June 2024

RHODE ISLAND ENERGY FACILITY SITING BOARD PROJECT SITING REPORT

The Narragansett Electric Company Tiverton Tap Rebuild Project

Tiverton, Rhode Island

Volume I

PREPARED FOR:

THE NARRAGANSETT ELECTRIC COMPANY
280 MELROSE STREET
PROVIDENCE, RI 02907

FOR SUBMITTAL TO:

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

PREPARED BY:

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This document has been reviewed for Critical Energy Infrastructure Information (CEII). [June 2024]

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GLOSSARY OF TERMS

ACSR	Aluminum Conductor Steel Reinforced
ACGIH	American Conference of Governmental and Industrial Hygienists
ASF	Area Subject to Flooding
ASSF	Area Subject to Storm Flowage
BMPs	Best Management Practices
Circuit	A system of conductors (three conductors or three bundles of conductors) through which an electric current flows
Company	The Narraganset Electric Company
Conductor	A metallic wire which serves as a path for electric current to flow.
Demand	The total amount of electric power required at any given time by an electric supplier's customers
Distribution Line or System	Power lines that operate under 69 kV
EFSB	Rhode Island Energy Facility Siting Board
EFSB Rules	State of Rhode Island Energy Facility Siting Board Rules of Practice and Procedure, 445 RICR-00-00-1, effective November 8, 2018
Electric Field	A field produced as a result of voltages applied to electrical conductors and equipment; usually measured in units of kilovolts per meter.
Electric Transmission	Facilities (≥ 69 kV) that transmit electrical energy from generating plants to substations, or from substation to substation
EMF	Electric and magnetic fields
Environmental Monitor	Inspects environmental conditions within the construction site, reviews the contractors' compliance with environmental permit conditions during the construction phase of a project, and makes recommendations for corrective actions to protect sensitive environmental resources proximate to a construction site
ESA	Endangered Species Act
FAA	Federal Aviation Administration
HUC	Hydrologic Unit Code
Hz	Hertz, a measure of the frequency of alternating current; expressed in units of cycles per second.
ICNIRP	International Commission on Non-Ionizing Radiation Protection
ISO	Independent System Operator
ISO-NE	ISO New England, Inc., the independent system operator of the New England electric transmission system.
kcmil	One thousand circular mils, approximately 0.0008 square inch, a measure of conductor cross-sectional area
kV	kilovolt - one kV equals 1,000 volts
kV/m	kilovolts per meter
Load	Amount of power delivered upon demand at any point or points in the electric system; load is created by the power demands of customers' equipment (residential, commercial and industrial)
mG	milligauss, a measure of magnetic field intensity

NAAQS	National Ambient Air Quality Standards
NRHP	National Register of Historic Places
NWI	National Wetland Inventory
OPGW	Optical Ground Wire
POWER	POWER Engineers, Inc.
Project	Tiverton Tap Rebuild Project
Report	Project Siting Report
RIDEM	Rhode Island Department of Environmental Management
RIGIS	Rhode Island Geographic Information System
RIHPHC	Rhode Island Historical Preservation & Heritage Commission
ROW	Right-of-way. Corridor of land within which a utility company holds legal rights necessary to build, operate, and maintain power lines
SRPW	Special Resource Protection Water
Study Area	A 5,000-foot-wide corridor measured 2,500 feet on either side of the subject Project ROW
TMDL	Total Maximum Daily Load
Transmission Line	An electric power line operating at 69,000 volts or more.
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USFS	United States Forest Service
USGS	United States Geological Survey
V/m	Volts per meter
Watercourses	Rivers, streams, brooks, waterways, lakes, ponds, swamps, bogs and all other bodies of water, natural or artificial, public or private

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1.0 INTRODUCTION

1.1 Project Overview

The Narragansett Electric Company (the Company) is proposing the Tiverton Tap Rebuild Project (Project) which is located in Tiverton, Rhode Island. The Company is seeking a determination from the Rhode Island Energy Facility Siting Board (EFSB) that the project does not constitute an alteration of a major energy facility as defined by Rhode Island General Laws (R.I.G.L.) § 42-98-4(b) in that the Project will not result in a significant impact on the environment or public health, safety, and welfare pursuant to the EFSB Rule, Section 1.6.F.

The Project is the rebuild of the existing L14 and M13 115 kilovolt (kV) Tiverton Tap Lines (Tiverton Tap or Taps), a distance of approximately 2.1 miles in Tiverton. The Tiverton Tap right-of-way (ROW) begins approximately 0.1 mile west of Route 24 at the Tiverton (Rhode Island)/Fall River (Massachusetts) border and continues south to the Tiverton Substation at 940 Fish Road in Tiverton.

1.2 Project Team

This Project Siting Report (Report) has been prepared by Company employees and consultants retained by the Company, including planners, engineers, and legal personnel. The description of the affected natural and social environments, and impact analyses were prepared by POWER Engineers, Inc. (POWER). Burns and McDonnell are responsible for the Project engineering and design documents, and the modeling and calculation of Electric and Management Fields (EMF). Exponent, Inc. prepared the analysis of the health effects of EMF.

1.3 Compliance with EFSB Requirements

This Report is being submitted to satisfy the applicable requirements of Rhode Island General Laws § 42-98-1 et seq., the Energy Facility Siting Act (the Act). It is in compliance with Section 4 of the 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. The EFSB Rules Section 1.6.F provides “[i]n the case of the construction of a power line of more than 1,000 feet but less than 6,000 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 EFSB Board and the council of any town or city affected by said construction at least 90 days before commencing construction.”

1.4 Organization of the Report

This Report has been prepared in accordance with the EFSB Rules to provide information on the potential impacts of the electric transmission system improvements proposed by the Company. The Purpose and Need for the Project is detailed in Section 2.0 of this Report. Section 3.0 provides a detailed description of the components of the Project, and discusses construction practices and sequencing, ROW maintenance practices, safety and public health considerations, estimated costs for the Project, and anticipated Project schedule. An analysis of the alternatives to the Project, together with reasons for the dismissal of those alternatives, is presented in Section 4.0. Detailed descriptions of the characteristics of the natural and social environments within and immediately surrounding the

Project location are included in Sections 5.0 and 6.0, respectively. Section 7.0 of this report identifies the potential impacts of the Project on the natural and social environments. Section 8.0 summarizes proposed mitigation measures which are intended to offset or eliminate the potential impacts associated with the Project. This Report also contains supporting mapping, figures, reports, agency correspondence, and engineering design information as applicable.

