabitatsState-Listed Species HabitatConservation Land*	<ul style="list-style-type: none">Soil StockpileTown BoundaryParcel BoundaryApproximate PipelineAccess GateCulvertsCatch BasinBike PathStonewallFence	<ul style="list-style-type: none">GuardrailSuperfund Site BoundaryTree to be Removed
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**Indicates Layers Set to Transparency*

1 inch = 100 feet
0 50 100 Feet

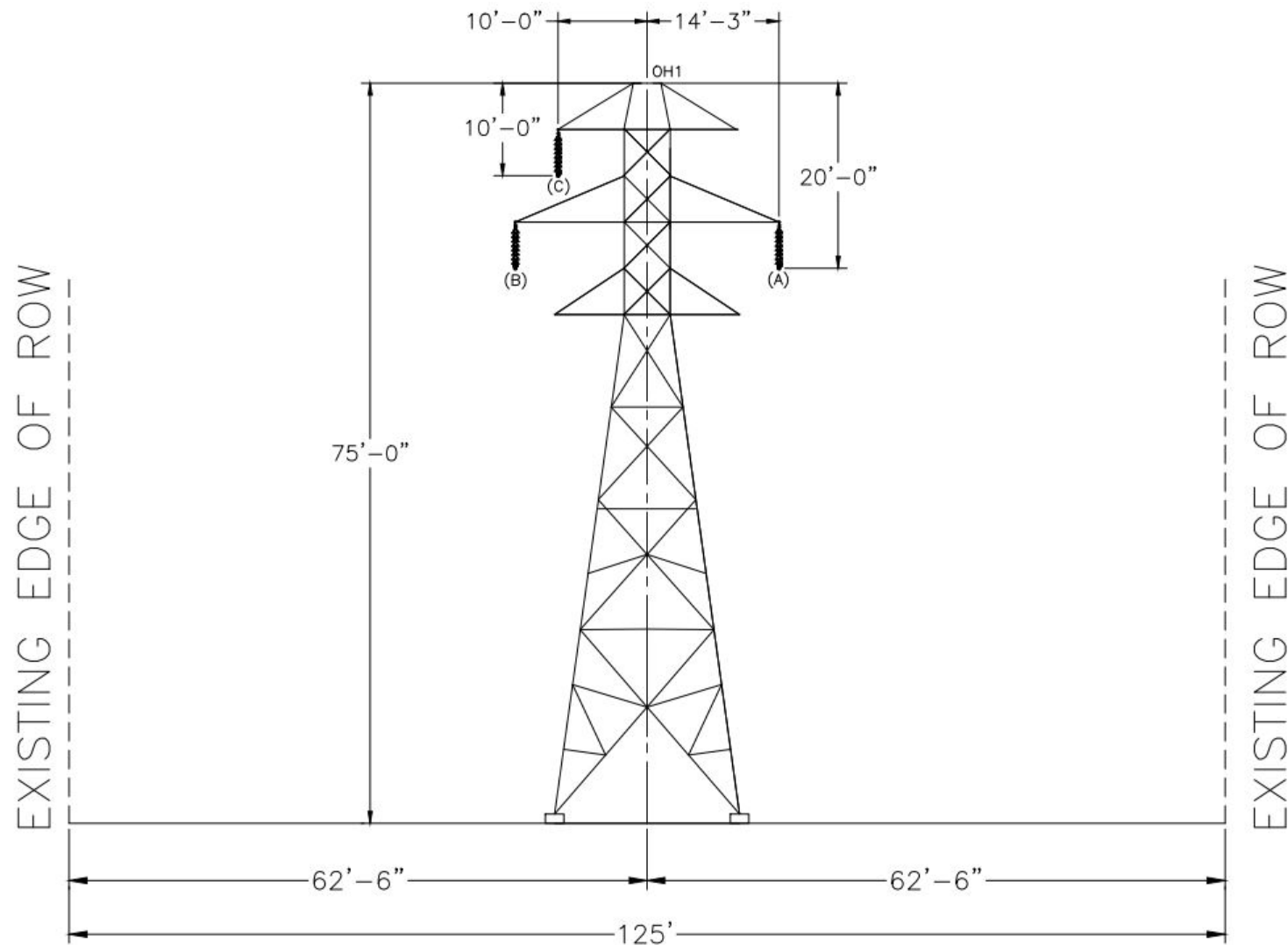
V148S LINE ASSET CONDITION REFURBISHMENT PROJECT

Figure 3-1
Project Alignment Drawings

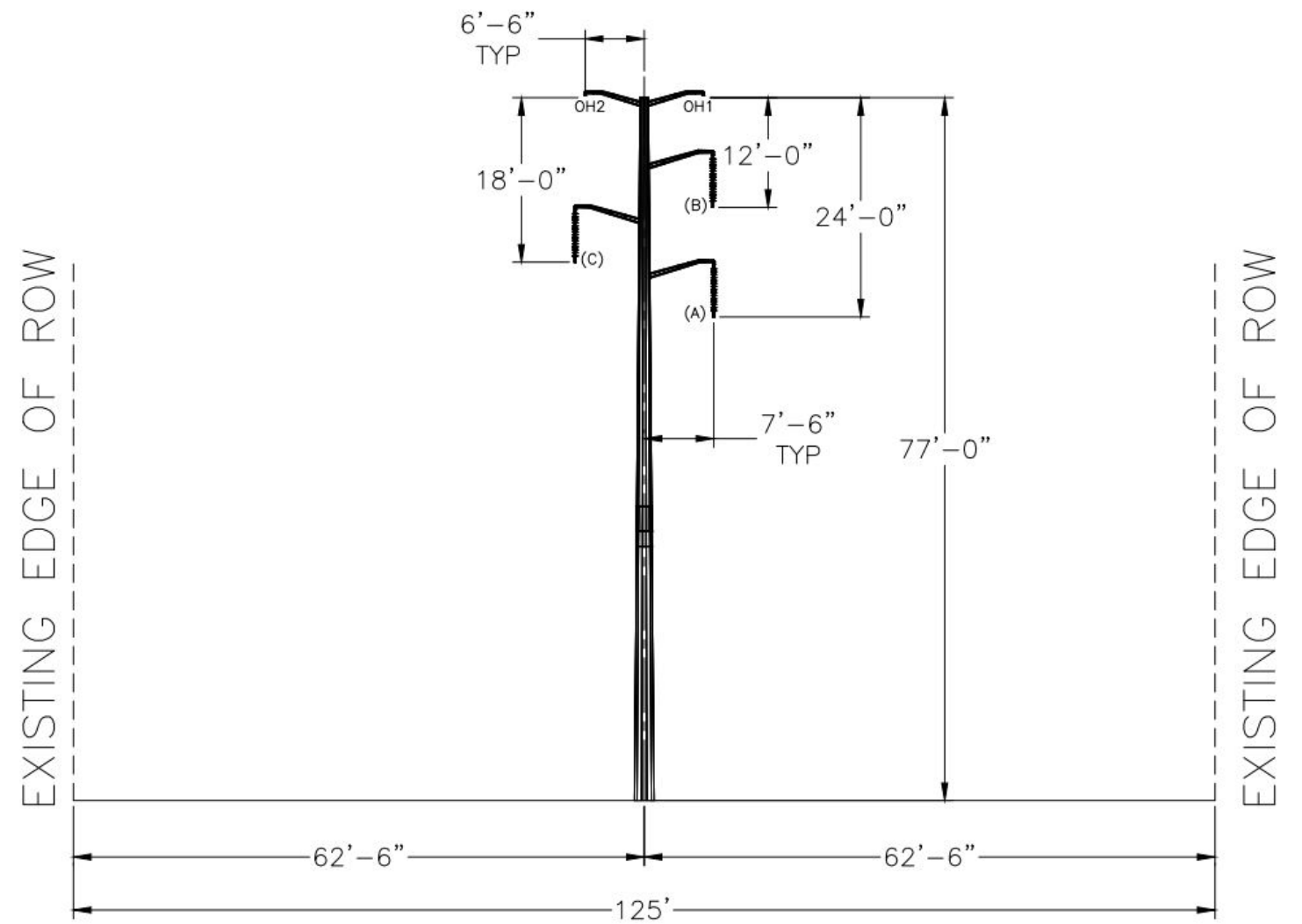
City of Cumberland, RI & North Attleborough, MA
Page 17 of 17

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

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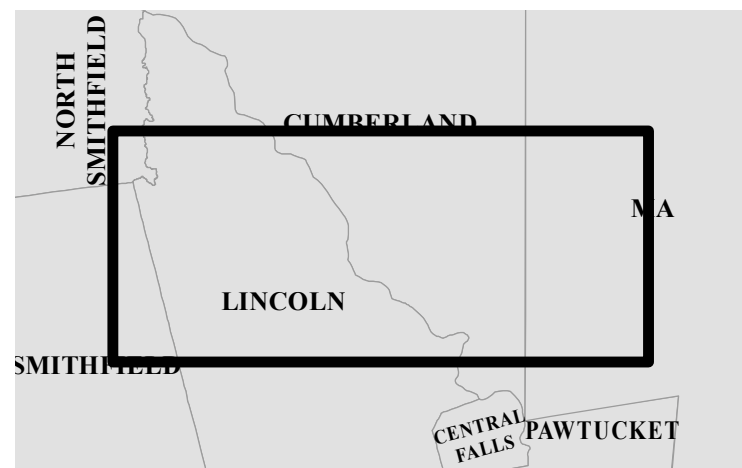
Existing Cross-Section
Washington St to STR 224A 2.0 Miles



Proposed Cross-Section
Washington St to STR 224A 2.0 Miles

Project Vicinity

Legend



V148S ACR Project Figure 3-2 Typical Structure Details - V148S

State of Rhode Island
Providence County:
Cities of Lincoln & Cumberland



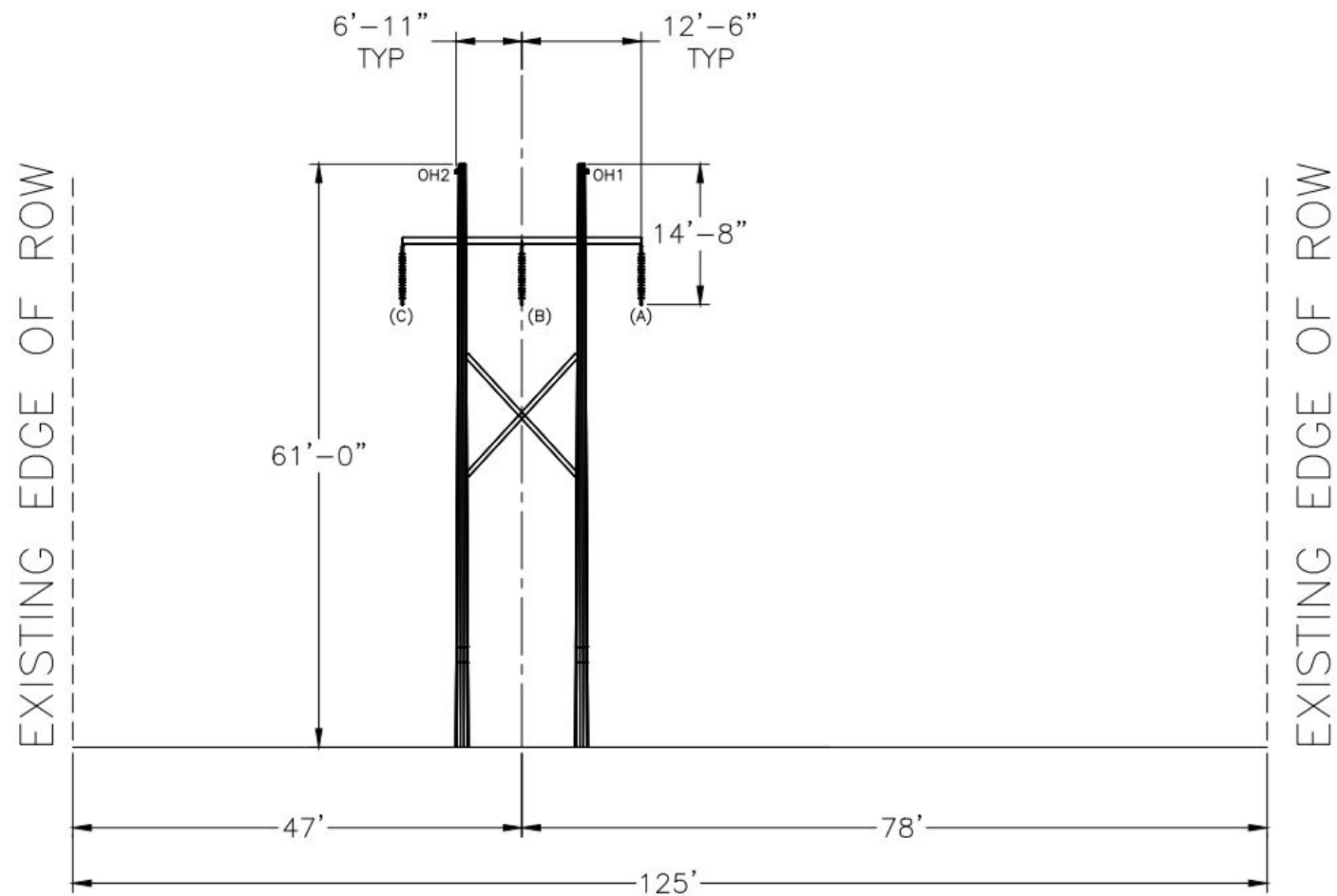
0 0.5 1 Miles

1" = 2,500'

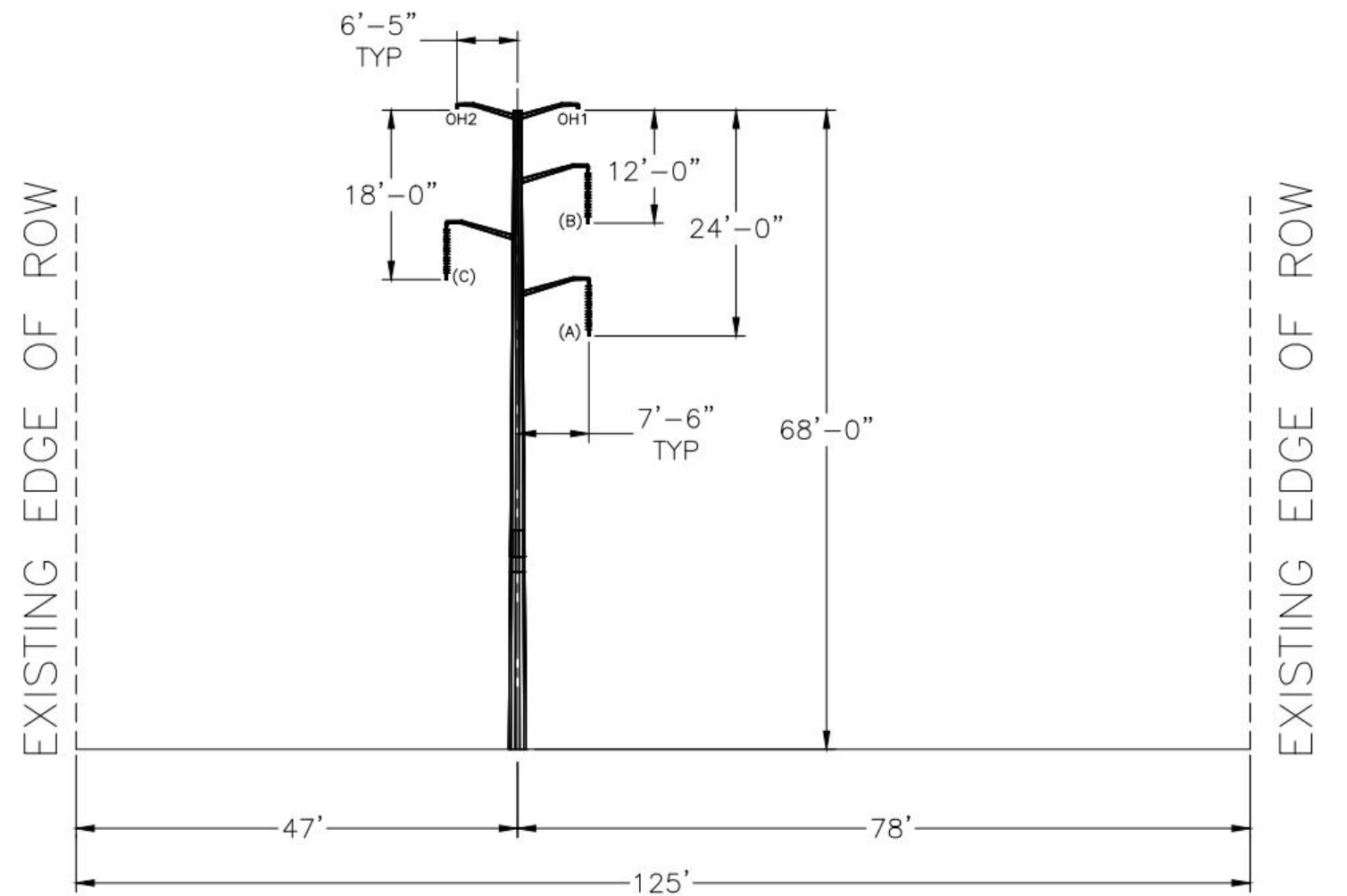
DATE: 11/5/2021

AUTHOR: LSTANLEY

NOT FOR
CONSTRUCTION



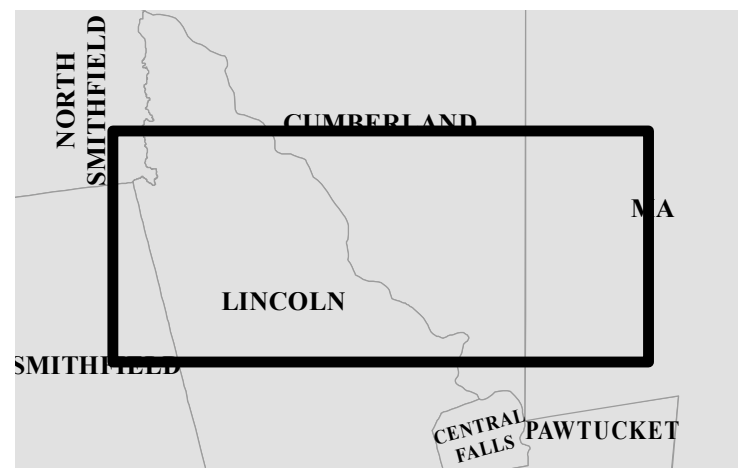
Existing Cross-Section
STR 224A to MA/RI Border - 3.0 Miles