2.0 PROJECT NEED

2.1 Introduction

The Company owns and operates approximately 400 miles of overhead and underground transmission lines exclusively in the State of Rhode Island. The system needs are identified through a combination of data collection activities, including desktop review, ground inspections, aerial inspections, and third-party condition assessments. The Company utilizes the collected data to apply a proactive asset management strategy to upgrade or rebuild transmission facilities to improve reliability and the longevity of the system while reducing maintenance costs.

The Tiverton Tap lines change ownership at the Massachusetts/Rhode Island state border.[1] The project needs and scope cover only the Rhode Island the Tiverton Taps (two circuits) to Tiverton 2 Substation, covering approximately 2.1 miles in Rhode Island.

2.2 Need

This Project focuses on improving the condition and performance of the Tiverton Tap Lines between the Massachusetts/Rhode Island state border and the Tiverton Substation. The lines provide an important source of energy to the Tiverton area. Additionally, the lines connect the taps to Tiverton Power Station to the electric grid. Tiverton Power Station is a combined-cycle gas turbine plant that provides approximately 273 megawatts to the New England power market. The Tiverton Tap lines have been identified for refurbishment because the wood structures are exhibiting signs of deterioration, such as discoloration, bowing, rotting, and woodpecker holes seen during ground inspections. Aluminum Conductor Steel Reinforced (ACSR) conductors lose mechanical strength over their service life due to corrosion and annealing, leading to an increased likelihood of broken strands and eventual conductor failure. The M13-1 and L14-1 Tiverton Taps contain a total of 58 structures. The M13-3 and L14-3 Tiverton 2 Taps contain eight structures. The primary structure type on the Taps is the wood H-frame

2.3 Conclusion

If the Tiverton Tap Lines are not rebuilt, the area may face future reliability issues resulting from the asset conditions of the Tiverton Tap Lines. The Project is needed to address the asset condition issues of the current lines.

[1] The Tiverton Tap lines cross the Massachusetts/Rhode Island state border; New England Power Company d/b/a National Grid (NEP) will be responsible for addressing reliability concerns on NEP-owned infrastructure. NEP anticipates an approximate Ready for Load date of October 2031 for their infrastructure.

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3.0 PROJECT DESCRIPTION AND PROPOSED ACTION

3.1 Scope of the Project

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

Structures along the Tiverton Tap (approximately 2.1 miles) will be replaced with single-circuit steel structures; dead-end and angle steel structures will be installed with concrete caisson foundations; and tangent structures will be direct-embed installations.

The Project involves the following improvements to the existing transmission assets:

- Rebuild of the existing 115 kV Tiverton Tap from the Fall River, MA and Tiverton border south to the existing Tiverton Substation located off of Fish Road in Tiverton, a distance of approximately 2.1 miles. A total of 58 structures will be replaced.
- Reconductor with 1113.0 kcmil ACSS overhead conductor.
- Replace existing overhead shield wire with new overhead 48 count fiber Optical Ground Wire (OPGW) on double-circuit structures. Each structure will have dual shielding.
- Restore and stabilize the affected areas within the ROW.

3.2 Description of the Existing Transmission Lines

3.2.1 L14 and M13 115 kV Transmission Lines

The width of the Tiverton Tap ROW is approximately 250 feet wide with a maintained clearing that is 120 to 150 feet wide. The height of the existing Tap Line transmission structures generally ranges from 31 to 71 feet and consist of wood H-frames.

3.3 Construction and Maintenance Practices

3.3.1 Construction Sequence

The Project will be constructed using conventional overhead electric transmission line construction techniques. The Company and its consultants conducted detailed constructability field reviews to determine access and workspace requirements, and to evaluate measures to avoid or minimize environmental impacts. The construction sequence is listed below.

1. Removal of vegetation and mowing within the ROW in advance of construction.
2. Installation of soil erosion and sediment controls.
3. Access road and work pad maintenance, and access route construction.
4. Installation of transmission structure foundations.
5. Installation of replacement structures and installation of conductors and OPGW.
6. Removal and disposal of existing transmission line components.
7. Restoration and stabilization of the ROW.

3.3.2 Construction Methods

Each construction activity is further described below.

Removal of Vegetation and ROW Mowing in Advance of Construction

The Company implements its Vegetation Management Procedures to maintain low-growing vegetation on its transmission ROW to provide safe clearances between vegetation and conductors as well as access to existing structures for maintenance and emergencies. Taller vegetation that may interfere with the operation and maintenance of the overhead wires is routinely managed, as well as growth of vegetation that may interfere with access to existing transmission structures. The Company is currently performing routine vegetation maintenance on its existing ROW as part of the normal maintenance cycle. Additionally, the Company has performed vegetation maintenance along the Project ROW to support equipment access for the subsurface investigation program, which was performed to support the engineering design of the Project.

Construction of the Project will require additional vegetation maintenance to provide safe vehicular and equipment access to existing structure locations and safe work sites for personnel within the ROW. This will include mowing of low-growing shrubs, vines and herbaceous vegetation, removal of taller trees below the conductors, and removal of danger and hazard trees as determined by the Company's Forestry group under the Vegetation Management Procedures. Danger and hazard trees must be removed to provide safe clearances between vegetation and transmission line conductors for the life of the asset to assist the reliable operation and maintenance of the transmission facilities.

Prior to vegetation removal and mowing, wetland boundaries will be clearly marked to prevent unauthorized encroachment into wetland areas. Appropriate forestry techniques will be implemented within wetlands to minimize ground disturbance. Other sensitive resources, such as cultural resource features, will be flagged and encompassed with protective fencing prior to removal of vegetation on the ROW. Existing access routes within the ROW will be used by vegetation management personnel and equipment. Road improvements will be kept to a minimum during this phase of the work. Temporary construction mats will be used to gain access to and across wetlands, to minimize wetland disturbance, and to provide a stable platform for safe equipment operation. Typical construction mats used for construction access consist of timbers that are bolted together into 4-foot by 16-foot sections and placed over wetland areas to distribute equipment loads and minimize impacts to the wetland and soil substrates in accordance with the Company's *ROW Access, Maintenance, and Construction Best Management Practices* document (EG-303NE). Temporary construction mat roads placed in wetlands for vegetation removal will be installed, used for vegetation removal, and then removed by the contractor.