Proposed Cross-Section
STR 224A to MA/RI Border - 3.0 Miles

Project Vicinity

Legend



V148S ACR Project

Figure 3-2 Typical Structure Details - V148S

State of Rhode Island
Providence County:
Cities of Lincoln & Cumberland



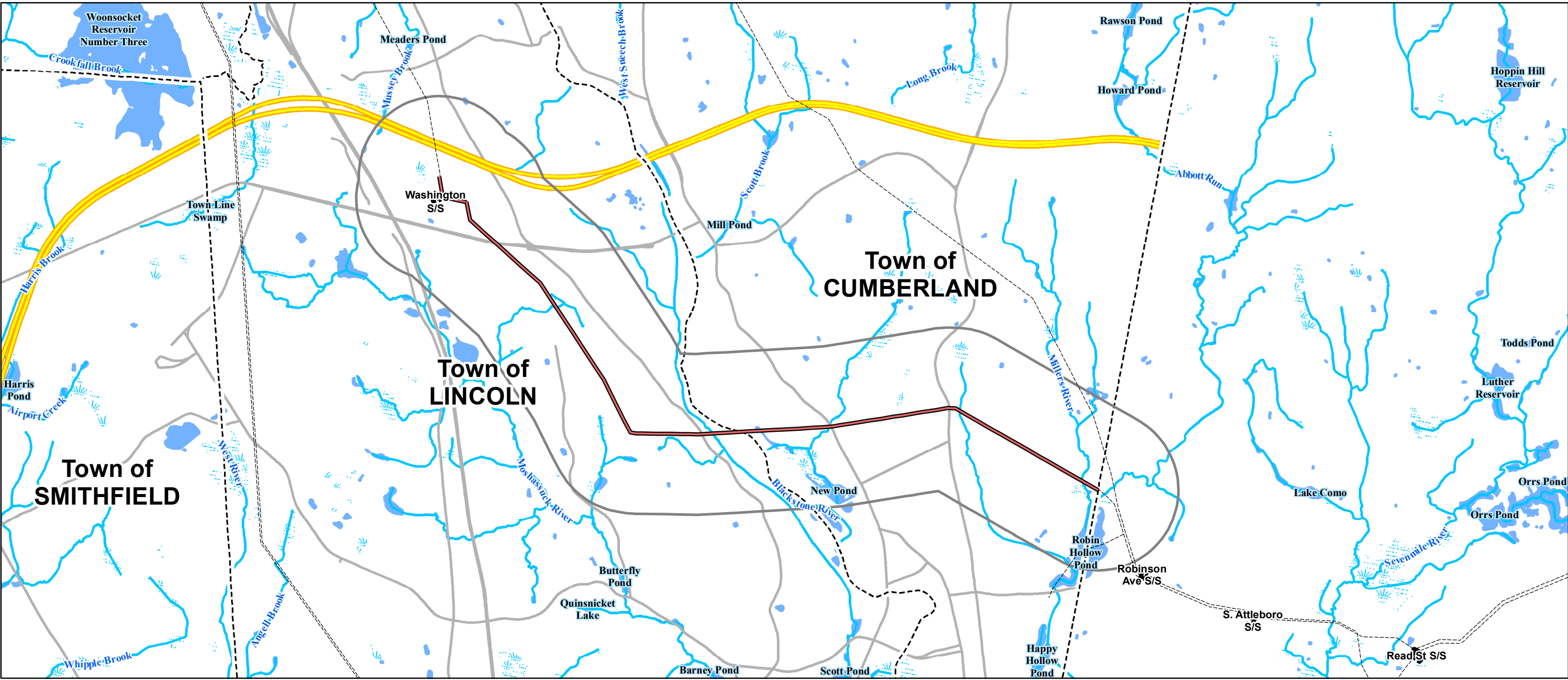
0 0.5 1 Miles

1" = 2,500'

DATE: 11/5/2021

AUTHOR: LSTANLEY

NOT FOR
CONSTRUCTION



Legend

Project Features

- Project Features
- Existing Transmission Line
- 5,000 Foot Study Area
- Substation Site

Transportation Features

- Interstate Highway
- US Highway
- State Highway

Political Boundaries

- Town Boundary

Water Features

- River or Stream
- Lake or Pond
- Swamp or Marsh

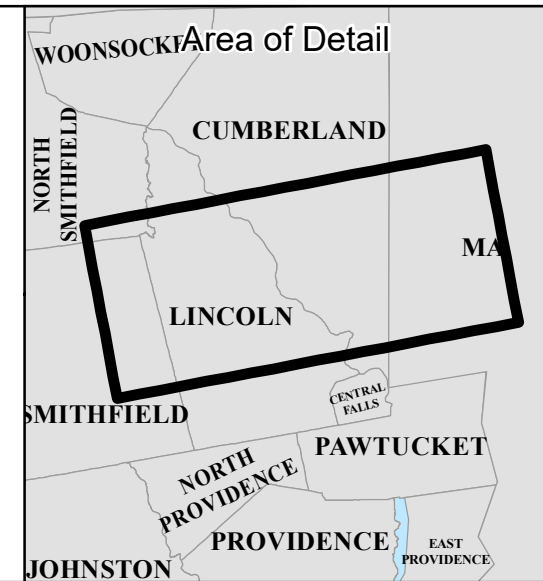
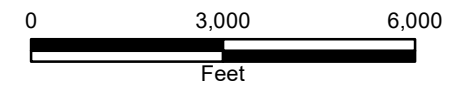
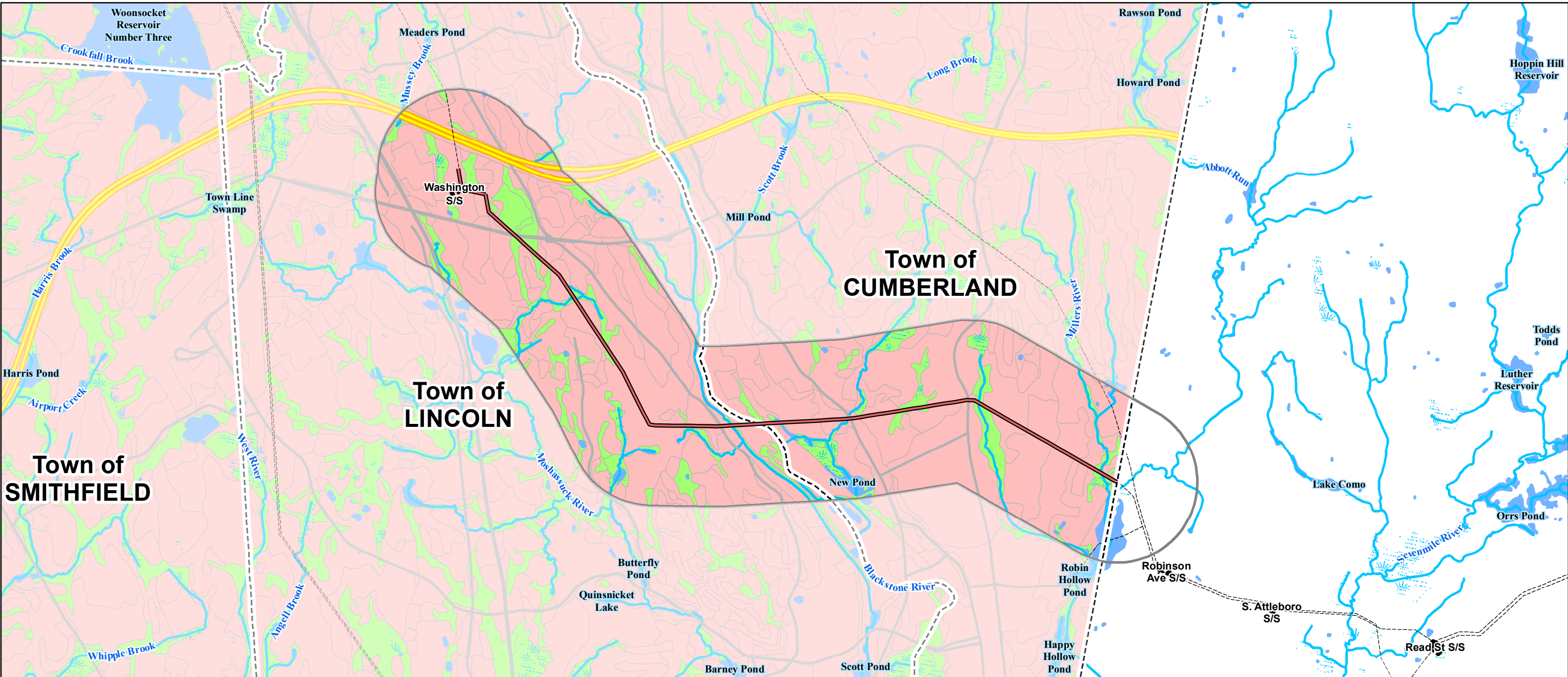


Figure 5-1
Study Area

V148S ACR Project





Legend

Project Transmission Line

- Project Transmission Line
- Existing Transmission Line
- 5,000 Foot Study Area
- Substation Site

Transportation Features

- Interstate Highway
- US Highway
- State Highway

Political Boundaries

- Town Boundary

Water Features

- River or Stream
- Lake or Pond
- Swamp or Marsh

Hydric Rating

- Yes
- No

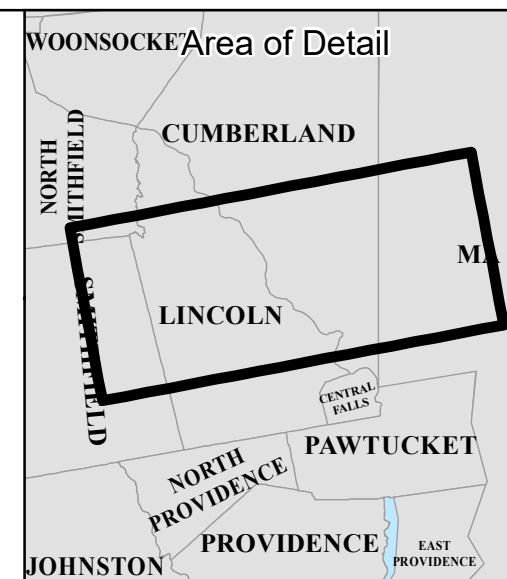
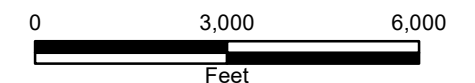
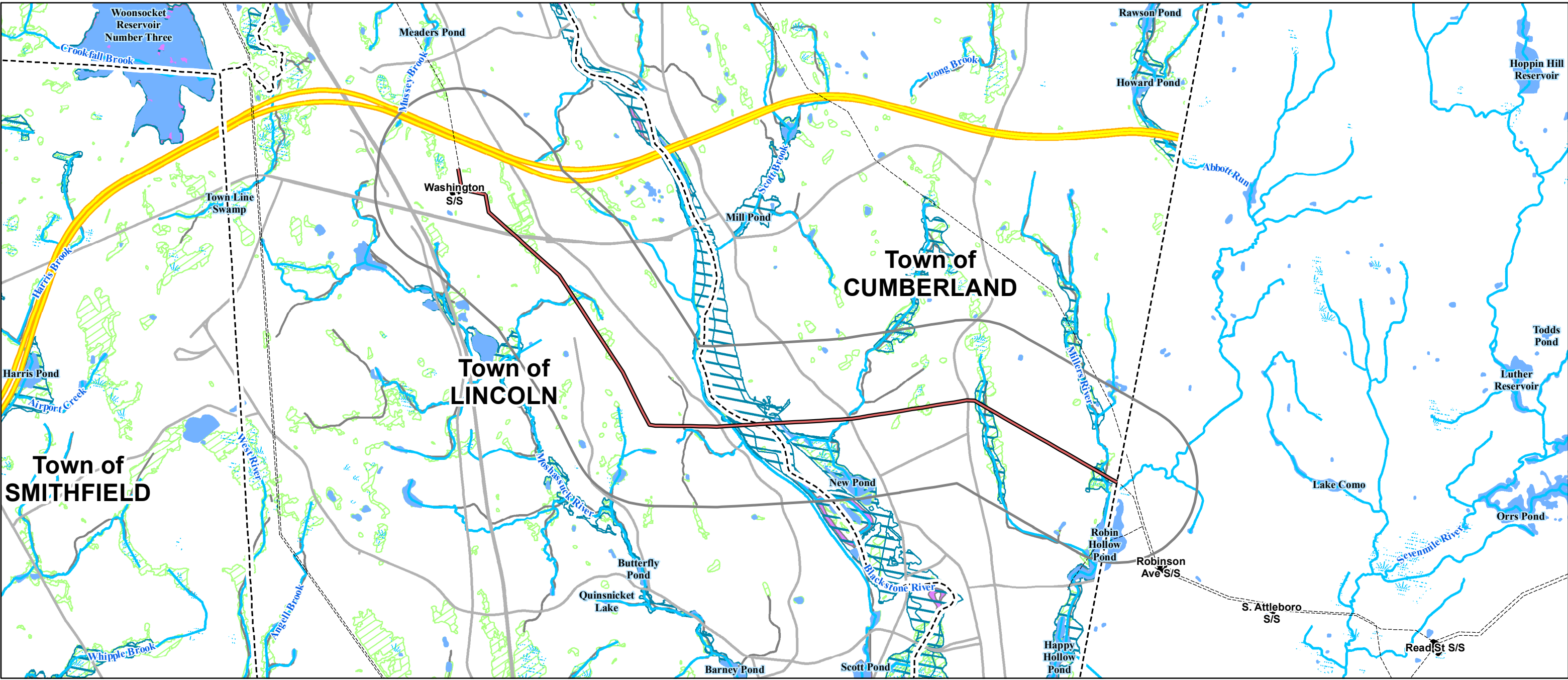


Figure 5-2
Hydric Soils

V148S ACR Project





Legend

Project Transmission Line

- Project Transmission Line
- Existing Transmission Line
- 5,000 Foot Study Area
- Substation Site

Transportation Features

- Interstate Highway
- US Highway
- State Highway

Political Boundaries

- Town Boundary

Water Features

- River or Stream
- Lake or Pond
- Swamp or Marsh

Wetlands

- FEMA Flood Hazard (DFIRM 100yr)
- NWI Freshwater Wetland
- NWI Wetland

Area of Detail

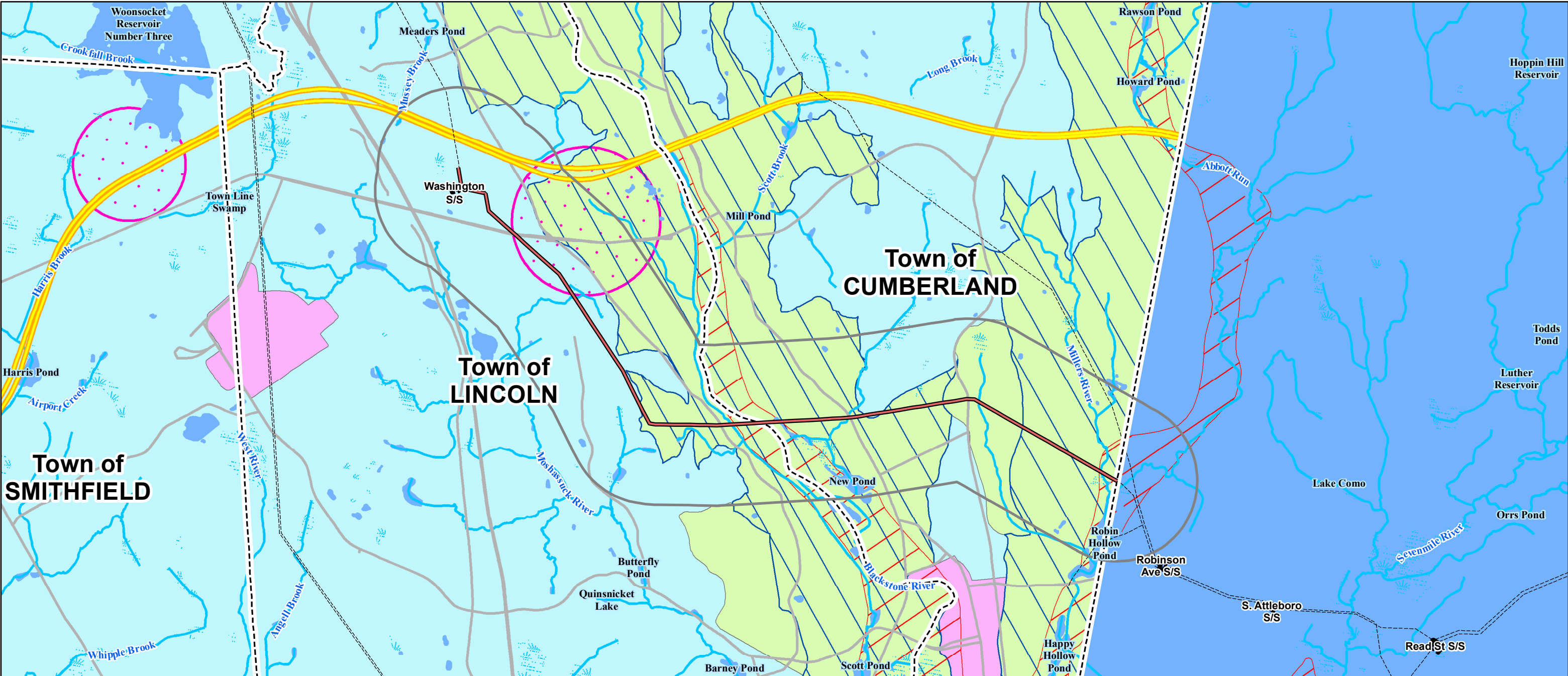
Figure 5-3
Wetland Resources

V148S ACR Project

0 3,000 6,000
Feet

BSC GROUP nationalgrid

DATE: 11/17/2021



Legend

Project Transmission Line

- Project Transmission Line
- Existing Transmission Line
- 5,000 Foot Study Area
- Substation Site

Transportation Features

- Interstate Highway
- US Highway
- State Highway

Political Boundaries

- Town Boundary

Water Features

- River or Stream
- Lake or Pond
- Swamp or Marsh

Groundwater Resources

- Groundwater Reservoir

- Groundwater Recharge Areas

- Non-Community Wellhead Protection Areas

Groundwater Quality Standard

- GA
- GAA
- GB

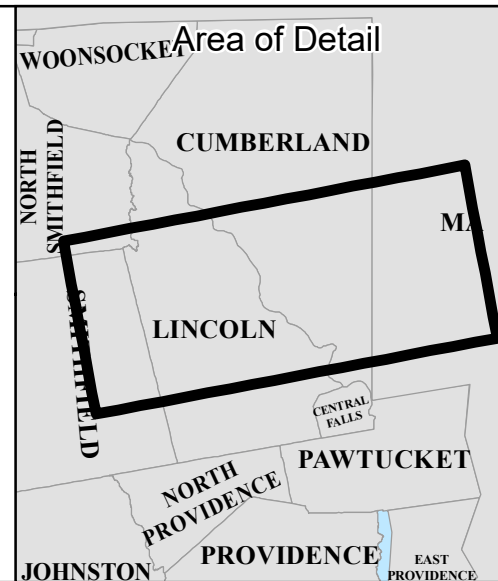
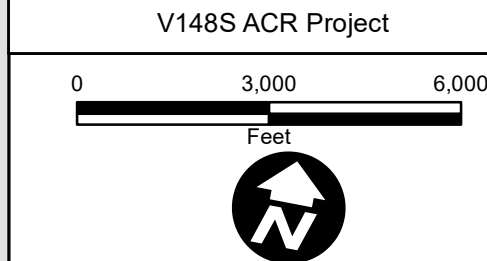
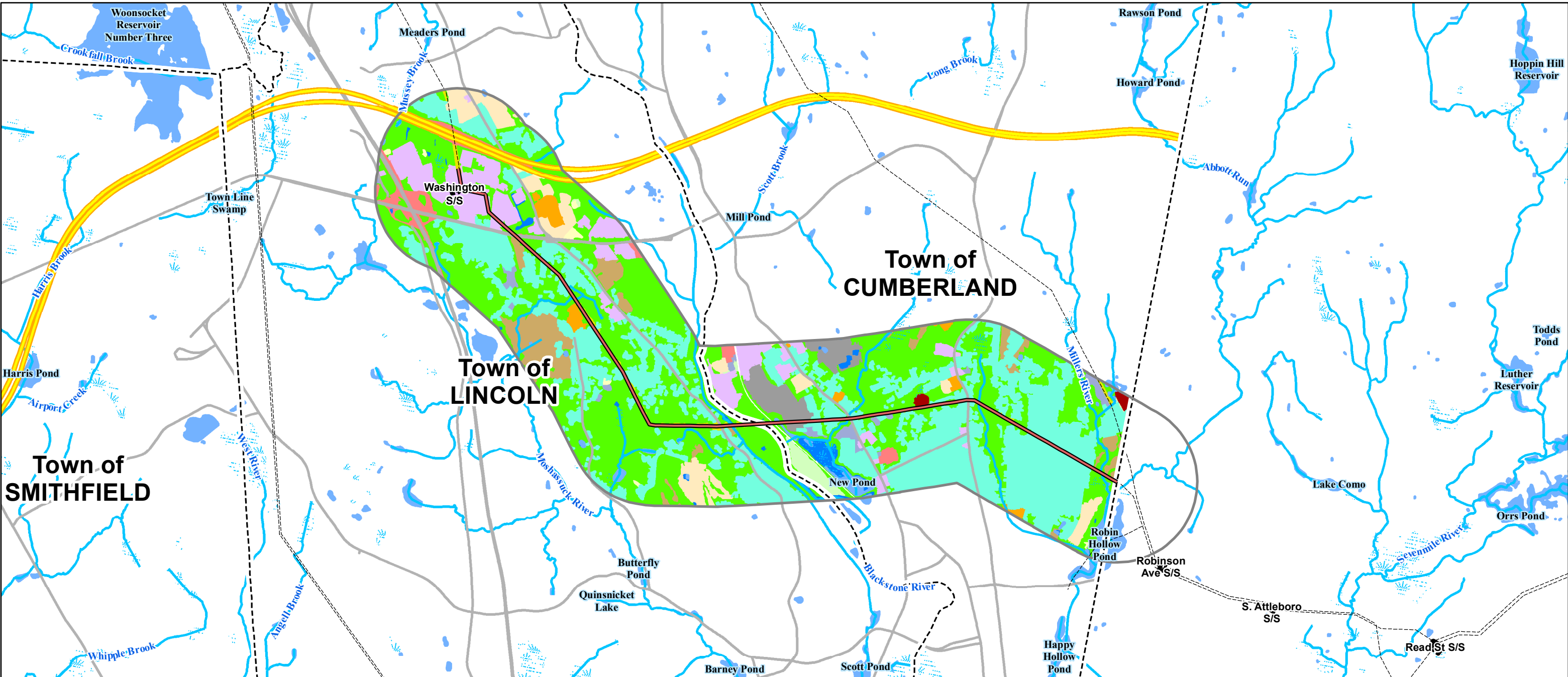


Figure 5-4
Groundwater Resources





Legend

Project Transmission Lines

Project Transmission Lines

Existing Transmission Line

5,000 Foot Study Area

Substation Site

Transportation Features

Interstate Highway

US Highway

State Highway

Political Boundaries

Town Boundary

Water Features

River or Stream

Lake or Pond

Swamp or Marsh

Land Use / Land Cover

Commercial

Residential

Institutional (schools, hospitals, churches, etc.)

Transitional Areas

Transportation

Agriculture, Pasture, or Orchard

Recreation

Brushland

Forest

Utility Easement

Mines, Quarries and Gravel Pits

Waste Disposal (landfills, junkyards, etc.)

Vacant Land

Wetland

Water

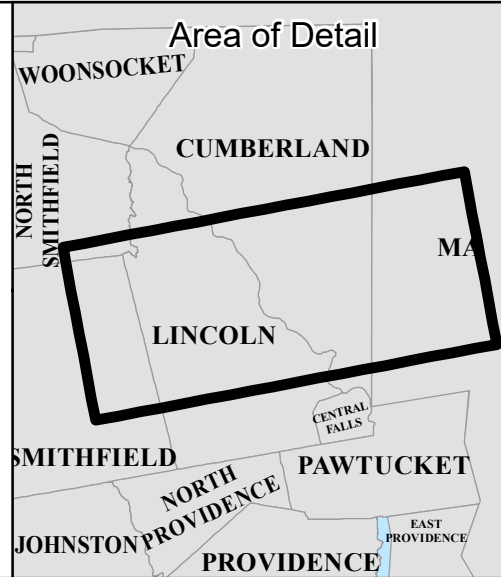
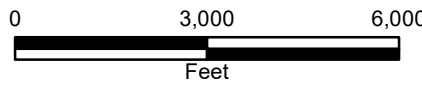


Figure 6-1

Land Use Classification

V148S ACR Project



BSC GROUP

nationalgrid

DATE: 11/17/2021



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

1 February, 2022

Michael Wierbonics
USACE
(via email)

Re: Narragansett Electric Line V148S, Cumberland, RI

Dear Mr. Wierbonics,

The Rhode Island Historical Preservation and Heritage Commission (RIHPHC) has determined that the proposed construction for the above-referenced project will have no adverse effect on the Stateline site, potentially eligible for listing on the National Register of Historic Places. The possibly adverse effect of construction will be mitigated by archaeological work conducted by PAL Inc prior to construction. It is our understanding that no additional archaeological work will occur at the Millers River East Site since that existing structure will be removed and the pole "butts" will be left in the ground, and unless there are changes to this scope of work, we have no further concerns with regard to that site.

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

Very truly yours,

Jeffrey Emidy
Acting Executive Director, RIHPHC

Cc: Greg Dubell, PAL Inc.

From: [Milliman, Alison](#)
To: [Alderton, Emily](#)
Subject: FW: [EXTERNAL] : Northern Long Eared Bat Consultation
Date: Thursday, May 6, 2021 11:03:19 AM

From: Brown, Charles (DEM) <charles.brown@dem.ri.gov>
Sent: Monday, January 11, 2021 9:05 AM
To: Milliman, Alison <AMilliman@bscgroup.com>
Subject: RE: [EXTERNAL] : Northern Long Eared Bat Consultation

Hi Alison,
I have reviewed the plans you provided entitled "V148S Line Asset Condition Refurbishment Project Soil Boring Locations". There are no known northern long-eared bat maternity roost trees or hibernacula in or near the proposed project location. If you have any other questions please feel free to contact me.

Charlie Brown
Wildlife Biologist
Rhode Island Division of Fish and Wildlife
(401) 789-0281

From: Milliman, Alison <AMilliman@bscgroup.com>
Sent: Friday, January 8, 2021 5:39 PM
To: Brown, Charles (DEM) <charles.brown@dem.ri.gov>
Subject: RE: [EXTERNAL] : Northern Long Eared Bat Consultation

Hi Charlie,

Thank you for your quick response! The Project is to complete exploratory soil borings along an existing transmission line right-of-way in Lincoln and Cumberland (with portions in the State of MA). We are required to complete the Section 7 consultation due to the use of temporary construction matting in WOTUS (which triggers a Self-Verification Notification to the Army Corps). Please see attached for a USGS locus map of the proposed soil boring locations.

Thank you,

Alison

From: Brown, Charles (DEM) <charles.brown@dem.ri.gov>
Sent: Friday, January 8, 2021 2:45 PM
To: Milliman, Alison <AMilliman@bscgroup.com>
Subject: RE: [EXTERNAL] : Northern Long Eared Bat Consultation

Hi Alison,

For inquiries regarding the Natural Heritage database you should reach out to Paul Jordan, Supervising GIS Specialist at paul.jordan@dem.ri.gov. For any inquiries involving NLEB, he will probably direct you to me. If you can send me a site map of the projects in question and a brief project description I can provide you with assessment of potential proximity to any NLEB locations and that should satisfy your Section 7 requirements. In short, there are no known NLEB maternity roost trees in RI, we do have several known hibernacula.

Charlie Brown

Wildlife Biologist

R.I. Division of Fish and Wildlife

(401) 789-0281

From: Milliman, Alison <AMilliman@bscgroup.com>

Sent: Friday, January 8, 2021 12:31 PM

To: Brown, Charles (DEM) <charles.brown@dem.ri.gov>

Subject: [EXTERNAL] : Northern Long Eared Bat Consultation

Hello Mr. Brown,

In accordance with the Section 7 Process, I am required to enquire about Hibernacula and Maternity Roost Tree Location Information for an upcoming Project in Rhode Island. USFWS requires that applicants who submit an IPaC request information for hibernacula and maternity roost trees kept in state Natural Heritage Inventory databases. Would you please advise if such database exists and how I can access it? The Project activities are proposed in Lincoln and Cumberland, RI.

Thank you,

Alison

Alison Milliman | Sr. Project Manager, Associate

BSC Group [bscgroup.com]

33 Waldo Street | Worcester | MA 01608

direct | (401)742-0487

From: [Portante, Theresa](#)
To: [Milliman, Alison](#)
Subject: FW: [EXTERNAL] : Rare Species Info Request
Date: Tuesday, August 6, 2019 9:52:04 AM
Attachments: [HeritageData_LineV148.zip](#)

From: Jordan, Paul (DEM) [mailto:paul.jordan@dem.ri.gov]
Sent: Friday, March 22, 2019 1:15 PM
To: Portante, Theresa <tportante@bscgroup.com>
Subject: RE: [EXTERNAL] : Rare Species Info Request

File attached

Paul Jordan
Supervising GIS Specialist
Division of Planning & Development
RI Department of Environmental Management
235 Promenade Street
Providence, RI 02908
(401)222-2776 x4315
paul.jordan@dem.ri.gov

From: Portante, Theresa <tportante@bscgroup.com>
Sent: Friday, March 22, 2019 12:48 PM
To: Jordan, Paul (DEM) <paul.jordan@dem.ri.gov>
Subject: [EXTERNAL] : Rare Species Info Request

Hi Paul,

I am working on a Narragansett Electric Company project for structure footer maintenance along the V148 Transmission Line spanning from North Smithfield, Rhode Island to Lincoln, Rhode Island. Based on a review of the Natural Heritage locations, nineteen structures appear to be in rare species habitat.

Please refer the attached shapefiles for the structure and access locations.

We are reaching out to you to determine the species and any other information/ requests that may be needed for working at these sites. We will be filing with Corps for temporary wetland impacts associated with access in wetland areas. We appreciate any assistance you can provide.

Thank you,

Theresa

Theresa Portante | Manager of Ecological Services-WOR, Senior Associate

BSC Group [bscgroup.com]

33 Waldo Street | Worcester | MA 01608

direct | 617-896-4509

cell | 978-376-7070

main | 508-792-4500



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:

May 06, 2021

Consultation code: 05E1NE00-2021-TA-2996

Event Code: 05E1NE00-2021-E-09172

Project Name: V148S Line Asset Condition Refurbishment Project

Subject: Verification letter for the 'V148S Line 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 Emily Alderton:

The U.S. Fish and Wildlife Service (Service) received on May 06, 2021 your effects determination for the 'V148S Line 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.

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

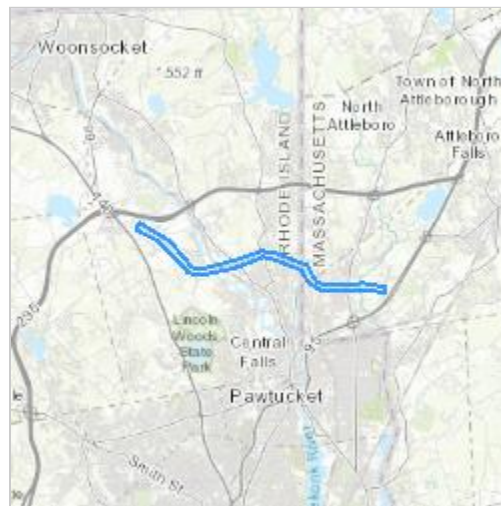
V148S Line Asset Condition Refurbishment Project

2. Description

The following description was provided for the project 'V148S Line Asset Condition Refurbishment Project':

The New England Power Company (NEP) and The Narragansett Electric Power Company (TNEC) are proposing various general maintenance and system improvement activities along the existing V148S Transmission Line right-of-way (ROW) between the Washington #126 Substation in Lincoln, RI, and the Read Street #9 Substation in Attleboro, MA. In total, the V148S line ROW is approximately seven miles in length, and 1.2 square miles in area, and passes through the towns of Lincoln and Cumberland (RI), and North Attleborough and Attleboro (MA). The proposed refurbishment activities include structure replacements, overhead maintenance, shield wire replacement, and grading to provide adequate work space for Project activities for future maintenance, and reestablishing pre-existing access roads where required to safely access the structures. Work is anticipated to begin in the summer of 2022, and continue through the year.

Approximate location of the project can be viewed in Google Maps: <https://www.google.com/maps/@41.9259045,-71.39211496176192,14z>

**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.

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:

0.1

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

0

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

0.1

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



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:

May 06, 2021

Consultation Code: 05E1NE00-2021-SLI-2996

Event Code: 05E1NE00-2021-E-09166

Project Name: V148S Line 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://](http://www.fws.gov/migratorybirds/CurrentBirdIssues/Hazards/towers/comtow.html)

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-2996

Event Code: 05E1NE00-2021-E-09166

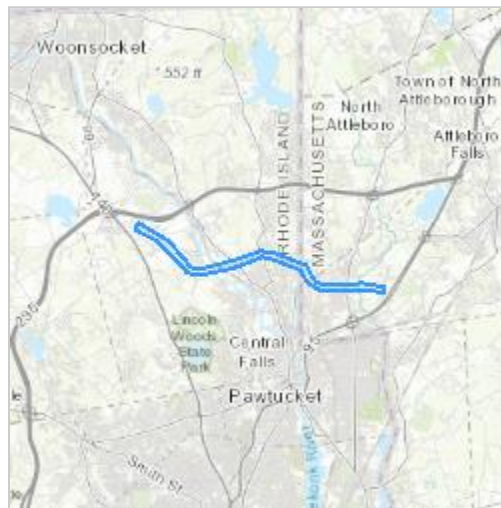
Project Name: V148S Line Asset Condition Refurbishment Project

Project Type: TRANSMISSION LINE

Project Description: The New England Power Company (NEP) and The Narragansett Electric Power Company (TNEC) are proposing various general maintenance and system improvement activities along the existing V148S Transmission Line right-of-way (ROW) between the Washington #126 Substation in Lincoln, RI, and the Read Street #9 Substation in Attleboro, MA. In total, the V148S line ROW is approximately seven miles in length, and 1.2 square miles in area, and passes through the towns of Lincoln and Cumberland (RI), and North Attleborough and Attleboro (MA). The proposed refurbishment activities include structure replacements, overhead maintenance, shield wire replacement, and grading to provide adequate work space for Project activities for future maintenance, and reestablishing pre-existing access roads where required to safely access the structures. Work is anticipated to begin in the summer of 2022, and continue through the year.

Project Location:

Approximate location of the project can be viewed in Google Maps: <https://www.google.com/maps/@41.9259045,-71.39211496176192,14z>



Counties: Massachusetts and Rhode Island

Endangered Species Act Species

There is a total of 1 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 Fisheries¹, 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 <i>Myotis septentrionalis</i> No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/9045	Threatened

Critical habitats

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

Exponent®

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

2014-2018

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

2014-2018

Prepared for:

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

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Acronyms and Abbreviations

μT	Microtesla
AC	Alternating current
ALL	Acute lymphoblastic leukemia
ALS	Amyotrophic lateral sclerosis
ALT	Alanine aminotransferase
AMI	Acute myocardial infarction
AST	Aspartate aminotransferase
CI	Confidence interval
CNS	Central nervous system
DMBA	7,12-dimethylbenz[a]anthracene
DNA	Deoxyribonucleic acid
EHC	Environmental Health Criteria
ELF	Extremely low frequency
EMF	Electric and magnetic fields
EPA	Environmental Protection Agency
G	Gauss
HCN	Health Council of the Netherlands
HLRN	Hemolymphoreticular neoplasia
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
LSPC	Lotus seedpod procyanidins
MDA	Malondialdehyde
mG	Milligauss
mg/L	milligrams per liter
OR	Odds ratio

RR	Relative risk
SCENIHR	Scientific Committee on Emerging and Newly Identified Health Risks
SCHEER	Scientific Committee on Health, Environmental and Emerging Risks
SOD	Superoxide dismutase
TWA	Time weighted average
V/m	Volts per meter
WHO	World Health Organization

Limitations

At the request of the New England Power Company, d/b/a National Grid, 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.

1 Executive Summary

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

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. Section 3 of this report provides information on the nature and sources of ELF EMF, as well as typical exposure levels.

Research on ELF EMF and health began with the goal of finding therapeutic 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 40 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.

Guidance on the possible health risks of all types of exposures comes from health risk assessments or systematic weight-of-evidence evaluations of the cumulative literature on a particular topic conducted by expert panels organized by scientific organizations. Policy makers and the public should look to the conclusions of these reviews, since they are conducted using set 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 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. Section 3 of this report provides a summary of the methods used to conduct a health risk assessment.

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

New human, animal, and in vitro studies published since the 2002 IARC Monograph, 2002 [*sic*] do not change the overall classification of ELF as a possible human carcinogen (WHO, 2007, p. 347).

Acute biological effects [i.e., short-term, transient health effects such as a small shock] have been established for exposure to ELF electric and magnetic fields in the frequency range up to 100 kHz that may have adverse consequences on health. Therefore, exposure limits are needed. International guidelines exist that have addressed this issue. Compliance with these guidelines provides adequate protection. Consistent epidemiological evidence suggests that chronic low-intensity ELF magnetic field exposure is associated with an increased risk of childhood leukaemia [*sic*]. 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).

Exponent's report provides a systematic literature review and a critical evaluation of relevant epidemiologic and *in vivo* studies published from December 2014 through December 2018. 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 “[b]ased on a recent in-depth review of the scientific literature, the WHO concluded that current evidence does not confirm the existence of any health consequences from exposure to low level electromagnetic fields.”¹

¹ <https://www.who.int/peh-emf/about/WhatisEMF/en/index1.html>. Accessed January 19, 2019.

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. 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.

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.

2 Introduction

Questions about electric and magnetic fields (EMF) and health are commonly raised during the permitting of transmission lines. Numerous national and international scientific and health agencies have reviewed the research and evaluated potential health risks of exposure to extremely low frequency (ELF) EMF. The most comprehensive 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, taking into account the strength and quality of the individual research studies they evaluated.