Mowing will occur on access points and at work and pull pads. Limited tree removal will occur within the ROW, as needed. Generally, trees to be removed will be cut close to the ground, leaving the stumps and roots in place, which will reduce soil disturbance and erosion. The Company is planning to use the existing network of access roads previously established on the ROW to the greatest extent practicable. Small trees and shrubs within the limits work pads/grading and the ROW will be mowed as necessary with the intent of preserving root systems and low-growing vegetation to the extent practical. Brush, limbs, and cleared trees will be mowed or chipped. Chipped material will be removed from the site or applied to upland areas as an erosion control measure, with prior approval. Post-construction, the ROW will be allowed to naturally revegetate.

In certain environmentally sensitive areas such as wetlands, it may be necessary and desirable to leave felled trees and snags to decompose in place rather than to disturb soft organic substrates while removing them. Where the ROW crosses streams and brooks, vegetation along the stream bank will be selectively cut to minimize the disturbance to bank soils and to reduce the potential for Project-related soil erosion. A minimum of a 25-foot-wide riparian zone will be maintained along watercourses, to the extent feasible.

Installation of Soil Erosion and Sediment Controls

Following vegetation management activities, soil erosion and sediment control devices such as straw wattles/bales, siltation fencing, and/or chip bales will be installed 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 Department of Environmental Management's (RIDEM's) *Wetlands Best Management Practices Manual,* and EG-303NE.

The installation of sediment control devices will be overseen by the Company's environmental compliance monitor. During construction, these devices will be periodically inspected by the environmental compliance monitor, and the findings will be reported regularly to Company's Construction Supervisor. The soil erosion and sediment controls will be installed between the work site and environmentally sensitive areas such as wetlands, streams, drainage courses, roads and adjacent properties when work activities will disturb soils and result in the potential for 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 demarcate the limits of disturbance and to contain construction activities within approved areas.

Where dewatering is necessary during excavations within or adjacent to wetland areas, water will be pumped into appropriate dewatering basins or filter bags. At all times, dewatering will be performed in compliance with EG-303NE and all relevant permits and approvals. The dewatering basins and all accumulated sediment will be removed following dewatering operations and the area will be seeded and mulched. Soil erosion and sediment controls will be used to contain excess soil.

Staging areas and equipment storage, where feasible, will be situated outside of 100-foot and 200-foot regulated contiguous areas, where feasible. Equipment refueling (except for fixed equipment such as drill rigs) will occur outside of environmentally sensitive areas and secondary containment will be utilized when refueling and when equipment containing fuel or oil is stored onsite. Where structures are located in or near wetlands, proper soil erosion and sediment controls will be installed to contain the work areas.

In accordance with Best Management Practices (BMPs), construction mats, soil erosion and sediment controls, and other preventative measures will be implemented, as appropriate, in resource areas temporarily disturbed by construction. Herbaceous vegetation in disturbed areas will be restored using a native wetland or conservation seed mix. In tree removal areas, enhancements may be proposed as mitigation for important wildlife features lost due to tree removal and construction activities. Potential enhancement activities include seeding, planting native shrub species, leaving snags, and placing woody debris, slash, or stone piles to create wildlife cover.

Construction and Improvements to Access Roads

The Company proposes to improve existing access roads and construct new access routes to reach replacement structures locations, and to provide the ability to construct, inspect and maintain the L14 and M13 Tap Lines. Where feasible, the Company plans to use its existing network of access roads to construct the Project. Many of these existing access roads will require maintenance or upgrading to support construction vehicles and equipment. For example, clean gravel, clean washed stone or trap rock may be used to stabilize and level the roads for construction vehicles. Construction of new access roads and access road improvement and maintenance will be carried out in compliance with the conditions and approvals of the appropriate federal, state, and local regulatory agencies. 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. Stabilized crushed stone aprons underlain by geotextile fabric will be used at all access road entrances to public roadways to clean the tires of construction vehicles and minimize the migration of soil off-site. In uplands and in state regulated 100-foot and 200-foot contiguous areas, access road improvements will be left in place to facilitate future access to the ROW for inspection, and operation and maintenance purposes.

Access across wetlands, where upland access is not available, will be accomplished by the temporary placement of construction mats. Construction mats will be removed following completion of construction, and areas will be restored to reestablish pre-existing topography and hydrology. The use of construction mats allows for heavy equipment access within wetland areas. The use of construction mats minimizes the need to remove vegetation beneath the access way and helps to reduce the degree of soil disturbance by distributing the weight of equipment over a larger area, minimize soil compaction and rutting in soft wetland soils.

Construction mats will be certified clean by the vendor prior to installation. Clean is defined as being free of plant matter (stems, flowers, roots, etc.), soil, or other deleterious materials prior to being brought to the project site. Any equipment or construction mats that have been placed or used within areas containing invasive species within the Project site shall be cleaned of plant matter, soil, or other deleterious materials at the site of the invasive species prior to being moved to other areas on the project site to prevent the spread of invasive species from one area to another. Mats will be cleaned prior to removal at the completion of the Project.

Installation of Structure Work Pads and Staging Areas

Upland work pads will be constructed at structure locations by grading or adding gravel and clean washed 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 mulch and seeded to allow vegetation to re-establish. In uplands and in state regulated 100-foot and 200-foot contiguous areas, stone-covered work pads will remain in place on a case-by-case basis to facilitate future access for inspection, operation, and maintenance purposes. At locations in 100-foot and 200-foot contiguous areas where stone-covered work pads may remain in place, those work pads will be stabilized and reseeded or, as an alternative, constructed with temporary construction mats. In wetlands, these work pads will be constructed with temporary construction mats and will be removed after the completion of construction activities. Wetlands will be restored to pre-construction configuration and elevations to the extent practicable. If necessary, vegetation will also be restored within the wetland through native seeding.

Installation of Foundations and Structures

Structures will be installed either on reinforced concrete caisson foundations or direct embedment, dependent upon the structure type and location. Angle and dead-end transmission structures and the river crossing structures are proposed to be installed on concrete caisson foundations.

The predominance of the proposed transmission structures will be direct-embed structures where the pole butt is inserted into an excavated hole in the ground. The overhead conductors are placed in a vertical configuration on one side of the transmission pole structure. To address engineering design requirements and construction feasibility, direct-embedded pole structures may be encased within a corrugated metal pipe or metal casing. Depending on structural loading modified stone, flowable fill, or concrete will be used to backfill around the pole and within the corrugated metal pipe or casing. This engineering design will result in a more reliable and robust transmission grid.

Excavation for direct embedment structures will be performed using a soil auger or standard excavation equipment depending on field conditions. Excavations will range from approximately 15 to 18 feet in depth (depending on soil conditions and depth of bedrock), with diameters averaging eight feet wide. A corrugated metal pipe will be placed vertically into the hole and backfilled. The poles will be field assembled and inserted by cranes into the embedded steel casings. The annular space between the pole and the steel casing will then be backfilled with crushed stone.

Some structures will require drilled concrete caisson foundations, typically 20 to 35 feet deep (depending on soil conditions and depth of bedrock), with typical diameters in the range of approximately 6 and 10 feet. These structures will include steel monopoles and steel H-frame steel structures. Caissons will be constructed by drilling a vertical shaft, installing a steel reinforcing cage, placing steel anchor bolts, pouring concrete, and backfilling. Typical structure details are provided in Appendix D. Structures will be lifted by a crane and placed and secured onto the anchor bolts.

On the Tiverton Taps, there are 58 new transmission structures to be installed and 58 existing transmission structures to be removed.

Excavated soil will be temporarily stockpiled next to the excavation; however, this material will not be placed directly into wetland areas. The stockpile of excavated material will be enclosed by staked straw bales or other sediment controls. Additional controls, such as watertight mud boxes, will be used for saturated stockpile management in work areas in wetlands (i.e., construction mat platforms) where sediment-laden runoff would pose an issue for the surrounding wetland. Following the backfilling operations, excess soil will be spread over unregulated upland areas or removed from the site in accordance with the Company's policies and procedures.

Dewatering may be necessary during excavations or pouring concrete for foundations. Dewatering will be performed in compliance with the Company's EG-303NE. Handling and management of wetland soils will be performed in accordance with a wetland soils management plan to be prepared by the contractor and accepted by the Company. Rock that is encountered during foundation excavation will generally be removed by means of drilling with rock coring augers. This method allows the same drill rig to be used and maintains a constant diameter hole. However, in some cases, rock hammering and excavation may be used to break up the rock. If overnight dewatering is required, the contractor will develop a plan for review and approval by the Company prior to commencing overnight dewatering activities to include full-time monitoring of overnight dewatering activities.

Dust suppression methods will be used during drilling operations, as deemed necessary, to minimize fugitive dust emissions. In addition, minimal quantities of earth will be moved or impacted during construction at each structure locations. Therefore, any impacts from fugitive dust particles will be of short duration and localized.

Installation of Conductor, Optical Ground Wire, and Shield Wire

Following the construction of transmission line structures, insulators will be installed to isolate the energized power conductors from the structure. OPGW, shield wire, and power conductors will then be installed using stringing blocks and wire stringing equipment. First, a temporary lead line will be installed on the structures within a given stringing section. The lead line will then be used to pull the final wire into place. The wire stringing equipment will be used to pull the conductors from a wire reel on the ground through stringing blocks attached to the structures 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. These guard structures are used to ensure public safety and uninterrupted operation of other utility equipment by keeping the wire away from other utility wires and clear of the traveled way at these crossing locations. Construction of temporary wire stringing and pulling sites on the ROW will be required to provide safe and level locations for equipment and personnel to perform wire stringing operation. The Company may use helicopter installation in some locations.

Removal and Disposal of Existing Transmission Line Components

As part of the Project, the Company will need to remove existing structures from the ROW. The Company proposes to recycle as much of the removed material as possible. Those components that are not salvageable and any debris that cannot be recycled will be removed from the ROW and disposed of at an approved off-site facility. Such materials will be handled in compliance with applicable laws and regulations and in accordance with the Company’s policy and procedures.

The Company’s Procurement Group manages the recycling and disposal of company facilities, equipment, and materials. The Procurement Group will oversee the recycling and disposal activities associated with the Project and incorporate these materials into the recycling program as appropriate.

Restoration and Stabilization of the ROW

Restoration efforts, including removal of construction debris, final grading, stabilization of disturbed soil, and the installation of permanent sediment control devices, will be completed following construction. 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 stone walls will be restored to the pre-existing conditions, if affected during construction. The Company has identified locations on the ROW where access roads and work pads will remain in place but will be covered with topsoil and seeded to more fully restore sections of the ROW. Where authorized by property owners, permanent gates and access roadblocks will be installed at key locations to restrict unwarranted access and trespass onto the ROW by unauthorized persons or vehicles. Regulated environmental resources that are temporarily disturbed by construction will be restored in accordance with applicable permit conditions.

3.3.3 Construction Traffic and Mitigation

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

The Company's contractors will coordinate closely with the representatives of Tiverton, and the Rhode Island Department of Transportation to develop Traffic Management Plans and Temporary Traffic Controls, as necessary, for work within state and local roads. At locations where construction equipment must be staged in the road, the contractors will follow a pre-approved work zone traffic control plan with appropriate police details. The Company will comply with required measures to ensure a safe environment for traffic flow and construction crews in and around the roadways. Appropriate safety measures will be implemented to allow safe traffic patterns for vehicles, bicyclists and pedestrians.

3.3.4 Construction Work Hours

Proposed construction work hours for the Project will be between 7:00 a.m. and 7:00 p.m. Monday through Friday when daylight permits and between 7:00 a.m. and 5:00 p.m. on Saturday. Some limited construction may occur outside of standard work hours when needed to complete certain activities. For example, some work tasks such as pulling in new conductor or concrete pours, once started, must be continued to completion, and may go beyond normal work hours.

The Town of Tiverton has enacted local ordinances for construction noise. The Tiverton ordinance (Section 38-144) indicates that properly permitted construction activities are allowed between the hours of 7:00 a.m. and 9:00 p.m. each day; the Company's proposed work hours are within this timeframe. The Company may seek a variance from the municipalities for the tasks described above that 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 Independent System Operation New England (ISO-NE) based on regional system load and weather conditions, can be limited. Such scheduled outages will have no effect on electric service to local customers. Work requiring scheduled outages and crossings of certain transportation and utility corridors may need to be performed on a limited basis outside of normal work hours, including on Sundays and holidays.

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

3.3.5 Environmental Compliance Monitoring

Throughout the construction-phase of the Project, the Company will retain the services of an environmental compliance monitor who will verify and report on compliance with all federal, state, and local permit requirements and the Company's policies and procedures. At regular intervals and after periods of prolonged or heavy precipitation or excessive snow melt, the environmental compliance monitor will inspect the environmental controls to confirm they are functioning properly. Prior to the start of construction, Project personnel will be trained on Project environmental requirements and permit conditions, including erosion and sediment controls, 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. The Company will conduct regular construction progress meetings to reinforce the construction team's awareness of these environmental requirements. Pre-construction "look-ahead meetings" will take place in the field with appropriate Project personnel. The Company's environmental compliance monitor will attend these meetings to provide feedback on environmental requirements and compliance to construction personnel.