National Grid requested that 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 2015 Rhode Island Transmission Projects.² Exponent's 2015 report systematically evaluated peer-reviewed research and reviews by scientific panels published through November 2014. This current report updates this earlier report with a systematic evaluation of peer-reviewed research and reviews by scientific panels published from December 2014 through December 2018 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 (Figure 1). Both electric fields and magnetic fields are properties of the space near these electrical sources. Forces are experienced by objects capable

² Exponent, Inc. *Current Status of Research on Extremely Low Frequency Electric and Magnetic Fields and Health: Rhode Island Transmission Projects – The Narragansett Electric Company d/b/a/ National Grid.* Prepared for the Rhode Island Energy Facility Siting Board. March 9, 2015.

of interacting with these fields; electric charges are subject to a force in an electric field, and moving charges experience a force in a magnetic field.

- **Electric fields** are the result of voltages applied to electrical conductors and equipment. The electric field is expressed in measurement units of volts per meter (V/m) or kilovolts per meter (kV/m); 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.³ 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.

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

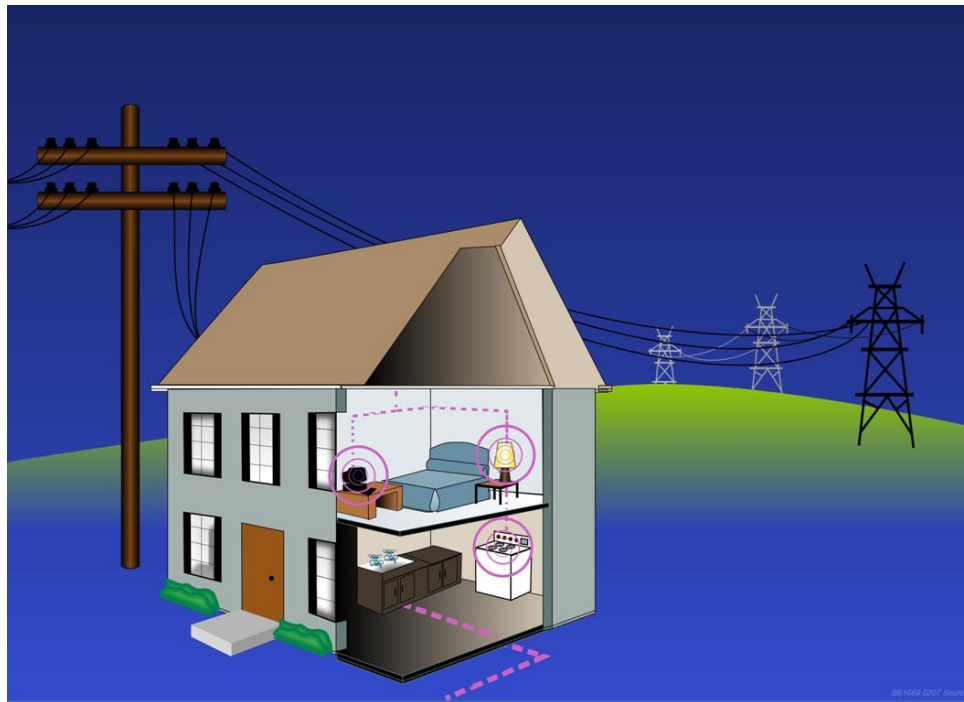


Figure 1. Numerous sources of ELF EMF in our homes (appliances, wiring, currents running on water pipes, and nearby distribution and transmission lines).

Sources and exposure

The intensity of both electric fields and magnetic fields diminishes with increasing distance from the source. Electric 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., transportation systems, 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).

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).⁴
 - In general, personal magnetic-field exposure is greatest at work and during travel (Zaffanella and Kalton, 1998).
- *Residential magnetic-field exposure:*
 - The highest magnetic-field levels are typically found directly next to appliances (Zaffanella, 1993). For example, Gauger (1985) reported the maximum AC magnetic field at 3 centimeters from a sampling of appliances as 3,000 mG (can opener); 2,000 mG (hair dryer); 5 mG (oven); and 0.7 mG (refrigerator).
 - 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

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

three-phase electric power distribution and transmission lines tended to have higher at-home magnetic-field levels (Zaffanella and Kalton, 1998).

- Residential magnetic-field levels are caused by currents from nearby transmission and distribution systems, pipes or other conductive paths, and electrical appliances (Zaffanella, 1993).
- *Workplace magnetic-field exposure*
 - Some occupations (e.g., electric utility workers, sewing machine operators, telecommunication workers) have higher exposures due to work near equipment with high magnetic-field levels (NIEHS, 2002).
- *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, and as discussed in a National Institute of Environmental Health Sciences booklet on EMF (NIEHS, 2002).

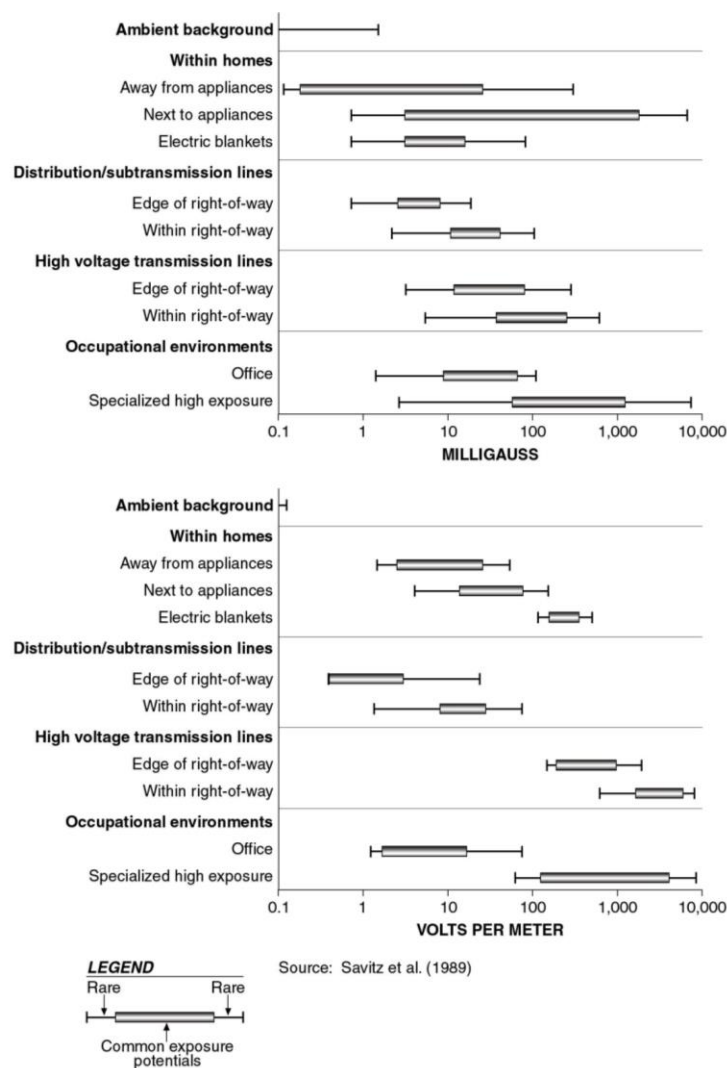


Figure 2. Electric- and magnetic-field strengths in the environment.

Known effects

Similar to virtually any exposure, adverse effects can be expected from exposure to very high levels of ELF EMF. If the current density or electric field induced by an extremely strong magnetic field exceeds a certain threshold, excitation of muscles and nerves is possible (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 are acute and shock-like effects that cause no long-term damage or health consequences. Limits for the general public and workplace have been set to prevent these effects, but 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 8.

3 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 United States Environmental Protection Agency (EPA), which sets guidance for public exposures; the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR); and the United States National Toxicology Program (USEPA, 1993, 1996; WHO, 1994; SCENIHR, 2012; NTP, 2015). Two steps precede a weight-of-evidence evaluation: a systematic review to

identify the relevant literature and an evaluation of each relevant study to determine its strengths and weaknesses.

The following sections discuss important considerations in the evaluation of human health studies of 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. They include the classification of residences based on the relative capacity of nearby power lines to produce magnetic fields (i.e., wire code categories); occupational titles; calculated magnetic-field levels based on job histories (i.e., a job-exposure matrix [JEM]); residential distance from nearby power lines; spot measurements of magnetic-field levels inside or outside residences; 24-hour and 48-hour measurements of magnetic fields in a particular location in a house (e.g., a child's bedroom); calculated magnetic-field levels based on the characteristics of nearby power installations; and personal measurements of magnetic fields for a 24-hour or 48-hour period.

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 as the locations one frequents change and as 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 take into account all magnetic-field sources. ELF EMF can be estimated indirectly by assigning an estimated amount of exposure to an individual based on calculations considering

nearby power installations or a person's job title. For instance, a relative estimate of exposure could be assigned to all machine operators based on historical information on the magnitude of the magnetic field produced by the machine. Indirect measurements are not as accurate as direct measurements because they do not contain information specific to that person or the exposure situation. In the example of machine operators, the indirect measurement may not account for how much time any one individual spends working at that machine or any potential variability in magnetic fields produced by the machines over time. In addition, such occupational measurements do not take into account the worker's residential magnetic-field exposures.

While JEMs are an advancement over earlier methods, they still have some important limitations, as highlighted in a review by Kheifets et al. (2009) summarizing an expert panel's findings.⁵ A person's occupation provides some relative indication of the overall magnitude of their occupational magnetic-field exposure, but it does not take into account the possible variation in exposure due to different job tasks within occupational titles, the frequency and intensity of contact to relevant exposure sources, or variation by calendar time. This was highlighted by a study of 48-hour magnetic-field measurements of 543 workers in Italy in a variety of occupational settings, including: ceramics, mechanical engineering, textiles, graphics, retail, food, wood, and biomedical industries (Gobba et al., 2011). There was significant variation in this study between the measured TWA magnetic-field levels for workers in many of the International Standard Classification of Occupations' job categories, which the authors attributed to variation in industry within these task-defined categories.

Types of health research studies

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

⁵ 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.

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 differences in exposure histories exist. In cohort studies, on the other hand, individuals within a defined cohort of people (e.g., all persons working at a utility company) are classified as exposed or non-exposed and followed over time for the incidence of disease. Researchers then compare disease incidence in the exposed and non-exposed groups.

Experimental studies are designed to test specific hypotheses under controlled conditions and are vital to assessing cause-and-effect relationships. An example of a human experimental study relevant to this area of research would be studies that measure the impact of magnetic-field exposure on acute biological responses in humans, such as hormone levels. These studies are conducted in laboratories under controlled conditions. *In vivo* 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 as they relate to the same exposure in intact 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.

Both of these approaches—epidemiologic and experimental laboratory studies—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 field sources, or individual behaviors 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 tissues and cells are generally considered supplementary.

Estimating risk

Epidemiologists measure the statistical association between exposures and disease in order to estimate risk. This brief summary 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 (Reis et al., 2007). RRs are calculated to evaluate whether a particular exposure or inherent quality (e.g., EMF, diet, genetics, race) is associated with a disease outcome. This is calculated by looking at the absolute risk in one group relative to a comparison group. For example, white children 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 were 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 (Linnet, 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 Surgeon General of the United States 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

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.

Source: Department of Health and Human Services, 2004

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.

4 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 used standard scientific procedures, as outlined in its Preamble and described above in Section 3, to conduct the review. The Task Group responsible for the report's overall conclusions consisted of 21 scientists from around the world with expertise in a wide range of scientific disciplines. They relied on the conclusions of previous weight-of-evidence reviews,⁶ 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

⁶ 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.

confidence. *Limited evidence of carcinogenicity* describes a body of epidemiologic research where the findings are inconsistent or there are outstanding questions about study design or other methodological issues that preclude making a conclusion. *Inadequate evidence of carcinogenicity* describes a body of epidemiologic research where it is unclear whether the data is supportive or unsupportive of causation because there is a lack of data or there are major quantitative or qualitative issues. A similar classification system is used for evaluating *in vivo* studies and mechanistic data for carcinogenicity.

Summary categories are assigned by considering the conclusions of each body of evidence (epidemiologic, *in vivo*, and *in vitro*) together. 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.

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* (49 percent).⁷ 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

⁷ <https://monographs.iarc.fr/agents-classified-by-the-iarc/>. Accessed January 19, 2019.

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 (p. 347).

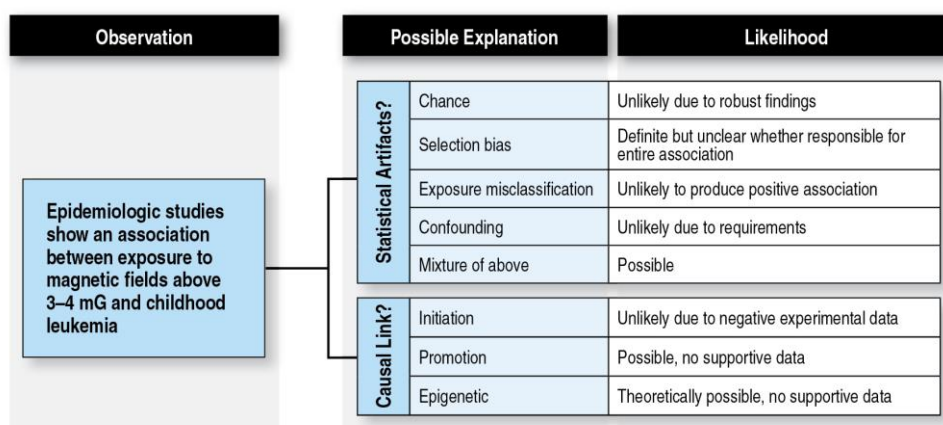
Acute biological effects [i.e., short-term, transient health effects such as a small shock] have been established for exposure to ELF electric and magnetic fields in the frequency range up to 100 kHz that may have adverse consequences on health. Therefore, exposure limits are needed. International guidelines 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 [*sic*]. However, the evidence for a causal relationship is limited, therefore exposure limits based upon epidemiological evidence are not recommended, but some precautionary measures are warranted (p. 355, WHO, 2007).

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

Childhood cancers. The WHO report paid particular attention to childhood leukemia because the most consistent epidemiologic association in the area of ELF EMF and health research has been reported between this disease and TWA exposure to high magnetic-field levels. Two pooled analyses reported an association between childhood leukemia and TWA magnetic-field exposure >3 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.

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



Source: Adapted from Schüz and Ahlbom (2008)

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

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

Breast cancer. The WHO concluded that the more recent studies they reviewed on breast cancer and ELF EMF exposure were higher in quality compared with earlier studies, and for that reason, they provide strong support to previous consensus statements that magnetic-field exposure does not influence the risk of breast cancer. In summary, the WHO stated “[w]ith these [more recent] studies, the evidence for an association between ELF magnetic-field exposure and the risk of female breast cancer is weakened considerably and does not support an association of this kind”

(WHO, 2007, p. 9). The WHO recommended no further research with respect to breast cancer and magnetic-field exposure.

Adult leukemia and brain cancer. The WHO concluded, “In the case of adult brain cancer and leukaemia [*sic*], 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 [*sic*]. The evidence that ELF field exposure can enhance tumour [*sic*] 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.

5 Current Scientific Consensus

The following sections identify and describe epidemiologic and *in vivo* studies related to ELF EMF and health published between December 2014 and December 2018. 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 4. A previous Exponent report summarized the literature through November 2014⁸ 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 15 million up-to-date citations from MEDLINE and other life science journals for biomedical articles (<http://www.pubmed.gov>). A well-defined search strategy was used to identify English language literature indexed between December 2014 and December 2018.⁹ All fields (e.g., title, abstract, keywords) were searched with various search strings that referenced the exposure and disease of interest.¹⁰ A researcher with experience in this area reviewed the titles and abstracts of these publications for inclusion in this evaluation. The following specific inclusion criteria were applied:

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

⁸ Exponent, Inc. *Current Status of Research on Extremely Low Frequency Electric and Magnetic Fields and Health: Rhode Island Transmission Projects – The Narragansett Electric Company d/b/a/ National Grid*. Prepared for the Rhode Island Energy Facility Siting Board. March 9, 2015.

⁹ Since there is sometimes a delay between the publication date of a study and the date it is indexed in PubMed, it is possible that some studies not yet indexed, but published prior to December 2018, are not included in this update.

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

2. **Exposure.** The study must have evaluated 50/60-Hz AC ELF EMF.
3. **Exposure assessment methods.** Included studies evaluate exposure beyond self-report of an activity or occupation. Included studies estimated exposure through various methods including calculated EMF levels using distance from power lines; measured TWA exposure; and average exposure estimated from JEMs.
4. **Study design.** Study design includes 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 4) with regard to mechanistic data from *in vitro* studies since this field of study is less informative to the risk assessment process (IARC, 2002).
5. **Peer-review.** The study must have been peer-reviewed and published. Therefore, no conference proceedings, abstracts, or on-line material were included.

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 3 through 9 list the relevant studies that were published from December 2014 through December 2018 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. (2010) 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, three large case-control studies from France (Sermage-Faure et al., 2013), Denmark (Pedersen et al., 2014a), and the United Kingdom (Bunch et al., 2014) 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).

All three 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., 2014a, p. N81).

Recent studies (December 2014 through December 2018)

Several recent studies analyzed the same populations used in two of the three case-control studies summarized above (Bunch et al., 2014; Pedersen et al., 2014a).

The authors of the previous Danish study (Pedersen et al., 2014a) also evaluated whether consideration of other potential risk factors for childhood leukemia may influence the results in relation to distance to power lines (Pedersen et al., 2014b). Adjustments for socioeconomic status, mother’s age, birth order, domestic radon exposure, or traffic-related air pollution were reported not to affect associations relating to power lines. The authors reported a statistical interaction between distance to power lines and radon exposure; however, they attributed these findings to chance, as these results were based on a small number of cases. Pedersen et al. (2015) reported the results of another case-control study using a study population that mostly overlapped with the previous two papers (Pedersen et al., 2014a, 2014b). Pedersen et al. (2015) included all children in Denmark diagnosed before 15 years of age with a first primary leukemia (n=1,536), central nervous system (CNS) tumor (n=1,324), or malignant lymphoma (n=417) between 1968 and 2003. Cases were identified from the Danish Cancer Registry. Two to five controls (n=9,129) for each case were selected randomly from the Danish childhood population and were matched to cases based on their sex and year of birth. For all study subjects, average magnetic-field exposure levels were calculated from overhead 50- to 400- kilovolt (kV) power lines based on their residential addresses from 9 months before birth until the diagnosis. The authors reported no statistically significant associations between all cancers combined and the three types of cancers separately and estimated exposures ≥ 0.4 microtesla (μT) (4 mG) compared to <0.1 μT (1 mG). The large number of cases and controls in the study, the inclusion of

residential history and exposure assessment throughout the children's entire lifetime, control for some potential confounders (including radon exposure, traffic-related air pollution, and socioeconomic status) and the reliance on reliable population-based cancer and population registries in Denmark are among the strengths of the study. Reliance on calculated magnetic-field levels for exposure assessment and lack of details on the accuracy of the input data to these calculations, including historical line loading and distance to residence, and the small number of cases in the highest exposure categories despite that large study size, are among the limitations of the paper.