In addition to retaining the services of an environmental compliance monitor, the Company will require construction personnel 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 and construction best management practices, driving safety, and good house-keeping practices on the ROW.

3.3.6 Safety and Public Health Considerations

The Company will design, build, and maintain the Project so that the health and safety of the public are protected. This will be accomplished through adherence to all applicable regulations, and industry standards and guidelines established for the protection of the public. Specifically, the Project will be designed, built, and maintained in accordance with the Company's own standards as well as the National Electric Safety Code. The facilities will be designed in accordance with sound engineering practices using established design codes and guides published by, among others, the Institute of Electrical and Electronic Engineers, the American Society of Civil Engineers, the American Concrete Institute, and the American National Standards Institute.

Practices which will be used to protect the public during construction will include, but not be limited to, establishing traffic control plans for construction traffic on busy streets to maintain safe driving conditions, restricting public access to work areas, noise and dust control, and coordination with the Town of Tiverton during construction.

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

3.3.7 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 has already undertaken efforts in this regard - a comprehensive stakeholder outreach campaign to educate and inform neighborhood residents, municipal officials, and businesses about the full scope of work to be undertaken to support this Project. Pre-construction outreach activity has included notifications to abutters and conversations with Project stakeholders regarding a variety of topics including grants of access, environmental matting needs, proposed structure locations, vegetation management, etc. The Company is committed to maintaining those conversations throughout the Project.

To date, the Company has completed the following activities listed below in furtherance of its outreach efforts.

- Meetings with the Town of Tiverton representatives 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 and email.
- Fact sheets, door hangers, FAQs, timelines, etc.
- Advertising.

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

State and Local Meetings

The Project team has met, and will continue to meet as needed, with all relevant governmental bodies with interest in, or impacted by, the Project scope. In advance of the filing, the Project team has met with Town representatives of Tiverton, Rhode Island to outline the Project need, benefits and high-level details around the Project route, local impacts, and tentative Project schedule. In addition, the Project team has briefed the Rhode Island Department of Transportation and other relevant state agencies. The Project team will continue to meet regularly with governmental stakeholders throughout the construction schedule to ensure a timely flow of information and provide opportunities for input.

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 close proximity to the Project to provide interested parties with an opportunity to learn more about the Project and ask questions of Project subject matter experts. Thus far, an open house session was held for the Project on January 30, 2024, at the Fort Barton Elementary School in Tiverton. Information about Company-hosted meetings will also be made available on the Project website, communicated via mailings, and promoted through local advertising.

Project Website

A Project website was developed (www.portsmouth-tiverton-electric-upgrades.com). 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 is available for interested parties to send questions or comments. The Project e-mail is listed in Project outreach materials, including fact sheets, mailings, the website, and signage at community events. An interactive map is featured on the website so interested parties can review the Project footprint and progress.

Project Hotline

A local phone number will be designated as the Project Hotline for the Project as the Company approaches the start of construction. The Project Hotline number will be listed in Project outreach materials, including fact sheets, mailings, the website, and signage at community events. A Project representative will staff the hotline and the Company pledges to respond within two businesses days to all inquiries – most often on the same business day whenever practical.

Abutter Communications

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

Door-to-Door Outreach

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

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 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.

Project Materials

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

3.3.8 Estimated Project Costs

The Company has prepared Project cost estimates as identified in Table 3-1. The cost estimates presented have an accuracy of +/- 30%. Estimated costs include costs of materials, labor and equipment, escalation, contingency and risk.

TABLE 3-1 ESTIMATED PROJECT COSTS

PROJECT COMPONENTS	ESTIMATED COST ($M)
Tiverton Tap Rebuild	$8,059,000

3.3.9 Project Schedule

The overall construction of the Project is expected to take approximately eight months to complete. The Company is anticipating having all permits-in-hand by September 2024. Construction is anticipated to begin in October 2024 and continue through Q2 2025.

The Company has developed a preliminary schedule based on time estimates for planning and engineering, permitting and licensing, construction, and schedule outages (Table 3-2). The overall ready for load date is anticipated by Q2 2025.

TABLE 3-2 PRELIMINARY PROJECT SCHEDULE*

ACTIVITY	ESTIMATED START DATE	ESTIMATED COMPLETION DATE
Planning and Engineering	Q4 2022	Q2 2024
Permitting and Licensing	Q2 2023	Q3 2024
Construction	Q4 2024	Q2 2025
Facilities Ready for Load	Q2 2025	
Final Restoration and Stabilization	Q2 – Q3 2025	

Note: *The construction schedule is dependent upon the availability of line outage windows, and the receipt of all applicable permits and approvals.

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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 asset condition refurbishments on the M13 and L14 Tap Lines. As described in Section 2.0, the Project is needed to improve reliability.

An important goal in the planning and development of the proposed electric transmission system improvements was to ensure that the solutions selected to meet the electrical system needs were the most appropriate in terms of cost and reliability, and that environmental impacts are minimized to the fullest extent possible. Analyses were undertaken to evaluate the feasibility of alternatives to the Project to ensure these objectives were met.

Section 4.2 describes the no-action alternative, Section 4.3 describes the underground line alternative, and Section 4.4 describes the Project.

4.2 No-Action Alternative

The no-action alternative would leave the Tiverton Tap lines in their current condition, not meeting existing reliability and safety standards. The Tiverton Tap lines are considered to be some of the poorer performing circuit on the Company's transmission system. The existing wood poles along the line are showing signs of significant asset deterioration due to rotting, woodpecker holes, bowing, and discoloration. Insulators on structures throughout the line also show signs of flashing, chips, and breaks. The conductor damage indicates a high risk of failure due to historical operations and insufficient design against increased severe weather patterns. Failures along the line due to the current asset condition will not only impact customer interruptions but pose severe public safety risks. For these reasons, the No Action is not an acceptable alternative for maintaining a firm and reliable electric supply for customers as it would not address the need to bring the Tiverton Tap lines up to current codes and resolve the condition and reliability issues. The no-action alternative is not acceptable from either an operational or reliability perspective.

4.3 New Underground Route Alternative

The Company considered two configurations for new underground transmission cables. The Company first considered the feasibility of constructing two new parallel 115 kV transmission cables within the existing ROW. The ROW rights along the Tiverton Tap ROW are held in fee by the Company. In this case, the Company may have the ability to propose underground as an option. One exception, though, may be at the high-pressure natural gas pipeline crossing located in Tiverton, as the natural gas facility predates the Company's acquisition of the fee interest. Algonquin Gas Transmission, the pipeline operator, could argue that an underground electric transmission facility may conflict with their rights to operate and maintain the natural gas pipeline. Impacts to the natural environment would be significantly more than the preferred alternative due to the need to excavate two, continuous trenches within the ROW for the installation of the duct bank and manhole systems that would house the underground transmission cables.

The Company considered a second underground configuration which would involve identifying and securing a route to construct two parallel 115 kV underground cables. The most feasible route would be identifying a route along existing public (state and local) roadways. Detailed surveys would be required to identify and evaluate the existing inventory and density of underground and overhead utilities located along the roadway route(s) to determine if there is available real estate to install two series of concrete duct bank and manhole systems. Relocating existing buried utilities is a high probability. An underground alternative located outside of the transmission line ROW would be much longer in length and impacts to the social environment would be significantly more than the preferred alternative because of the need for continuous construction with the public roadways affecting commuter traffic, and residential and commercial land uses along the public roadways. The cost of an underground alternative is at least ten times more costly than an overhead alternative, which would affect the Company's customer base.

For the reasons outlined above, the Company dismissed the underground alternative from further consideration.

4.4 Parallel Circuit Transmission Line Rebuild (Preferred Alternative)

The Company concluded that the proposed Project is the preferred alternative to meet the identified need. The proposed Project includes structure replacements along approximately 1.76 miles of the M13-1/L14-1 Tiverton Power Taps, and 0.20 miles of the M13-3/L14-3 Tiverton 2 Taps. The existing conductor (with the exception of 0.54 miles along the M13-1/L14-1 Tiverton Power Taps as described in Section 2.0) will be replaced (reconductored) with new single 1113 kcmil ACSS conductor. The existing shield wire will be replaced with OPGW from the Massachusetts/Rhode Island state border to Tiverton 2 Substation and the substation at the Tiverton Power Substation. The Company will be maintaining and upgrading access roads, signage and grounding along the full length of Project, as applicable. This option is the only alternative that addresses the need to resolve the condition and reliability issues with the existing lines.

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

4.5 Conclusion

The Company evaluated alternatives in the development of the Project as described above. Ultimately, the Company concluded that upgrading and reconductoring the existing M13 and L14 Taps is significantly preferred to the other alternatives because it will: (i) resolve the age, condition, and reliability concerns with the M13 and L14 taps while meeting the need for the Project at the lowest possible cost; (ii) minimize environmental impacts; and (iii) be completed in the shortest timeframe.

5.0 DESCRIPTION OF AFFECTED NATURAL ENVIRONMENT

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

The Project involves the rebuild of the existing 115 kV transmission lines mostly within the Company's existing ROW easements and primarily within the maintained portion of the existing ROW. As a result, the Project is anticipated to have only limited and temporary impacts on the natural environment including, soils, vegetation, surface water, wetland and waterbodies, and wildlife. The Project is anticipated to have no impact on geology and therefore the geological characteristics are not included in the below assessment.[2]

5.1 Project Study Area

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

5.2 Topography, Drainage Basins, and Floodplains

The Project area consists of existing and maintained overhead electric transmission ROW. Topography within the ROW is variable with sections of relatively flat lands and sections of rolling hills with moderate slopes. Elevations range widely from approximately 10 to 150 feet above mean sea level throughout the ROW.

The Project lies wholly within the Narragansett Bay drainage basin. Sub-watersheds within major basins are further delineated into smaller watersheds identified by a unique level, Hydrologic Unit Code (HUC- 12), of which two are crossed by the Project. From north to south, the Project ROW traverse the Quequechan River sub-watershed (HUC-12 010900040803) and the Sakonnet River sub-watershed (HUC-12 010900040910) (Rhode Island Geographic Information Systems 2007). No drinking water supply watersheds are crossed by the Project.

No Federal Emergency Management Agency-mapped 100-year floodplains are present within the Project area.

5.3 Soils

Because soils will be disturbed and graded for access roads, work pads and pull pads during Project construction, information concerning the physical properties, classification, agricultural suitability, and erodibility of soils near the Study Area (Figure 5-1) were obtained from the Natural Resource Conservation Service. The Soil Survey delineated map units that may consist of one or more soil

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

series and/or miscellaneous non-soil areas that are closely and continuously associated on the landscape. In addition to the named series, map units include specific phase information that describes the texture and stoniness of the soil surface and the slope class. The soil series within the Study Area were identified. Common soil types found within the Study Area include udorthents-urban land complex, Canton and Charlton fine sandy loams, 3 to 15% slopes, very rocky, and Freetown Muck. These soil types make up approximately 56% of the Study Area soils. Study Area hydric soil (organic, wetland soil) status is depicted on Figure 5-2.

5.3.1 Erosive Soils

The erodibility of soils is dependent upon the slope of the land and the texture of the soil. Soils are given an erodibility factor (K), which is a measure of the susceptibility of the soil to erosion by water. Soils having the highest K values are the most erodible. K values range from 0.02 to 0.69 and vary throughout the depth of the soil profile with changes in soil texture. Very poorly drained soils and certain floodplain soils usually occupy areas with little or no slope. Therefore, these soils are not subject to erosion under normal conditions and are not given an erodibility factor. Soil map units with moderate or higher erosion hazard within in the Study Area include Bridgehampton silt loam, Broadbrook silt loams, Broadbrook silt loam, Broadbrook very stony silt loam, Mansfield mucky silt loam, Mansfield very stony mucky silt loam, Narragansett silt loam, Narragansett very stony silt loam, Newport silt loam, Newport very stony silt loam, Newport extremely stony silt loam, and Udorthents-Urban land complex. These soil map units have a K factor value of 0.15 to 0.43 and make up approximately 33% of the Study Area.

5.3.2 Prime Farmland Soils

Prime farmland, as defined by the United States Department of Agriculture (USDA), is the land that is best suited to producing food, feed, forage, fiber, and oilseed crops. It has the soil quality, growing season, and moisture supply needed to economically produce a sustained high yield of crops when it is treated and managed using acceptable farming methods. Farmland of statewide importance is land, in addition to prime farmland, that is of statewide importance for the production of food, feed, fiber, forage and oilseed crops. Generally, farmlands of statewide importance include those lands that do not meet the requirements to be considered prime farmland, yet they economically produce high yield of crops when treated and managed with modern farming methods. Some may produce as high a yield as prime farmland if conditions are favorable.