In a separate analysis of the previous study population in the United Kingdom (Bunch et al., 2014), the investigators also examined the distance of high-voltage underground cables (mostly AC 275 kV and 400 kV) to case and control residences (Bunch et al., 2015). Over 52,000 cases of childhood cancer occurring between 1962 and 2008 in England and Wales, along with their matched controls, were included in these analyses. The authors reported no statistically significant associations or exposure-response trends between childhood leukemia and distance to power lines or calculated magnetic-field levels from the underground cables. The authors concluded that their results further detract from the hypothesis that exposure to magnetic fields explains the associations observed in earlier studies.

Based on additional analyses of the data, Bunch et al. (2016) reported that the association with distance to power lines observed in earlier years, which was more pronounced among older children (10 to 14 years of age), and for myeloid leukemia, were linked to calendar year of birth or year of cancer diagnosis, rather than the age of the power lines. The authors noted this finding implies that whatever factor or factors might have resulted in the apparent risk increase in the earlier years of the study are less likely to be linked to the newly built or existing power lines and more likely to be related to a yet to be identified characteristic of the population (or chance variation) in those years. Analyses by regions of the country did not suggest any clear pattern. The authors concluded that their findings, overall, do not provide support for the etiologic role of magnetic fields in the reported associations. Furthermore, Swanson and Bunch (2018) reanalyzed the data in Bunch et al. (2014) by using finer distance categories with cut-points at every 50-meter distance from the power lines in various periods from 1962 to 2008. The authors reported that no overall associations between distance categories and childhood leukemia were

observed for the period including 1980 and later, and that associations for periods prior to 1980 showed no monotonic or consistent pattern with distance. Thus, Swanson and Bunch concluded that their finding “weakens the evidence that any elevated risks are related to magnetic fields” (Swanson and Bunch, 2018, p. N30).

Crespi et al. (2016) reported the results of a large, record-based, case-control study of childhood leukemia ($n=5,788$) and CNS tumors ($n= 3,308$) diagnosed between 1986 and 2008 and residential proximity to high-voltage overhead power lines (60 kV to 500 kV) in California. Cases were identified from the California Cancer Registry. Controls were selected from the California Birth Registry and matched to cases based on their age and sex; birth records were also obtained for cases. For all subjects, distance of the address at birth to the nearest power line was estimated using geographic information systems, aerial imaging from Google Earth, and site visits for a subset of subjects. Additional details on methods are presented in Kheifets et al. (2015). Crespi et al. (2016) reported no consistent overall associations between risk of leukemia or CNS tumor and residential distance to power lines with voltage of ≥ 200 kV. A statistically non-significant increase was reported for childhood leukemia among subjects with addresses closer than 50 meters to power lines at ≥ 200 kV. Analyses that also included lower voltage lines revealed no associations with either leukemia or CNS tumors.

Kheifets et al. (2017a) and Amoon et al. (2018a) conducted additional analyses using the same California study population as Crespi et al. (2016). Kheifets et al. (2017a) reported on childhood leukemia and calculated magnetic fields from California power lines. The authors calculated magnetic-field levels at birth address using geographic information systems, aerial imagery, historical information on load and phasing, and site visits; additional details on the magnetic-field calculations are presented in a separate publication (Vergara et al., 2015). In the main analyses by Kheifets et al. (2017a), which included all cases of leukemia and primary controls with geocode accuracy, the authors used unconditional logistic regression models that controlled for age, sex, race/ethnicity, and socioeconomic status. Overall, the authors reported no consistent pattern of association; they reported a slight, statistically non-significant, negative association in the intermediate exposure categories (1 to 2 mG and 2 to 4 mG) compared to the lowest exposure category (<1 mG), and a small, statistically non-significant, positive association in the highest exposure category (≥ 4 mG) (OR 1.5, 95% CI 0.7-3.2). The authors reported

similar results in subgroup and sensitivity analyses and commented that all estimates had wide CIs. The authors concluded that their study “does not in itself provide clear evidence for risk associated with greater exposure to magnetic fields from power lines, but could be viewed as consistent with previous findings of increased risk” (Kheifets et al., 2017a, p. 1117). Thomas (2018) commented that while the Kheifets et al. (2017a) study had low potential for selection bias due to its record-based methods, the study may be subject to exposure misclassification resulting in bias towards the null because the exposure assessment considered residential proximity only to high-voltage power lines and other sources, including distribution lines, were ignored.

Amoon et al. (2018a) assessed the potential impact of residential mobility of the study subjects (i.e., moving residences between birth and diagnosis) on the associations reported in Crespi et al. (2016). The authors reported that while children that moved tended to be older, lived in housing other than a single-family home, had younger mothers and fewer siblings, and were of lower socioeconomic status, changing residences was not associated with either calculated fields or proximity to ≥ 200 -kV power lines. Thus, the authors concluded that “[m]obility appears to be an unlikely explanation for the associations observed between power lines [*sic*] exposure and childhood leukemia” in the California study (Amoon et al., 2018a, p. 459).

Epidemiologists from Italy published two papers that describe the methods (Magnani et al., 2014) and results (Salvan et al., 2015) of a case-control study of childhood leukemia and residential exposure to 50-Hz magnetic fields. The study included a total of 412 leukemia cases less than 10 years of age diagnosed between 1998 and 2001 and 587 controls matched to cases based on sex, date of birth, and geographic location. The authors assessed exposure to residential ELF magnetic fields by extended measurements (24 to 48 hours) in the children’s bedroom. The authors used conditional logistic regression to calculate RR and adjust for potentially confounding variables. In their analyses, the researchers evaluated various exposure metrics (e.g., measures of central tendency or peak-exposure measures; continuous or categorical exposures based on measurements during nighttime, weekend, or entire measurement periods). The authors also assessed the potential role of residential mobility of the subjects in the observed associations. None of the analyses reported consistent exposure-response patterns. The main limitations of the study include the potential for differential participation of controls and cases

and differences in participation rates of the study subjects based on their socioeconomic status, which in combination may result in a reference group that is not fully representative of the underlying population at risk. In turn, this may bias the calculated effect estimates. The low prevalence of subjects with higher estimated average exposures (particularly exposure >3 mG) results in a limitation of the statistical power of the study.

Amoon et al. (2018b) conducted a meta-analysis of epidemiologic studies of residential distance to power lines and childhood leukemia. The authors pooled the data from 11 studies with record-based assessments of residential distance from high-voltage power lines from 10 countries (Australia, Brazil, Denmark, France, Italy, Norway, Sweden, Switzerland, the United Kingdom, and the United States); this included the previously mentioned studies by Pedersen et al. (2014a), Sermage-Faure et al. (2013), Bunch et al. (2014), and Crespi et al. (2016). In total, 29,049 cases and 68,231 controls were included in the analyses. The authors reported no association when proximity to transmission lines with any voltage was investigated; the adjusted OR for residential distance <50 meters, as compared to distances ≥ 300 meters, was 1.01 [95% CI, 0.85-1.21]. For power lines with voltages of ≥ 200 kV, the adjusted OR (1.13) for distances <50 meters also was not statistically significant (95% CI, 0.92-1.93). The reported associations were slightly stronger for leukemia case diagnoses before 5 years of age and in study periods prior to 1980. Adjustment for various potential confounders (e.g., socioeconomic status, dwelling type, residential mobility) had little effect on the estimated the associations.

Kheifets et al. (2017b) conducted a comparative analysis of epidemiologic studies of childhood leukemia that investigated the association between childhood leukemia and ionizing radiation (i.e., radon or gamma radiation) or non-ionizing radiation (i.e., ELF EMF), or both, in an attempt to evaluate to what extent bias, confounding, and other methodological issues might be responsible for the reported associations. The authors reported that while they found some indication of bias, they found little evidence that confounding has a substantial influence on results.

A small cross-sectional study of 22 cases of childhood ALL and 100 controls from Iran reported a statistically significant association with “prenatal and postnatal childhood exposure to high voltage power lines” (Tabrizi and Bigdoli, 2015, p. 2347). The study, however, would carry very

little weight, if any, in an overall evaluation, because of its cross-sectional study design, very small sample size, and a complete lack of information on exposure assessment in the study. Tabrizi and Hossein (2015) published an apparent duplication of the study with near identical results and limitations. A letter to the editor that highlighted major flaws in the study pointed out the apparent duplication and suggested retraction of the second publication (Dechent and Driessen, 2016).

A Greek case-control study examined the association between parental occupational exposures and childhood acute leukemia at a major pediatric hospital in Athens (Kyriakopoulou et al., 2018). The study included 108 cases of ALL or acute myeloid leukemia under the age of 15, and 108 controls matched on age, gender, and ethnicity. The parents' job titles held during four different exposure periods (1 year before conception, during pregnancy, during breastfeeding, and from birth until diagnosis) were evaluated for exposure (exposed versus unexposed) to four agents (high contact level, chemicals, electromagnetic fields, and ionizing radiation) based on the authors' review of literature and their professional judgment. A total of six cases (5.6%) and six controls (5.6%) were categorized as exposed to electromagnetic¹¹ fields. No statistically significant associations were observed between electromagnetic-field exposure and childhood acute leukemia for any of the four periods of exposure. No associations were observed between childhood acute leukemia and the remaining exposure categories; however, the authors did observe that high birth weight and family history of cancer were associated with the development of leukemia.

Chinese researchers have published several meta-analyses in recent years. Su et al. (2016) conducted a meta-analysis of 11 case-control studies and 1 cohort study that investigated the association between parental exposure to ELF magnetic fields and risk of childhood leukemia in the offspring. Overall, neither maternal nor paternal occupational ELF magnetic-field exposure was associated with childhood leukemia risk.

The authors noted, however, that they observed an association when they combined small and low-quality studies, but not when they combined larger and high-quality studies. This indicates

that sampling and other biases may contribute to the reported associations in small, low-quality studies.

Zhang et al. (2016) combined epidemiologic studies of all types of cancer in their meta-analyses, including studies of adult and childhood cancers. Since various adult and childhood cancers have very different etiologies and biological mechanisms, it is scientifically not defensible to expect that any specific exposure will have an identical effect on the risk of all types of cancers, which renders the study's main results mostly meaningless, or difficult to interpret at best.

Assessment of residential exposure to EMF among children also continues to be of interest. While not linked to any specific health outcomes, EMF exposure assessment studies of children were recently reported from Australia, Italy, Spain, and Switzerland (Karipidis, 2015; Struchen et al., 2016; Liorni et al., 2016; Gallastegi et al., 2016). Magne et al. (2017) conducted a national survey of ELF magnetic-field exposure in France, including a representative sample of close to 1,000 children 0 to 14 years of age. The study was purely an exposure assessment study and the authors did not investigate any health outcome in relation to magnetic-field exposure. The authors conducted 24-hour measurements of ELF magnetic-field exposure for the included children and reported that 3.1% of the study participants had a 24-hour average exposure $>0.4 \mu\text{T}$ (4 mG). Only 0.8% of the children, however, had 24-hour average exposure $>0.4 \mu\text{T}$ (>4 mG) when exposure from alarm clocks was excluded. The authors also reported that none of the children with 24-hour average exposure $>0.4 \mu\text{T}$ (>4 mG) lived within 125 meters of a 225-kV transmission line or within 200 meters of a 400-kV transmission line.

Assessment

In summary, while most of the recently published large and methodologically advanced studies showed no statistically significant associations between estimates of exposures from power lines (e.g., Bunch et al., 2014, Pedersen et al., 2014a, 2014b, Pedersen et al., 2015; Crespi et al., 2016; Kheifets et al., 2017a), and the most recent pooled analyses indicated weaker and statistically non-significant associations (Amoon et al., 2018b), the association between childhood leukemia and magnetic fields observed in some earlier studies remains unexplained. Thus, the results of

¹¹ In this context, electromagnetic is used to refer to ELF magnetic fields.

recent studies do not change the classification of the epidemiologic data as limited. This is the assessment of the most recent weight-of-evidence review released in 2015 by SCENIHR,¹² which concluded that the epidemiologic studies on childhood leukemia and EMF exposure continued to “prevent a causal interpretation” (SCENIHR, 2015). A similar conclusion was reached in a recent assessment conducted by a research consortium funded by the European Union, which concluded that recent research results have not provided new evidence that would change the overall conclusion reached by IARC in 2002, and the current evidence is consistent with the *possibly carcinogenic* classification (Schüz et al., 2016).

Table 2. Relevant studies of childhood leukemia

Author	Year	Study Title
Amoon et al.	2018a	Residential mobility and childhood leukemia.
Amoon et al.	2018b	Proximity to overhead power lines and childhood leukaemia: an international pooled analysis.
Bunch et al.	2015	Magnetic fields and childhood cancer: an epidemiological investigation of the effects of high-voltage underground cables.
Bunch et al.	2016	Epidemiological study of power lines and childhood cancer in the UK: further analyses.
Chang et al.	2014	Validity of geographically modeled environmental exposure estimates.
Crespi et al.	2016	Childhood leukaemia and distance from power lines in California: a population-based case-control study.
Dechent and Driessen	2016	Re: Role of Electromagnetic Field Exposure in Childhood Acute Lymphoblastic Leukemia and No Impact of Urinary Alpha- Amylase - a Case Control Study in Tehran, Iran.
Gallastegi et al.	2016	Characterisation of exposure to non-ionising electromagnetic fields in the Spanish INMA birth cohort: study protocol.
Karipidis et al.	2015	Survey of residential power-frequency magnetic fields in Melbourne, Australia.
Kheifets et al.	2015	Epidemiologic study of residential proximity to transmission lines and childhood cancer in California: description of design, epidemiologic methods and study population.
Kheifets et al.	2017a	Residential magnetic fields exposure and childhood leukemia: a population-based case-control study in California.
Kheifets et al.	2017b	Comparative analyses of studies of childhood leukemia and magnetic fields, radon and gamma radiation.
Kyriakopoulou et al.	2018	Parental occupational exposures and risk of childhood acute leukemia.

¹² On July 8, 2015, SCENIHR was renamed the Scientific Committee on Health, Environment, and Emerging Risks (SCHEER). Since any publications by this body referenced in this report were published before the name was changed, all citations to their publications note SCENIHR rather than SCHEER.

Author	Year	Study Title
Liorni et al.	2016	Children's personal exposure measurements to extremely low frequency magnetic fields in Italy.
Magnani et al.	2014	SETIL: Italian multicentric epidemiological case-control study on risk factors for childhood leukaemia, non hodgkin lymphoma and neuroblastoma: study population and prevalence of risk factors in Italy.
Magne et al.	2017	Exposure of children to extremely low frequency magnetic fields in France: Results of the EXPERS study.
Pedersen et al.	2014b	Distance to high-voltage power lines and risk of childhood leukemia – an analysis of confounding by and interaction with other potential risk factors.
Pedersen et al.	2015	Residential exposure to extremely low-frequency magnetic fields and risk of childhood leukemia, CNS tumour and lymphoma in Denmark.
Salvan et al.	2015	Childhood leukemia and 50 Hz magnetic fields: findings from the Italian SETIL case-control study.
Schüz et al.	2016	Extremely low-frequency magnetic fields and risk of childhood leukemia: A risk assessment by the ARIMMORA consortium.
Struchen et al.	2016	Analysis of personal and bedroom exposure to ELF-MFs in children in Italy and Switzerland.
Su et al.	2016	Associations of parental occupational exposure to extremely low-frequency magnetic fields with childhood leukemia risk.
Swanson and Bunch	2018	Reanalysis of risks of childhood leukaemia with distance from overhead power lines in the UK.
Tabrizi and Bidgoli	2015	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.
Tabrizi and Hosseini	2015	Role of Electromagnetic Field Exposure in Childhood Acute Lymphoblastic Leukemia and No Impact of Urinary Alpha- Amylase--a Case Control Study in Tehran, Iran.
Vergara et al.	2015	Case-control study of occupational exposure to electric shocks and magnetic fields and mortality from amyotrophic lateral sclerosis in the US, 1991-1999.
Zhang et al.	2016	Meta-analysis of extremely low frequency electromagnetic fields and cancer risk: a pooled analysis of epidemiologic studies.
Comment on Kheifets et al. (2017a)		
Thomas	2018	Re: Kheifets et al. (2017): Residential magnetic fields exposure and childhood leukemia: a population-based case-control study in California.

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 [*sic*], 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 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.

In addition, the childhood leukemia study by Bunch et al. (2014), described above, also included cases of brain cancer (n=11,968) and other solid tumors (n=21,985) among children in the United Kingdom between 1962 and 2008. No association was reported by the authors between brain cancer or other cancers and distance to transmission lines.

Recent studies (December 2014 through December 2018)

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., 2015; Bunch et al., 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. In Bunch et al. (2015), the authors reported a statistical association for childhood brain cancer and an intermediate category of distance (20 to 49.9 meters), but noted that “such an elevation does not

form part of a coherent pattern with other studies” and thus they were “therefore inclined to regard this as a chance result” (Bunch et al., 2015, p. 695). The authors observed no statistically significant trend with distance. Follow-up analyses of the same population that investigated the occurrence of cancer separately among younger and older children (Bunch et al., 2016) identified no “persuasive or consistent pattern” for brain tumors. The epidemiologic studies of childhood cancer conducted in Denmark and California also included cases of CNS tumors (Pedersen et al., 2015; Crespi et al., 2016). Pedersen et al. (2015) reported a non-statistically significant association between CNS tumors and exposure, regardless of the period investigated. Crespi et al. (2016) reported no evidence of increased risk for CNS cancers (all types).

An Italian case-control study examined the risk of neuroblastoma among children 0 to 10 years of age in relation to maternal characteristics and perinatal exposures (Parodi et al., 2014). A total of 207 cases diagnosed between 1998 and 2001 and 1,475 controls were included in the study. Exposure to ELF magnetic fields was based on 48-hour measurements in the children’s beds. The authors reported no associations either with measures of central tendency (arithmetic and geometric means) or with peak exposure measures (90th and 95th percentiles) of ELF magnetic fields. The authors did report statistically significant associations, however, with maternal exposure to hair dye and solvents.

Su et al. (2018) conducted a meta-analysis of epidemiologic studies that investigated the association between parental occupational exposure to ELF magnetic fields and childhood CNS tumors. The authors included a total of 22 case-control and cohort studies published as of December 2017 in their analysis. For CNS tumors, they reported no statistically significant associations for paternal exposure to ELF magnetic fields, but reported a weak statistically significant association (OR = 1.16, 95% CI 1.06, 1.26) for maternal exposure based on a subset of eight studies. The authors reported no association for neuroblastoma with either maternal or paternal exposure to ELF magnetic fields. Study quality, as assessed by the authors, had inconsistent effects on the associations reported for maternal and paternal exposure. The authors noted that, when based on higher quality studies, observed associations were stronger for maternal exposure but weaker for paternal exposure. It is noteworthy that associations were statistically significant only when studies using non-quantitative exposure methods (i.e., relying on job titles only) were pooled, but no associations were reported based on studies with a

quantitative exposure assessment. The authors also reported evidence for publication bias. While most of the included studies investigated cancer among children, some of the studies also included persons with tumors diagnosed up to 30 years of age, which is an additional limitation of the analysis.