Prime farmland and farmland of statewide importance located within the Study Area are identified in Table 5-1. Approximately 2% of the Study Area is made up of soils classified as Prime Farmland Soils, and approximately 2% of the Study Area is made up of soils classified as Farmland of Statewide Importance.

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

SOIL MAP UNIT SYMBOL	NAME	PRIME FARMLAND	FARMLAND OF STATEWIDE IMPORTANCE
BmB	Bridgehampton silt loam, till substrate, 3 to 8 percent slopes		X
BrB	Broadbrook silt loam, 3 to 8 percent slopes	X	
CdB	Canton and Charlton fine sandy loams, 3 to 8 percent slopes	X	
Se	Stissing silt loam		X

Source: Natural Resources Conservation Service

5.4 Description of Uplands

The Project is located within a managed transmission line ROW where vegetation is maintained as low-growing shrub and herbaceous habitats. The Project ROW and surrounding areas are largely developed and as a result the majority of the ROW features upland area. Undeveloped portions of the ROW are predominately surrounded by upland forest characterized by broad-leaved deciduous tree species including northern red oak (*Quercus rubra*), eastern white oak (*Quercus alba*) and red maple (*Acer rubrum*). Within upland portions of the maintained ROW, routine vegetation management has favored the establishment of early successional shrubland. Shrub species commonly found within the managed ROW include roundleaf greenbrier (*Smilax rotundifolia*), rambler rose (*Rosa multiflora*), Virginia creeper (*Parthenocissus quinquefolia*), sweet fern (*Comptonia peregrina*), and blackberry (*Rubus* spp.) interspersed with sweet pepperbush (*Clethra alnifolia*) and smooth arrowwood (*Viburnum dentatum*). Patches of herbaceous vegetation interspersed within shrub-dominated areas included species such as Canada goldenrod (*Solidago canadensis*), wrinkle-leaved goldenrod (Solidago rugosa), flat-top goldenrod (*Euthamia graminifolia*), and hay-scented fern (*Dennstaedtia punctilobula*).

In addition to the natural environment, there are a variety of upland land cover types adjacent to the ROW. Uplands adjacent to both transmission Tap lines in Tiverton are dominated by undeveloped upland forest and several areas of industrial development.

5.5 Water Resources

5.5.1 Surface Waters

The Study Area lies entirely within the Narraganset Bay subbasin. Within the subbasin, the Project crosses two watersheds including Narragansett Bay-Frontal Rhode Island Sound in Fall River, Massachusetts and Tiverton, Rhode Island and the Lower Taunton River watershed in Fall River, Massachusetts and Tiverton, Rhode Island (RIGIS 2007). Watersheds are further delineated into smaller sub watersheds identified by a unique level, Hydrologic Unit Code (HUC-12). The Project ROW crosses two sub watersheds, including Quequechan River and Sakonnet River, as detailed in Table 5-2.

TABLE 5-2 HYDROLOGIC UNIT CODE-12 SUB WATERSHEDS CROSSED BY THE PROJECT

LINE SEGMENT	BEGIN STRUCTURE	END STRUCTURE	HUC12 CODE AND NAME
Tiverton Tap	L14 Tap 27/M13 Tap 27	T1-10/T2-10	010900040803 Quequechan River
Tiverton Tap	T1-11/T2-11	T1-1/T2-1	010900040910 Sakonnet River

Source: RIGIS 2007

The named surface water resources and classifications within the Study Area are listed in Table 5-3. Pursuant to the Rhode Island Water Quality Regulations (250-RICR-150-05-1), the waters of the state of Rhode Island (meaning all surface water and groundwater of the State) are assigned a Use Classification which is defined by the most sensitive uses which it is intended to protect. Waters are classified according to specific physical, chemical, and biological criteria which establish parameters of minimum water quality necessary to support the water Use Classification. The water quality classification of the major surface waters within the Study Area are identified in the descriptions of the water bodies that follow.

1. All streams tributary to Class A waters shall be Class A.

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

Special Resource Protection Waters are high quality surface waters identified as having significant ecological or recreation uses. No Special Resource Protection Waters are located within the Study Area.

TABLE 5-3 NAMED SURFACE WATER RESOURCES WITHIN THE STUDY AREA

WATER BODY NAME	TOWN	USE CLASSIFICATION	FISHERY DESIGNATION	WATER BODY CROSSED
Cook Pond[1]	Fall River, MA	C	Warm	No
Sucker Brook[1]	Fall River, MA Tiverton, RI	B A	Warm Warm	No No
Tributary to Sin and Flesh Brook	Tiverton, RI	B1	Warm	Yes

Notes: [1]These waterbodies are located within the Study Area but not within the Project ROW.
Use Classification:
A: These waters are designated for primary and secondary contact recreational activities and for fish and wildlife habitat. They shall be suitable for compatible industrial processes and cooling, hydropower, aquacultural uses, navigation, and irrigation and other agricultural uses. These waters shall have excellent aesthetic value.
B: These waters are designated for fish and wildlife habitat and primary and secondary contact recreational activities. They shall be suitable for compatible industrial processes and cooling, hydropower, aquacultural uses, navigation, and irrigation and other agricultural uses. These waters shall have good aesthetic value.
B1: These waters are designated for primary and secondary contact recreational activities and fish and wildlife habitat. They shall be suitable for compatible industrial processes and cooling, hydropower, aquacultural uses, navigation, and irrigation and other agricultural uses. These waters shall have good aesthetic value. Primary contact recreational activities may be impacted due to pathogens from approved wastewater discharges. However, all Class B criteria must be met.
C: These waters are designated for secondary contact recreational activities and fish and wildlife habitat. They shall be suitable for compatible industrial processes and cooling, hydropower, aquacultural uses, navigation, and irrigation and other agricultural uses. These waters shall have good aesthetic value.
Source: State of Rhode Island Water Quality Regulations 250-RICR-150-05-01. Available at https://rules.sos.ri.gov/regulations/part/250-150-05-1, accessed on February 23, 2024.

Pursuant to the requirements of Section 305(b) of the federal Clean Water Act, water bodies that are determined to be not supporting their designated uses in whole or in part are considered impaired and scheduled for restoration. The causes of impairment are those pollutants or other stressors that contribute to the actual chemical contaminants, physical parameters, and biological parameters. Sources of impairment are not determined until a total maximum daily load (TMDL) assessment is conducted on a water body. Table 5-4 lists the impaired surface water resources in the Study Area based on the State of Rhode Island 2022 Impaired Waters Report (RIDEM 2022).