Assessment

Overall, the weight-of-evidence does not support an association between magnetic-field exposures and the development of childhood brain cancer. The results of recent studies do not alter the classification of the epidemiologic data in this field as inadequate, 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 [*sic*]” (SCENIHR, 2015, p. 158).

Table 3. Relevant studies of childhood brain cancer

Authors	Year	Study
Bunch et al.	2015	Magnetic fields and childhood cancer: an epidemiological investigation of the effects of high-voltage underground cables.
Bunch et al.	2016	Epidemiological study of power lines and childhood cancer in the UK: further analyses.
Crespi et al.	2016	Childhood leukaemia and distance from power lines in California: a population-based case-control study.
Parodi et al.	2014	Risk of neuroblastoma, maternal characteristics and perinatal exposures: the SETIL study.
Pedersen et al.	2015	Residential exposure to extremely low-frequency magnetic fields and risk of childhood leukaemia, CNS tumour and lymphoma in Denmark.
Su et al.	2018	Association between parental occupational exposure to extremely low frequency magnetic fields and childhood nervous system tumors risk: A 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)

Recent studies (December 2014 through December 2018)

Grundy et al. (2016) conducted a population-based case-control study of male breast cancer and occupational exposure to magnetic fields. The authors identified cases (n=115) from eight Canadian provinces through the provincial cancer registries between 1994 and 1998, and selected controls (n=570), matched on age and sex, from provincial health insurance plans or using random-digit dialing. The authors obtained information on demographic characteristics and occupational history through self-administered questionnaires. An expert review assessed occupational exposure to magnetic fields. Each occupation was assigned an average exposure value; these values were then grouped into three categories ($<0.3 \mu\text{T}$ [$<3 \text{ mG}$], 0.3 to <0.6 [3 to $<6 \text{ mG}$], and $\geq 0.6 \mu\text{T}$ [$\geq 6 \text{ mG}$]) using cut-points based on the distribution of residential exposures reported in a previous study (Green et al., 1999). The authors reported statistically non-significant risk increases with the highest average exposure $\geq 0.6 \mu\text{T}$ ($\geq 6 \text{ mG}$) compared to

exposure $<0.3 \mu\text{T}$ ($<3 \text{ mG}$), and with having an exposed job ($\geq 0.3 \mu\text{T}$ [$\geq 3 \text{ mG}$]) for at least 30 years compared to never having an exposed job. The authors noted that the remaining results were “inconsistent” and thus the study provides “limited support” for the hypothesis that magnetic-field exposure increases the risk of breast cancer in men (Grundy et al., 2016, p. 586). Selection of a subset of the controls using random-digit dialing, and reliance on self-reported information for exposure assessment represent a limitation of the study.

As summarized in the section on childhood leukemia, Zhang et al. (2016) combined epidemiologic studies of all types of cancer in their meta-analysis, including studies of adult and childhood cancers. This renders their main conclusions mostly meaningless, or difficult to interpret at best. Based on a sub-analysis that included 23 epidemiologic studies, the authors reported no statistically significant associations for breast cancer.

Assessment

The conclusion that there is no association between ELF EMF and breast cancer, as also expressed by the WHO, continues to be valid. The most recent case-control study, which reported no statistically significant associations with male breast cancer, adds to the growing body of null evidence for a role for magnetic-field exposure in breast cancer development in either residential or occupational settings. The recent review by SCENIHR (2015) concluded that overall studies on “adult cancers show no consistent associations” (p. 158).

Table 4. Relevant studies of breast cancer

Authors	Year	Study
Grundy et al.	2016	Occupational exposure to magnetic fields and breast cancer among Canadian men.
Zhang et al.	2016	Meta-analysis of extremely low frequency electromagnetic fields and cancer risk: a pooled analysis of epidemiologic studies.

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 have been 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.

Recent studies (December 2014 through December 2018)

Carlberg et al. (2017, 2018) published the results of two case-control epidemiologic studies of occupational exposure to ELF EMF and brain cancer. Both studies relied on data from previously published case-control studies in Sweden (Hardell et al., 2006, 2013; Carlberg et al., 2013, 2015). Carlberg et al. (2017) included 1,346 living glioma cases diagnosed between the periods of 1997 to 2003 and 2007 to 2009 and 3,485 controls, ascertained from the Swedish Population Registry, who were matched to cases on sex and 5-year age group. Occupational exposure to ELF EMF was assessed from self-reported questionnaires on lifetime occupational history and a previously developed JEM (Turner et al., 2014). Overall, the authors observed no association with cumulative exposure to ELF EMF. Statistically significant associations were reported for grade IV astrocytoma and cumulative and average exposure when restricted to exposure experienced during the more recent exposure periods (1 to 14 years prior to diagnosis). The authors reported no association, however, with more distant exposure periods (15 to 20+ years) and observed no associations for other tumor grades. The authors hypothesized that the observed association for grade IV astrocytoma in the recent exposure periods is the result of a potential effect on cancer promotion. Because deceased subjects were excluded from the

analyses, and the reported association was limited to tumors of the highest grade (with the highest mortality rate), there is a high likelihood that the reported pattern of results arose due to differential exclusion of rapidly fatal cases among patients with the highest-grade tumors.

Carlberg et al. (2018) included 1,592 meningioma cases and 3,485 controls. The investigators used a similar approach and methods as in the previous study (Carlberg et al., 2017). The authors reported no trend or association between meningioma development and any of the investigated metrics of occupational exposure to ELF EMF (i.e., average occupational exposure, highest exposed job, or cumulative exposure) regardless of the time windows investigated (i.e., exposure during 1 to 14 years prior to diagnosis, or exposure more than 15 years prior to diagnosis).

Turner et al. (2017) investigated the potential interaction between occupational exposure to ELF magnetic fields; various chemicals, including cadmium, chromium, iron, and nickel; solvents, benzo(a)pyrene, polycyclic aromatic hydrocarbons; and environmental tobacco smoke, on brain cancer development within the INTEROCC case-control study. The current study presented additional analyses to an earlier study that examined ELF magnetic fields and brain cancer (Turner et al., 2014), and included 1,939 glioma and 1,822 meningioma cases, along with 5,404 controls matched on sex and age. Occupational exposure to both ELF magnetic fields and the chemicals of interest were assessed using JEMs. While some of the sub-analyses in the earlier study (Turner et al., 2014) reported both positive and negative associations for brain cancer development, overall there was no association with lifetime cumulative or average exposure for either main type of brain cancer. In the Turner et al. (2017) follow-up analysis, the authors reported that there was “no clear evidence” for an interaction between occupational exposure to ELF magnetic fields and occupational exposure to any of the included chemicals for either glioma or meningioma (p. 802).

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 5. Relevant studies of adult brain cancer

Authors	Year	Study
Carlberg et al.	2017	Case-control study on occupational exposure to extremely low-frequency electromagnetic fields and glioma risk.
Carlberg et al.	2018	Case-control study on occupational exposure to extremely low-frequency electromagnetic fields and the association with meningioma.
Turner et al.	2017	Occupational exposure to extremely low frequency magnetic fields and brain tumor risks in the INTEROCC study.

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 the previous Exponent report did not change the WHO conclusion.

Recent studies (December 2014 through December 2018)

Talibov et al. (2015) conducted a study of acute myeloid leukemia and occupational exposure to ELF magnetic fields and electric shocks within the Nordic Occupational Cancer study population. The case-control study included 5,409 cases diagnosed between 1961 and 2005 in Finland, Iceland, Norway, and Sweden, and 27,045 controls matched on age, sex, and country. Lifetime occupational exposure to ELF magnetic fields and shocks were assessed with JEMs based on jobs reported on the censuses. Potential confounding variables, including work-related exposure to benzene and ionizing radiation, were adjusted for in the analyses. The authors

reported no associations between leukemia and exposure to ELF magnetic fields or electric shocks among either men or women, and the authors concluded that “the evidence base linking ELF-MF [magnetic fields] with AML [acute myeloid leukemia] risk remains weak” (Talibov et al., 2015, p. 1084).

Huss et al. (2018a) conducted a census-based retrospective cohort study examining exposure to ELF magnetic fields and death from several types of hematopoietic malignancies within the Swiss National Cohort. The authors included a total of 3.1 million economically active individuals between 30 and 65 years of age (for men) or 62 years of age (for women) who participated in the 1990 or 2000 census, or both, in Switzerland. Mortality from different malignant neoplasms of the lymphoid and hematopoietic tissue (i.e., various types of acute and chronic leukemias and lymphomas) was evaluated from 1990 to 2008. The authors included death due to lung cancer in the analyses as a “negative control outcome”—the authors hypothesized *a priori* that lung cancer was not associated with exposure to ELF magnetic fields (Huss et al., 2018a, p. 468). Occupational exposure to ELF magnetic fields was assessed based on the study subjects’ job title as reported at the time of the census and a JEM developed for ELF magnetic fields. In addition, they assessed potential confounding by other occupational exposures, including solvents, pesticides, herbicides, metals, and electric shocks by applying corresponding JEMs to the study subjects’ job titles and adjusting for the exposures in the main analyses.

None of the hematopoietic cancer types included in the main analyses was statistically associated with either exposure corresponding to a median intensity of 0.19 μT or a higher exposure of 0.52 μT in the fully-adjusted models. Adjustment for the other occupational exposures had a very small effect on the risk estimates. The authors reported statistically significant associations for myeloid leukemia among men who were ever highly exposed at the time of both censuses ($n=6$) and for acute myeloid leukemia among men who were ever highly exposed at the time of both censuses and additionally during their vocational training ($n=5$). As noted, both estimates were based on a very small number of cases. Lung cancer mortality, included as a negative control, showed statistically significant associations and a clear exposure-response pattern with exposure to ELF magnetic fields. This finding clearly indicates that confounding by smoking, which is a well-established cause of both lung cancer and leukemias/lymphomas, remains a major weakness

of the study, and may explain the association reported in some of the sub-analyses. The authors concluded that their analysis “provided no convincing evidence for an increased risk of death” from hematopoietic cancers in workers occupationally exposed to ELF magnetic fields (Huss et al., 2018a, p. 467).

In the same study, Huss et al. (2018a) also conducted a meta-analysis of 28 epidemiologic studies of occupational exposure to ELF magnetic fields and acute myeloid leukemia published until September 2017. The authors reported a weak overall association, with a summary RR of 1.21 (95% CI: 1.08, 1.37).

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 6. Relevant studies of adult leukemia

Authors	Year	Study
Huss et al.	2018a	Occupational extremely low frequency magnetic fields (ELF-MF) exposure and hematolymphopoietic cancers - Swiss National Cohort analysis and updated meta-analysis.
Talibov et al.	2015	Occupational exposure to extremely low-frequency magnetic fields and electrical shocks and acute myeloid leukemia in four Nordic countries.

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 also 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 going about in the 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 development effects published subsequent to the WHO 2007 report included ones focusing on miscarriage or stillbirth (Wang et al., 2013; Shamsi Mahmoudabadi et al., 2013; Auger et al., 2012) and birth outcomes (de Vocht et al., 2014; Mahram and Ghazavi, 2013). 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. These authors’ 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.

Recent studies (December 2014 through December 2018)

Several epidemiologic studies investigated the potential association between ELF magnetic-field exposure and miscarriage (Li et al., 2017; Sadeghi et al., 2017) or birth outcomes (de Vocht et al., 2014; Eskelinen et al., 2016; Migault et al. 2018). Li et al. (2017) 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 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.

While personal exposure measurements are an improvement over some of the earlier studies, the collection of only one measurement over a single 24-hour period during pregnancy is a limitation of the Li et al. (2017) study, as day-to-day changes in exposure cannot be captured. No information was provided in the paper on the exact timing of the measurement (i.e., whether the measurement day preceded or followed the occurrence of miscarriage among cases); this is a substantial limitation as measurements taken following miscarriage in a substantial fraction of cases was a major criticism of the previous study by the same research team (Li et al., 2002). Li et al. (2017) also failed to measure 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). Varying levels of mobility between women with healthy pregnancies and women who suffer a

miscarriage remain a viable alternative explanation for the findings in both the previous and the current studies.

Iranian scientists (Sadeghi et al., 2017) conducted a case-control analysis of preterm birth and residential distance to high-voltage overhead power lines. The researchers identified 135 cases of live spontaneous preterm birth in an Iranian hospital between 2013 and 2014 and compared their estimated exposure to 150 controls with term live births selected using randomized-digit dialing. Exposure was defined as maternal residence during pregnancy located within 600 meters of a high-voltage power line as determined by use of a geographical information system. The study reported no statistically significant association between preterm birth and the mothers' residential distance from power lines (<600 meters compared to ≥ 600 meters). The authors reported a similar absence of an association with birth defects, which were more common among children with preterm birth. One of the main limitations of the study is the reliance on maternal address within 600 meters to high-voltage power lines as a surrogate for exposure. No elevation of ELF EMF levels can be expected for distances from approximately 100 to 600 meters in that zone; thus, no valid conclusions can be drawn from the study with respect to exposure to EMF.

A study from the United Kingdom investigated birth outcomes in relation to residential proximity to power lines during pregnancy between 2004 and 2008 in Northwest England (de Vocht et al., 2014). The researchers examined hospital records of over 140,000 births; distance to the nearest power lines were determined using geographical information data. The authors reported moderately lower birth weight within 50 meters of power lines but observed no statistically significant increase in risk of any adverse clinical birth outcomes (e.g., preterm birth, small for gestational age, low birth weight). The limitations of the study include its reliance on distance for exposure assessment and the potential for confounding by socioeconomic status, which were discussed by the authors. A follow-up analysis of the same data suggested that the observed association in the de Vocht et al. (2014) study, at least partially, may be due to confounding and missing data (de Vocht and Lee, 2014).

Eskelinen et al. (2016) examined the potential association between residential exposure to magnetic fields and time to pregnancy, low birth weight, and being small for gestational age among 373 mothers who gave birth between 1990 and 1994 in Kuopio University Hospital,

Finland. The study population was selected from the birth registry of the hospital. To increase the prevalence of women with high exposure to EMF and the range of exposure levels in the study, the scientists selected mothers with residences in close proximity to nearby sources (e.g., transmission lines, underground cables, transformers). They assessed exposure to magnetic fields through spot measurements in the home and through a questionnaire that requested information on occupational and residential sources of EMF (e.g., electrical appliances and equipment). None of the exposure metrics used to assess EMF exposure in the study was statistically associated with measures of fetal growth or time to pregnancy. Consideration of various metrics, including residential measurements and availability of personal level information on potential confounders, were among the strengths of the study, while the relatively few subjects with higher estimated average exposures ($>0.4 \mu\text{T}$ [$>4 \text{ mG}$]) subjects limited the study's statistical precision, which was noted by de Vocht and Burstyn (2016).

Migault et al. (2018) studied the relationship between maternal cumulative exposure to ELF EMF and two pregnancy outcomes (moderate prematurity and being small for gestational age) within the Elfe study. The Elfe study is a prospective birth cohort that included 18,329 infants born at 33 weeks of gestation or more in France during 2011 and is designed to follow the children until 20 years of age. Cumulative exposure to both occupational and residential ELF EMF during pregnancy was assessed using the mothers' self-reported occupation and the INTEROCC JEM. The JEM also included exposure estimates for five non-professional categories, including housewife, student, and unemployed, that were used to estimate residential exposure. The authors observed no statistically significant association between maternal cumulative exposure and moderate prematurity or small for gestational age when they evaluated any of the exposure metrics (categorical, binary, or continuous). The authors noted that the ability to consider both occupational and residential exposures in their cumulative estimates is a strength of the study but suggested that the small sample size in the high exposure categories limited the study's power to detect a potential association.

Using data from the Danish National Birth Cohort, Sudan et al. (2017) conducted a follow-up study to a previously reported association between intrauterine exposure to magnetic fields and childhood asthma (Li et al., 2011). The researchers examined 92,675 children born to 91,661 mothers who were pregnant between 1996 and 2002 and assessed intrauterine exposure of the

children using distance from the residence of the mother during pregnancy to the nearest power line. They observed no association between magnetic-field exposure estimated by distance from power lines and asthma development, regardless of how the asthma diagnosis was defined. The authors noted, however, that the majority of mothers and children in the dataset had no residential exposure from power lines (i.e., lived in a home that was located outside a specified distance to the nearest power line), thus limiting the ability to make firm conclusions. In addition, potential errors in the estimation of distances to power lines, which were used in the calculations of magnetic-field levels, are a limitation of the study's exposure assessment (Chang et al., 2014).

Darbandi et al. (2017) reviewed some of the human and animal studies published between 1978 and June 2016 that assessed the effects of EMF on male reproductive functions. The authors noted that the studies “provided contradictory results that were highly dependent on the exposure parameters,” including intensity and duration of exposure. The inconsistent findings summarized in this paper provide little new insight into this area of research.

Lewis et al. (2016) assessed the scientific literature on ELF EMF exposure and measures of infertility and adverse pregnancy outcomes published between 2002 and 2015. The authors reviewed the strengths and limitations of 13 published studies and concluded that design limitations in most studies may explain their inconsistent findings. The authors' recommendations for future studies included the selection of appropriate study populations, the assessment and control for potential confounding by the mothers' physical activity, the careful characterization of exposure to minimize measurement error, and the consideration of various exposure metrics within the study, among other recommendations.

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)

Table 7. Relevant studies of reproductive and developmental effects

Authors	Year	Study
Darbandi et al.	2017	The effects of exposure to low frequency electromagnetic fields on male fertility.
de Vocht et al.	2014	Maternal residential proximity to sources of extremely low frequency electromagnetic fields and adverse birth outcomes in a UK cohort.
de Vocht and Lee	2014	Residential proximity to electromagnetic field sources and birth weight: Minimizing residual confounding using multiple imputation and propensity score matching.
Eskelinen et al.	2016	Maternal exposure to extremely low frequency magnetic fields: Association with time to pregnancy and foetal growth.
Lewis et al.	2016	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.
Li et al.	2017	Exposure to magnetic field non-ionizing radiation and the risk of miscarriage: a prospective cohort study.
Migault et al.	2018	Maternal cumulative exposure to extremely low frequency electromagnetic fields and pregnancy outcomes in the Elfe cohort.
Sadeghi et al.	2017	Preterm birth among women living within 600 meters of high voltage overhead Power Lines: a case-control study.
Sudan et al.	2017	Re-examining the association between residential exposure to magnetic fields from power lines and childhood asthma in the Danish National Birth Cohort.
Comment on Eskelinen et al. (2016)		
de Vocht and Burstyn	2016	Comments on “Maternal exposure to extremely low frequency magnetic fields: Association with time to pregnancy and foetal growth.”

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, stating that, "[w]hen evaluated across all the studies, there is only very limited evidence of an association between estimated ELF exposure and [Alzheimer's] disease risk" (WHO 2007, p. 194). 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 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). The authors 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; Vergara et al., 2015; Fischer et al., 2015).

Recent studies (December 2014 through December 2018)

Koeman et al. (2015) studied the relationship between various occupational exposures and non-vascular dementia-related mortality using data from the Netherlands Cohort Study, a longitudinal

follow-up study of approximately 120,000 men and women 55 to 69 years of age at enrollment. The study authors identified 798 male and 1,171 female cases in the cohort diagnosed between 1986 and 2003 and obtained their lifetime occupational history by questionnaire. Using various JEMs, they assessed occupational exposures to solvents, pesticides, metals, ELF magnetic fields, electric shocks, and diesel exhaust. The authors reported moderate, but statistically non-significant, associations for non-vascular dementia and the highest estimates of exposures to metals, chlorinated solvents, and ELF magnetic fields. The association for magnetic fields, however, showed no exposure-response relationship based on cumulative exposure, and the authors concluded that the association observed for ELF magnetic fields and solvents might be attributable to confounding by exposure to metals. They reported no association for non-vascular dementia and exposure to electric shock.

Koeman et al. (2017) conducted a nested case-control analysis within the Netherlands Cohort Study that again assessed various occupational exposures, including solvents, pesticides, metals, ELF magnetic fields and electric shocks, and ALS mortality. The analysis included ALS cases (n=136) and a random subset (n=4,344) of the cohort study population. The authors reported a statistically significant association among men with “ever high” exposure; however, this was based on a small number of cases (n=9) in the high exposure category. In addition, they reported a statistically significant association between the ALS mortality among men for those with the highest 30 percent or more of cumulative ELF magnetic-field exposure; this association was no longer statistically significant when adjusted for the effects of other occupational exposures, including insecticides. They reported no statistically significant associations for other occupational exposures investigated in the study and that due to the overall low number of exposed women, risk analyses for women were “largely uninformative.”

Additional case-control studies of EMF exposure and ALS were conducted by Fischer et al. (2015), Vinceti et al. (2017), and Yu et al. (2014). Fischer et al. (2015) conducted a population-based case-control study of occupational exposure to electric shocks and magnetic fields and ALS in Sweden. The base population of the study included all individuals born in Sweden between 1901 and 1970 who were enumerated during the 1990 Swedish census. All cases of ALS in the study population, newly diagnosed between 1990 and 2010, were identified by record linkages to the Swedish patient and death registries. Five controls, individually matched to cases

on birth year and sex, were selected for each case from the study base. A total of 4,709 cases and 23,335 controls were included in the study. Occupational exposures were assessed by linking census-based information on occupations to previously developed JEMs. Overall, neither magnetic fields nor electric shocks were related to ALS. Among subjects <65 years of age, the authors reported statistically significant associations between ALS and exposure to electric shocks; however, they also observed a statistically non-significant decrease among subjects 65 years of age and older. The study has a number of strengths, which include its large sample size, population-based design, inclusion of incidence cases, and the reliance on multiple JEMs (three for EMF and two for electric shocks) for the exposure assessment.

Vinceti et al. (2017) conducted a population-based, case-control study of magnetic fields from high-voltage power lines and ALS within two regions in Italy. The authors included 703 ALS cases, diagnosed between 1998 and 2011, and a sample of 2,737 randomly selected controls from the same provinces. Based on information on residential addresses of the cases and controls, and information on high-voltage power lines with voltages between 132 and 380 kV, the authors modeled magnetic-field exposure at the study subjects' residences. The authors reported no statistically significant associations between ALS and calculated magnetic-field levels, and they observed no exposure-response trend. The authors concluded that their findings "appear to confirm" that exposure to magnetic fields from power lines occurring in the general population is not associated with an increased risk of ALS (Vincete et al., 2017, p. 583).

Yu et al. (2014) reported the results of a small case-control study of ALS that included 66 cases and 66 controls, and examined various lifestyle, environmental, and work-related variables as potential risk factors. Their results on occupational exposure to EMF, however, cannot be interpreted because of a severe error of combining estimates of ionizing and non-ionizing radiation exposures in their analysis.

Researchers have conducted several meta-analyses that examined exposure to ELF magnetic fields and ALS. Capozzella et al. (2014) reported the results of a meta-analysis of occupational exposure to ELF magnetic fields and various chemical agents and ALS; the authors reported weak associations with ELF magnetic fields. Two meta-analyses were published in 2018—one reviewed studies of residential exposure (Röösli and Jalilian, 2018), and the other reviewed

studies of occupational exposures (Huss et al., 2018b). Rösli and Jalilian (2018) combined data from five epidemiologic studies that examined residential exposure to ELF magnetic fields from high-voltage power lines and ALS. The authors reported no statistically significant associations; the pooled RR for the most exposed populations (either <200 meters from high-voltage lines or $>0.1 \mu\text{T}$ [$>1 \text{ mG}$]) was 0.71 (95% CI, 0.48-1.07). Huss et al. (2018b) conducted a meta-analysis combining data from 20 studies of occupational exposure to ELF magnetic fields and ALS. Overall, the authors reported a weak association with borderline statistical significance for ALS and estimated ELF magnetic-field levels (summary RR 1.14; 95% CI, 1.00-1.30). The authors reported a somewhat stronger association in a subset of six studies with full occupational history compared to studies where occupation was available only at certain time points. The authors also reported substantial heterogeneity among studies, evidence for publication bias, and the lack of a clear exposure-response relationship between estimates of ELF magnetic fields and ALS.

Recent reviews of environmental, occupational, and intrinsic risk factors for ALS did not conclude that there is a clear relationship between ELF magnetic fields or electric shocks and ALS (Ingre et al., 2015; Bozzoni et al., 2016).

Pedersen et al. (2017) updated a prior cohort study (Johansen, 2000) of occupational exposure to ELF magnetic fields and CNS disease, including dementia, motor neuron disease, Parkinson's disease, multiple sclerosis, and epilepsy, among more than 32,000 male electric utility workers in Denmark. The authors identified cases within the occupational cohort of electric utility workers from the Danish National Patient Registry diagnosed from 1982 to 2010. They estimated exposure to ELF magnetic fields using a JEM and company records of job title and area of work and classified into three categories ($<0.1 \mu\text{T}$ [$<1 \text{ mG}$], $0.1\text{-}0.99 \mu\text{T}$ [$1\text{-}9.9 \text{ mG}$], and $\geq 1.0 \mu\text{T}$ [$\geq 10 \text{ mG}$]).

Both external and internal comparisons were conducted: 1) disease incidence within the cohort was compared to disease incidence in the general population of Danish men (external comparison); and 2) disease incidence within exposed workers was compared to disease incidence among unexposed workers to account for the potential healthy-worker effect (internal comparison). No consistent pattern of disease association was reported by the authors for any of the investigated outcomes. While the external comparison indicated statistically significant

associations for all types of dementia in the highest exposure category of ELF magnetic fields, the internal comparison, which is the more appropriate comparison, reported no such associations. The authors reported no statistically significant increases with exposure to ELF magnetic fields for motor neuron disease, Parkinson's disease, multiple sclerosis, or epilepsy in either external or internal comparisons.

Brouwer et al. (2015) identified cases of Parkinson's disease diagnosed between 1986 and 2003 in a cohort of approximately 120,000 adults (i.e., the Netherlands Cohort Study, noted above). They assessed occupational exposure to EMF and electric shocks among the study subjects using JEMs. Based on a total of 609 cases of Parkinson's disease, the authors concluded that their results generally do not provide strong support for an association with EMF or electric shocks. A hospital-based case-control study in the Netherlands included 444 cases of Parkinson's disease and 876 matched controls (van der Mark et al., 2014). The authors assessed occupational exposure to EMF and electric shocks using work history and a JEM, and they reported no associations between any of the exposure metrics and Parkinson's disease.

Checkoway et al. (2018) investigated the association between Parkinsonism¹³ and occupational exposure to several agents, including endotoxin, solvents, shift work, and magnetic fields, among female Shanghai textile workers. The study included 537 retired cotton factory workers who were at least 50 years of age, and 286 age-matched controls who were retired cotton factory workers not exposed to cotton dust (which was used to define endotoxin exposure). Exposure to magnetic fields was assessed using a JEM. The authors reported no statistically significant associations between occupational exposure to magnetic fields and parkinsonism. They further did not observe statistically significant associations with endotoxin, shift work, or solvent exposure. Huss et al. (2015) conducted a meta-analysis of 11 studies of occupational exposure to ELF magnetic fields and Parkinson's disease. The authors observed no statistically significant association (summary RR 1.05, 95% CI 0.98-1.13) and they reported that overall, there was "no evidence that the exposure to ELF-MF [magnetic fields] increases the risk of Parkinson's disease" (Huss et al., 2015, p. 7348).

¹³ Parkinsonism is defined by Checkoway et al. (2018) as "a syndrome whose cardinal clinical features are bradykinesia, rest tremor, muscle rigidity, and postural instability. Parkinson disease is the most common neurodegenerative form of parkinsonism" (p. 887).

Jalilian et al. (2018) conducted a meta-analysis of 20 epidemiologic studies of occupational exposure to ELF magnetic fields and Alzheimer’s disease. The authors reported a moderate, but statistically significant overall association for Alzheimer’s disease (summary RR 1.63; 95% CI, 1.35-1.96), with weaker associations in cohort studies than in case-control studies. The authors also reported substantial heterogeneity among studies, and evidence for publication bias. Pooling results from studies with “higher risk” of bias, as assessed by the authors, resulted in stronger associations, suggesting that bias in the studies likely contributed to the reported associations.

A review of environmental risk factors for dementia concluded that the evidence for an association with ELF EMF was “mixed” and “moderate” and that “this complicated exposure requires some unpicking” (Killin et al., 2016, pp. 5, 23).

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). Results of recent studies have not materially changed this overall assessment.

Table 8. Relevant studies of neurodegenerative disease

Authors	Year	Study
Bozzoni et al.	2016	Amyotrophic lateral sclerosis and environmental factors.
Brouwer et al	2015	Occupational exposures and Parkinson's disease mortality in a prospective Dutch cohort.
Capozzella et al.	2014	Work related etiology of amyotrophic lateral sclerosis (ALS): a meta-analysis.
Checkoway et al.	2018	Occupational exposures and parkinsonism among Shanghai women textile workers.

Authors	Year	Study
Fischer et al.	2015	Occupational exposure to electric shocks and magnetic fields and amyotrophic lateral sclerosis in Sweden.
Huss et al.	2015	Extremely low frequency magnetic field exposure and parkinson's disease-- a systematic review and meta-analysis of the data.
Huss et al.	2018b	Occupational exposure to extremely low-frequency magnetic fields and the risk of ALS: A systematic review and meta-analysis.
Ingre et al.	2015	Risk factors for amyotrophic lateral sclerosis.
Jalilian et al.	2018	Occupational exposure to extremely low frequency magnetic fields and risk of Alzheimer disease: A systematic review and meta-analysis.
Killin et al.	2016	Environmental risk factors for dementia: a systematic review.
Koeman et al.	2015	Occupational exposures and risk of dementia-related mortality in the prospective Netherlands Cohort Study.
Koeman et al.	2017	Occupational exposure and amyotrophic lateral sclerosis in a prospective cohort.
Pedersen et al.	2017	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.
Röösli and Jalilian	2018	A meta-analysis on residential exposure to magnetic fields and the risk of amyotrophic lateral sclerosis.
Vinceti et al.	2017	Magnetic fields exposure from high-voltage power lines and risk of amyotrophic lateral sclerosis in two Italian populations.
Yu et al.	2014	Environmental risk factors and amyotrophic lateral sclerosis (ALS): a case-control study of ALS in Michigan.

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)

Recent studies (December 2014 through December 2018)

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).

Assessment

The conclusion that there is no association between magnetic fields and cardiovascular diseases has not changed. No original research studies have been identified on EMF and cardiovascular disease since Exponent’s previous report. Thus, earlier conclusions on the lack of an association between magnetic fields and cardiovascular disease remain relevant.

Table 9. Relevant studies of cardiovascular disease

Authors	Year	Study
Elmas	2016	Effects of electromagnetic field exposure on the heart: a systematic review.

In vivo studies related to carcinogenesis

In the field of ELF EMF research, a number of research laboratories have exposed rodents, including those with a particular genetic susceptibility to cancer, to high levels of magnetic fields over the course of the animals’ lifetime and performed tissue evaluations to assess the incidence of tumors in many organs. These studies are known as chronic bioassays.

In some of 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 magnetic fields at the same time that they were exposed to a known carcinogen to assess their cancer

promoting capability. A third 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 three types of studies were reviewed by the WHO.

Chronic bioassays

The WHO review described four large-scale, long-term studies of rodents exposed to magnetic fields over the course of their lifetime that did not report increases in any type of cancer (Mandeville et al., 1997; Yasui et al., 1997; Boorman et al., 1999a, 1999b; McCormick et al., 1999). No directly relevant animal model for childhood ALL existed at the time of the WHO 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 Lerchel, 2004). Following the release of the WHO review, Bernard et al. (2009) 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.

Carcinogenic agents plus magnetic fields (combined)

Studies investigating whether exposure to magnetic fields can promote cancer or act as a co-carcinogen treated animals to magnetic fields in combination with known cancer-causing agents, such as ionizing radiation, ultraviolet radiation, or other chemicals. 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). However, the WHO review did note 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 protocol 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.¹⁴

Magnetic-field effects on biological 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 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 being 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 (Glinka et al., 2013; Hassan and Abdelkawai, 2014; Manikonda et al., 2014; Akdag et al., 2013).

In summary, the WHO concluded the following with respect to *in vivo* research related to cancer: “There is no evidence that ELF [EMF] exposure alone causes tumours [*sic*]. The evidence that ELF field exposure can enhance tumour [*sic*] development in combination with carcinogens is inadequate” (WHO, 2007, p. 322). Subsequent research, as reviewed 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 2014 through December 2018)

Cancer bioassays

As noted above, none of the past large-scale, long-term bioassays of magnetic-field exposures reported that lifetime exposure to magnetic fields initiate or promote tumor development in rodents. Several newer studies that examined the tumor incidence in animals exposed to magnetic fields compared to that of unexposed controls over short or long periods of time are reviewed below.

¹⁴ The WHO concluded with respect to the German studies of mammary carcinogenesis, “Inconsistent results were obtained that may be due in whole or in part to differences in experimental protocols, such as the use of specific substrains” (WHO 2007, p. 321).

Qi et al. (2015) compared the development of tumors in mice that had been exposed to 50-Hz, 500-mG magnetic fields or control conditions for 12 hours per day beginning 1 week prenatally and continuing until 15.5 months after birth. The exposed mice had significantly reduced body weights compared to controls. Tumors were not increased in males, but chronic myeloid leukemias were significantly higher in exposed females compared to controls. Interpretation of these data is difficult because of the limited experimental detail provided and because the authors did not report data on overall survival or the expected background incidence of tumors in these mice. In addition, no details on how the mice were exposed to magnetic fields or controls for potential effects of important housing variables (noise vibration, light) were provided. The study also did not report whether the analyses of the data were performed by experimenters who were unaware of the exposure history of the mice.

The Ramazzini Institute in Italy measured the effects of 50-Hz magnetic fields (Experiment BT 1CEM) on the body weight, tumor incidence, and mortality of male and female rats exposed to 0 mG, 20 mG, 200 mG, 1,000 mG, 10,000 mG, or intermittent 1,000 mG magnetic fields (30 minutes on and 30 minutes off) for 19 hours per day from day 12 of gestation until death (Bua et al., 2018). Bua et al. (2018) reported no effect of magnetic-field exposure on the incidence of total tumors in any group exposed to magnetic fields or on food and water consumption, body weight, or survival. These results are not consistent with the Qi et al. (2015) study discussed above.

Bua et al (2018) reported a statistically significant 26.6% decrease in malignant tumors in male rats following lifelong exposure to a 1,000 mG magnetic field. Exposures of other groups of male or female rats to magnetic fields across a range from 200 mG to 10,000 mG did not affect the incidences of the specific types of malignancies reported, specifically mammary gland tumors, schwannomas of the heart, thyroid C-cell carcinomas, and hemolymphoreticular neoplasia (HLRN).

Bua et al. (2018) concluded that the study “provided no evidence of any carcinogenic effect related to the exposure of ELF EMF alone” (p. 274) This result is consistent with a previous report from this same laboratory (Soffritti, 2010) on Experiment BT 3CEM in which the incidence of benign or malignant mammary tumors or survival of female rats exposed to

10,000 mG magnetic fields for 19 hours per day beginning before birth and continuing for their remaining lifetime did not differ from unexposed controls. Contrary to good experimental practice, the control group in this study was the same as used in the other studies from this laboratory discussed below (Experiments BT2 CEM and BT3 CEM), and the 10,000 mG exposure group in the Bua et al. (2018) study is the same as in Experiment BT 3 CEM (Soffritti, 2010).

In Experiment BT 2 CEM, Soffritti et al. (2016a) reported that the incidences of benign and malignant tumors in male and female rats exposed to a 10,000 mG magnetic field over their lifetime were no different from those of control rats. Nor did they observe any differences between these groups with respect to C-cell tumors of the thyroid or HLRN.

These are only some of studies of EMF conducted by this laboratory and so their strengths and weaknesses will be discussed *in toto* in the next section.

Carcinogenic agents plus magnetic fields (combined)

The Ramazzini Institute reported two other studies in which rats were exposed to known carcinogenic agents combined with magnetic fields. Soffritti et al. (2016b) reported no effects of gamma radiation plus magnetic field treatment on the body weights or survival rates of male or female rats in Experiment BT3 CEM. The percent of animals with actual cancers of the mammary gland was slightly, but not significantly, greater in female rats exposed to radiation alone (7.6%) than radiation plus 200 mG magnetic fields (7.5%) but was significantly less than the percent of females with mammary tumors exposed to radiation plus 10,000 mG magnetic fields (16.1%). The incidence of mammary tumors in male rats exposed to radiation alone was no different from those exposed to radiation plus 200 mG magnetic fields or radiation plus 10,000 mG magnetic fields. The incidence of HLRN observed in the radiation group was not increased by the addition of 200 mG magnetic field but was increased by the addition of a 10,000 mG magnetic field. The authors assessed the incidence of malignant schwannomas in the heart, but there was no statistical difference between male rats treated with radiation or radiation plus magnetic fields at either field level or between any groups of exposed or control female rats. This particular study is deficient because it did not include groups of rats exposed just to 200 mG or 10,000 mG magnetic fields without radiation.

Soffritti et al. (2016b) used the same exposure apparatus and general methods as in Experiment BT 2 CEM to examine the effects of oral exposure to 50 milligrams per liter (mg/L) of formaldehyde, a known carcinogen, in drinking water for two years in combination with 10,000 mG, 50-Hz magnetic-field exposure. Controls were either unexposed (the same control group as reported in Experiments BT 1CEM and BT 3CEM) or treated with formaldehyde in drinking water only.

None of the treatment groups differed with respect to body weight or survival. Exposure to either magnetic fields alone or formaldehyde alone did not increase the incidence of total benign or malignant tumors above that observed in the control group, but the authors did not disclose the distribution of tumors across the different tissues, including the mammary gland, to this total. The incidences of malignant tumors, including C-cell carcinomas of the thyroid and lymphatic tumors, in male rats exposed to both formaldehyde plus magnetic fields were significantly different than those seen with formaldehyde treatment alone. These results were confounded, however, by the substantially reduced water intake levels over the first year of the study in males receiving formaldehyde in the drinking water with or without magnetic-field exposure. No effects were seen in females, except for an increase in thyroid adenomas and carcinomas in groups exposed to formaldehyde alone.

The strengths of the studies reported from the Ramazzini Institute include the large numbers of rats in each group and exposures over the animals' lifespan. These strengths, however, are outweighed by gross limitations in the design of the experiments and data analyses. The rats do not appear to have been randomly allocated to exposure groups and no data were presented to confirm the absence of the potentially confounding effects of noise and vibration. Cage lighting within the exposure room was not uniform, and the authors did not describe taking any measures to control this confounder. More important, the statistical analysis incorrectly treated each rat as the unit of analysis; however, because the rats were exposed in groups, each cage should have been the unit of analysis (Festing and Altmann, 2002). For some tumor types, the authors based their conclusions on only a few animals. Additionally, the large number of statistical tests performed could be expected to lead to false positive results by chance alone, but the authors did not adjust the statistical criteria to correct for this.

An additional concern is that the incidence of mammary cancers in unexposed controls in the Soffritti et al. (2016b) study and the Soffritti et al. (2015) study differs by more than two-fold, as does the incidence of cancers in rats exposed to 0.1 Gray¹⁵ of ionizing radiation. The large variation in the control incidence of mammary tumors across studies calls into question the biological relevance of the small differences in tumor incidences seen with and without different treatments within any single study.

Based on concerns about the ability of the Ramazzini scientists to properly distinguish between leukemias and lymphomas in certain tissues, the EPA has “decided not to rely on data from the RI [Ramazzini Institute] on lymphomas and leukemias in these IRIS [Integrated Risk Information System] assessments” (USEPA, 2017). Furthermore, scientists from EPA and the National Institute for Environmental Health Sciences have taken an unprecedented step to warn risk assessors about problems with cancer bioassays that have been conducted by the Ramazzini Institute, like those described above (Gift et al., 2013).

One other study investigated the therapeutic potential of high magnetic-field exposures in the treatment of tumors but it was conducted for a short duration only. Mahna et al. (2014), injected female mice with mouse mammary tumor cells, then exposed them to 150,000 mG, 50-Hz magnetic fields (10 minutes per day for 12 days). Other animal groups were exposed to magnetic fields and electrochemotherapy (a combination of chemotherapy with pulsed electric current applied to the skin to increase permeability of cancers cells to the drugs). A sham-exposed control group was included, but analyses were not conducted in a blinded manner. The authors reported that magnetic-field exposure alone or in combination with the other treatments reduced tumor volume. Although these studies suffer from various limitations, the results suggest that magnetic-field exposure may have therapeutic applications in the treatment of tumors. Field strengths, however, were relatively high, and it is possible that the observed responses were due to effects of an induced electric field, not the magnetic field per se.

¹⁵ Gray is the unit in which the absorbed dose of ionizing radiation, e.g., x-rays, is measured.

Magnetic-field effects on biological 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 deoxyribonucleic acid (DNA) and chromosomes have been given most attention and weight (IARC, 1999).

Alcaraz et al. (2014) exposed male mice to 2,000 mG, 50-Hz magnetic fields for 7 to 28 days. The study included no sham-exposed controls. Mice exposed to 50 centigrays of X-rays, which are known for their ability to damage DNA, served as positive controls and the analyses were conducted blind. The authors reported an increase in micronuclei produced by double-strand breaks of chromosomes in bone marrow erythrocytes 24 hours after magnetic-field exposure. The increase was not duration-dependent, however, and was substantially lower than that induced by X-rays.

Wilson et al. (2015) examined the effect of exposure to 100 to 3,000 mG, 50-Hz magnetic fields for 2 or 15 hours on the gene mutation frequency in the sperm and blood cells of mice. Sham-exposed mice were included as negative controls; mice exposed to X-rays served as positive controls. Mutation frequencies in blood cells of magnetic-field exposed mice were similar to those of the negative controls at 12 weeks after exposure. Mutation frequencies in sperm cells were slightly, but significantly, increased among magnetic-field exposed mice, although not in a dose-related manner. In contrast, X-rays significantly increased the mutation frequency in both cell types.

In a follow-on study to the report by Wilson et al., the same research team using the same experimental system tested whether concomitant exposure to magnetic fields and X-rays had a greater effect than X-rays alone (Woodbine et al., 2015). Mouse embryos were exposed to 3,000 mG, 50-Hz magnetic fields for 3 hours before and up to 9 hours after X-ray treatment. Controls were X-irradiated- and sham-exposed to magnetic fields. Additional controls were unexposed, sham-exposed, exposed to X-rays only (with or without sham-exposure), or exposed only to magnetic-fields. X-rays significantly increased DNA double-strand breaks at 1 hour after exposure and the number of breaks decreased to control levels within 6 to 11 hours post-exposure as the cells detected and repaired the DNA breaks. Magnetic-field exposure did not increase the amount of DNA breaks produced by X-rays nor affect the repair of DNA damage

caused by X-rays. One weakness of these studies is that the number of maternal animals per group was relatively small (n=1 to 4 per group).

Two recent studies examined DNA damage in human subjects exposed to EMF. Tiwari et al. (2015) investigated DNA damage in peripheral blood lymphocytes among 293 subjects in a cross-sectional study.¹⁶ The authors considered 142 subjects as “exposed to EMFs emitted from high-voltage (132-kV) substations for more than 2 years of occupational exposure” (Tiwari et al., 2015, p. 57). The authors provided no further details on how they determined exposure status. The exposed subjects were compared to 151 non-exposed individuals (controls) of similar socioeconomic status, but the authors did not indicate how they selected control subjects. The analyses did not consider nor control for the potential confounding effect of other occupational exposures, including chemicals. The authors assessed DNA damage using the alkaline Comet assay and coded examination of slides; they also assessed other parameters related to plasma epinephrine concentrations, lipid peroxidation, and nitric oxide expression levels. Although the Comet tail length exhibited a slightly larger range in the exposed group, there was no significant difference between the two groups in the degree of DNA damage observed. The levels of lipid peroxidation and nitric oxide, but not stress (as measured by epinephrine levels), increased in the substation group relative to the control group but, “[t]he oxidative stress markers showed no relationship with exposure variables as assessed from regression analysis” (Tiwari et al., 2015, p. 59).

Villarini et al. (2015) studied a group of 21 electric arc welders in a cross-sectional study. The authors used an alkaline Comet assay to assess DNA damage in the white blood cells of arc welders and controls. The occupational exposures of arc welders include various metal fumes, chemicals, and magnetic fields. The control group included non-exposed individuals (healthy blood donors) of similar age, residence, and smoking status. Exposed individuals wore personal dosimeters for a single work shift to measure magnetic fields, which averaged 78 mG. The study did not assess magnetic-field exposure (or other exposures such as to chemicals) in the non-exposed controls. Comet tail lengths were similar in both groups; however, the welders exhibited significantly lower tail intensity and tail moment values than did controls, suggesting

¹⁶ 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.

that they had a lower degree of DNA damage. The authors suggested that this unexpected finding may be related to the type of DNA damage that might occur with exposure to various metal fumes, including chromium and nickel; both may induce DNA-protein cross-links that would migrate to a lesser degree than non-cross-linked DNA in the assay. The absence of magnetic-field measurements of persons serving as controls precludes the drawing of any conclusions regarding the effects of EMF exposure on DNA damage.

Normal cellular processes produce reactive oxygen 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. Three studies investigated a variety of tissue indicators of oxidative stress. It is important, however, to not 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 which report that 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).

Because most cancers elicit a response from the immune system, blood levels of certain chemokines (important to inducing immune system functions) are reported to increase when various types of cancer occur. Li et al. (2018) investigated the chemokine response of Balb/c mice (100 per group) exposed to 50-Hz magnetic fields at levels of 0 (sham controls), 1,000 mG, 5,000 mG, and 25,000 mG for <1, 1, 10, 30, or 90 days. The mice were not randomly allocated to these groups and were housed in groups of 10. The mice were, however, randomly selected for weighing on alternate days. At each time point, blood was drawn from four mice and the average value reported. The investigators analyzed the samples for nine different chemokines that affect the immune response by promoting pro-inflammatory functions and recruiting immune cells to sites of infection. The investigators reported that exposure to magnetic fields over 90 days did not affect the body weight of the mice. Nor did the level of magnetic-field exposure have a significant effect on the chemokine levels in blood measured by immunoassay, with two exceptions: MCP-1 and EOTAXIN-1. The change in these chemokines was confirmed by ELISA assay and the clearest increase in levels was at 5,000 mG; magnetic field exposure at

the higher level of 25,000 mG reduced the increase in these chemokines. The authors report that they did not see the expected dose-dependent rise in chemokines.

Given the large number of mice (n=900) exposed in total using an exposure system in which only 10 mice could be exposed at a time for 8 hours per day, data collection must have continued for many months; thus, variations in multiple environmental and experimental variables likely affected the results. The 10 exposed mice in each group should have been used as the experimental unit in the statistical analyses, not the individual animals, and the failure to do so overestimates the differences between exposure conditions. Despite the large number of animals used in this study, only a small number of mice were included in each group for the purposes of data analysis and the reported variability of the cytokine measurement suggests that the results may not be very reliable. Given the limitations in the design and analysis of the study and the lack of dose-response, it is not clear that the differences reported are attributable to magnetic-field exposure *per se*. Further, because chemokines are important in eliciting immune reactions, an increase in chemokine levels may be indicative of a protective effect rather than increased susceptibility to cancer.

Luo et al. (2016) investigated potential effects of magnetic-field exposure on a variety of physiologic measures related to cellular oxidative processes. This study was predicated upon the theory that prolonged, uncompensated, high levels of oxidative products might contribute to cancer and neurodegenerative disease. The WHO (2007) and SCENIHR (2015) previously reviewed similar studies. Luo et al. (2016) suggested that a decline in superoxide dismutase (SOD) and a rise in malondialdehyde (MDA) in blood and the brain cortex are indicative of oxidative stress in cells.

Luo et al. (2016) randomly assigned male ICR mice in groups of 12 to 50-Hz, 40,000 mG, 60,000 mG, 80,000 mG, 100,000 mG magnetic fields, or sham-exposure (control) conditions for 4 hours per day and assayed the blood and brain for SOD and MDA levels after 7, 14, and 21 days. The authors observed noticeable and statistically significant changes in these two indicators with exposures at or above 80,000 mG in the predicted directions. The design of the study and the effects reported are similar to those reported in a previous study from this laboratory (Duan et al., 2014).

In the Luo et al. (2016) study, other groups of mice exposed to 80,000 mG magnetic fields also were orally administered 60, 90, or 120 mg of an antioxidant (lotus seedpod procyanidins [LSPC]) for 15 days before magnetic-field exposure and daily thereafter with magnetic-field exposure for an additional 28 days. The highest LSPC dose reversed the changes in SOD activity and MDA levels in the blood and brain cortex compared to mice exposed to magnetic fields only; changes in other oxidative indicators, including catalase, glutathione peroxidase, glutathione reductase, and glutathione-S-transferase, were also reversed. A strength of the study is that the authors tested for effects of magnetic fields at multiple exposure levels and randomized the mice to the experimental groups, which minimizes systematic bias. Yet, while the study was reported in detail, the analysis of the data was not performed blind, the authors reported no controls on noise and vibration from the magnetic-field coils and power supply, and like Bua et al. (2018), the authors did not properly account for the multiple animals exposed in each cage in the statistical analyses.

Another study also reported that extremely high levels of magnetic fields affected oxidative stress marker levels in blood and tissue. Li et al. (2015)¹⁷ randomly assigned eight male Wistar rats to each of the following groups: sham control and 50-Hz, 50,000 mG, 100,000 mG, or 200,000 mG magnetic fields for 10 weeks. At the conclusion of the experiment, the authors analyzed blood samples for indicators of liver damage (alanine aminotransferase [ALT] and aspartate aminotransferase [AST]) and oxidative stress indicators (SOD and MDA) in blood, liver, and spleen. In addition, immunoglobulin G, immunoglobulin A, and immunoglobulin M antibodies were measured in the blood as indicators of immune system function. The investigators report that magnetic-field exposure significantly increased ALT and AST levels in blood, which may reflect changes in liver function. The results also showed a dose-related decrease in SOD and an increase in MDA in blood, liver, and spleen, particularly at the 100,000 mG and 200,000 mG levels. All levels of magnetic-field exposure reportedly decreased antibody concentrations in blood. The design of this study was superior in a number of ways to those of the other studies reviewed above with respect to randomization. It is not clear, however, if the animals were exposed individually or in groups, the authors did not report if the analyses were performed in a blind fashion, and the exposure system that generated the extremely high

¹⁷ This is not the same scientist as the lead author of Li et al. (2018).

levels of magnetic fields to which the mice were exposed likely would have produced considerable noise and vibration that was not controlled for.

Assessment

One animal bioassay reported increased chronic myeloid leukemia in female, but not in male, mice exposed to magnetic fields from prior to birth through 15.5 months of age—a finding that conflicts with those of the other large-scale rodent bioassays reviewed by the WHO in 2007. Three other animal bioassays of long-term magnetic-field exposure as a possible carcinogen were published between 2014 and 2018, and as in previous studies of similar design, they demonstrated that magnetic fields do not cause cancer even when the exposure is life-long. Despite these results, there are serious concerns about the methods utilized in two of these studies and in two additional studies from the Ramazzini Institute in which lifelong exposures of rats to magnetic fields were combined with exposures to known carcinogens—ionizing radiation and formaldehyde. Neither of these latter studies showed convincing evidence in light of the studies' limitations that exposure to magnetic field plus carcinogens increased the overall incidence of tumors in male or female rats above that produced by these carcinogens alone. In a third study, the authors reported that extraordinarily high magnetic-field exposure (150,000 mG) compared to ICNIRP or ICES guidelines for public or occupational exposure, either alone or in combination with chemical therapeutic agents, for 10 days decreased the volume of tumors initiated by injecting mice with mammary tumor cells.

Recent studies also investigated two potential mechanisms related to carcinogenesis: genotoxicity and oxidative stress. Two of three studies of magnetic fields on DNA or chromosomes in animals reported no effects and two studies on indicators of DNA damage in human subjects reported no relationship to magnetic fields. Three other animal studies reported that magnetic-field exposure increased indicators of oxidative stress in blood and other tissues. The clearest effects of magnetic fields were reported at magnetic-field levels between 80,000 mG and 200,000 mG. All these studies had methodological limitations and the relevance of animal studies at such high field levels to persons in communities with far lower exposures is uncertain. These studies do not change the WHO's conclusion that the overall evidence from *in vivo* studies does not support the role of EMF exposures in genotoxic effects.

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

Table 10. Relevant *in vivo* studies related to carcinogenesis

Authors	Year	Study
Alcaraz et al.	2014	Effect of long-term 50 Hz magnetic field exposure on the micronucleated polychromatic erythrocytes of mice.
Bua et al.	2018	Results of lifespan exposure to continuous and intermittent extremely low frequency electromagnetic fields (ELFEMF) administered alone to Sprague Dawley rats
Li et al.	2015	Effect of long-term pulsed electromagnetic field exposure on hepatic and immunologic functions of rats
Li et al.	2018	Eotaxin-1 and MCP-1 serve as circulating indicators in response to power frequency electromagnetic field exposure in mice
Luo et al.	2016	Chemoprotective action of lotus seedpod procyanidins on oxidative stress in mice induced by extremely low-frequency electromagnetic field exposure
Mahna et al.	2014	The effect of ELF magnetic field on tumor growth after electrochemotherapy.
Qi et al.	2015	Effects of extremely low-frequency electromagnetic fields (ELF-EMF) exposure on B6C3F1 mice
Soffritti et al.	2015	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
Soffritti et al.	2016a	Life-span exposure to sinusoidal-50 Hz magnetic field and acute low-dose γ radiation induce carcinogenic effects in Sprague-Dawley rats
Soffritti et al.	2016b	Synergism between sinusoidal-50 Hz magnetic field and formaldehyde in triggering carcinogenic effects in male Sprague-Dawley Rats
Tiwari et al.	2015	Epinephrine, DNA integrity and oxidative stress in workers exposed to extremely low-frequency electromagnetic fields (ELF-EMFs) at 132 kV substations
Villarini et al.	2015	Primary DNA damage in welders occupational exposed to extremely-low-frequency magnetic fields (ELF-MF)
Wilson et al.	2015	The effects of extremely low frequency magnetic fields on mutation induction in mice.
Woodbine et al.	2015	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

6 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 5.

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

- **The European Health Risk Assessment Network on Electromagnetic Fields Exposure**
 - http://efhran.polimi.it/docs/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)
- **The Scientific Committee on Emerging and Newly Identified Health Risks (European Union)**
 - http://ec.europa.eu/health/ph_risk/committees/04_scenihhr/docs/scenihhr_o_007.pdf (SCENIHR, 2007)
 - http://ec.europa.eu/health/ph_risk/committees/04_scenihhr/docs/scenihhr_o_022.pdf (SCENIHR, 2009)
 - http://ec.europa.eu/health/scientific_committees/emerging/docs/scenihhr_o_041.pdf (SCENIHR, 2015)

The Swedish Radiation Protection Authority

- http://www.who.int/peh-emf/publications/reports/SWEDENssi_rapp_2006.pdf (SSI, 2007)
- http://www.who.int/peh-emf/publications/reports/SWEDENssi_rapp_2007.pdf (SSI, 2008)
- **The Swedish Radiation Safety Authority**
 - <http://www.stralsakerhetsmyndigheten.se/Publikationer/Rapport/Stralskydd/2013/201319/> (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/ee7b28e0fee04e80bc84c24663a004/201519-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)

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

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

The ICNIRP and ICES guidelines provide guidance to national agencies and only become legally binding if a country adopts them into legislation. The WHO strongly recommends that countries

adopt the ICNIRP guidelines or use a scientifically sound framework for formulating any new guidelines (WHO, 2006).

There are no national or state standards in the United States limiting exposures to ELF EMF based on health effects. Two states, Florida and New York, have enacted standards to limit magnetic fields at the edge of the right-of-way from transmission lines (NYPSC, 1978, 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.

Rhode Island does not have an EMF standard for transmission lines but the Energy Facility Siting Board in Rhode Island 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 11. Screening guidelines for EMF exposure

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

Sources: ICNIRP, 2010; ICES, 2002

8 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. A suggested weak statistical association between high, average magnetic fields and childhood leukemia has not been appreciably strengthened or substantially diminished by subsequent research, although the most recent studies tend to show no overall associations. 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 supporting a leukemogenic or other cancer risk associated with magnetic-field exposure. Publications on other cancer and non-cancer outcomes 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.

9 References

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