TABLE 5-4 IMPAIRED SURFACE WATER RESOURCES IN THE STUDY AREA

WATER BODY NAME	IMPAIRMENT	CATEGORY
Sucker Brook[1]	Enterococcus	4A
	Copper	5

Notes: [1]This waterway is located within the Study Area but not within the Project ROW.
Category 4A TMDL has already been completed. Waterbodies are listed and tracked under Category 4A when the TMDL has been completed by RIDEM and approved by United States Environmental Protection Agency.
Category 5 Impaired or threatened for one or more uses and requires a TMDL, development of TMDL needed.
Source: State of Rhode Island Water Quality Regulations 250-RICR-150-05-01. Available at https://rules.sos.ri.gov/regulations/part/250-150-05-1, accessed on February 23, 2024.

5.5.2 Wetlands and Waterbodies

On behalf of the Company, POWER wetland scientists completed a delineation of wetlands and waters of the United States on February 9 and 14, 2023; June 6, 2023; September 11-15, 2023; and October 3-6, October 10-13, and October 19, 2023. A total of 35 wetlands, 10 nontidal watercourses (7 perennial and 3 intermittent streams), and 1 tidal watercourse (the Sakonnet River) were identified and delineated. During field surveys, wetlands were identified and delineated in accordance with requirements of the Clean Water Act (33 United States Code §§ 1251 et seq., Section 404 and Section 401). Pursuant to the recently updated definition of "waters of the United States" effective September 8, 2023, relatively permanent standing or continually flowing bodies of water, including wetlands with a continuous surface connection to those waters, are subject to the federal Clean Water Act. Wetlands display evidence of three wetland indicators – predominance of hydrophytic (wetland) vegetation, hydric soils, and surface hydrology. This three-parameter approach was used by the field team to identify and delineate the wetlands in accordance with the 1987 *Corps of Engineers Wetland Delineation Manual* (United States Army Corps of Engineers [USACE] 1987) and the *subsequent Regional Supplement to the United States Army Corps of Engineers Wetland Delineation Manual: Northcentral and Northeast Region* (USACE 2012). Apart from unusual or atypical situations, evidence of wetland must be exhibited by all three parameters for an area or position to be designated as wetland.

Field methodology for the delineation of State-regulated resource areas within the ROW was based upon vegetative composition, presence of hydric soils, and evidence of wetland hydrology. The study methods included both on-site field investigations and off-site analysis to determine the wetland and watercourse resource areas on the Project ROW. Wetlands outside the ROW but within the Study Area were identified based on a desktop review of United States Fish and Wildlife Service's (USFWS') National Wetland Inventory (NWI) data, Rhode Island wetlands data (RIGIS 1993), and Massachusetts Department of Environmental Protection wetlands data (2017). Figure 5-3 depicts wetland resources within the Study Area based on available NWI and state wetland data.

A two-person field team comprised of a wetland ecologist and an environmental specialist performed a field survey to identify, characterize, and map coastal and freshwater wetland and watercourse resources along the Tiverton Tap and EMI Tap ROW. The survey area also included the following existing access roads/routes:

- An access road on Company property between Fish Road and Tiverton Substation in Tiverton, Rhode Island.
- An access road within the National Grid ROW off Route 24 in Fall River, Massachusetts.

The field team utilized a Juniper Geode GNS2 global navigation satellite system receiver paired with an iPad (or similar device) running Esri Field Maps software with a project-specific base map to provide real time sub-meter accuracy resource mapping. Wetland and stream boundary flags (pink and blue, respectively) were labeled with Resource Identification (ID) and Flag Number and hung on persistent vegetation in the field. The field-delineated wetlands included with permit plans (Appendix B) show the extent of field delineated wetlands, streams, and shoreline features.

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

In accordance with the provisions of the Rhode Island Fresh Water Wetlands Act and Rules, the Coast Resources Management Council Freshwater Wetlands in the Vicinity of the Coast, state-regulated freshwater wetlands include swamps, marshes, bogs, forested or shrub wetlands, emergent plant communities and other areas dominated by wetland vegetation and showing wetland hydrology. The wetlands have a regulated jurisdictional area which extends 100 feet outward from the edge of the wetland. The Rules also regulate activities in and around streams and open water bodies which include rivers, streams, ponds, Areas Subject to Storm Flowage (ASSFs), Areas Subject to Flooding (ASFs), and floodplains. The Study Area is primarily located within the Non-Urban River Protection Region 2, and a portion of the Stafford Pond drinking water supply watershed in Tiverton, Rhode Island. The rivers, streams, and drinking water supply reservoirs have a regulated jurisdictional area which extends 200 feet outward from the resource's bank.

POWER identified and mapped 15 wetlands within the survey area. Specific wetland features identified during the field review include both freshwater and coastal wetlands. The NWI wetlands and deepwater habitat classification system (Federal Geographic Data Committee 2013) defines wetland and deepwater habitat resources via a series of alpha-numeric codes which correspond to the classification nomenclature that best describes a particular wetland habitat type. Wetlands within the survey area were assigned the following NWI classification codes as determined by the wetland ecologist during the field review:

- Palustrine Emergent (PEM) wetlands are nontidal wetland systems dominated by emergent plants—i.e., erect, rooted, herbaceous hydrophytes, excluding mosses and lichens—as the tallest life form with at least 30% areal coverage. This vegetation is present for most of the growing season in most years. These wetlands are usually dominated by perennial plants.
- Palustrine Forested (PFO) wetlands are nontidal wetland systems where trees are the dominant life form—i.e., the tallest life form with at least 30 percent areal coverage. Trees are defined as woody plants at least six meters (20 feet) in height.
- Palustrine Scrub-shrub (PSS) wetlands are nontidal wetland systems where woody plants less than six meters (20 feet) tall are the dominant life form—i.e., the tallest life form with at least 30 percent areal coverage. The "shrub" life form includes true shrubs, young specimens of tree species that have not yet reached six meters in height, and woody plants (including tree species) that are stunted because of adverse environmental conditions.

The 15 wetland resources identified within the survey area are individually summarized in Table 5-5. Information included in Table 5-5 includes field-verified wetland community type(s) assigned to wetlands per the NWI wetlands and deepwater habitat classification system (Federal Geographic Data

Committee 2013). Hydric ratings of soils underlying wetland areas were determined from the USDA's Natural Resources Conservation Service's Web Soil Survey (2023) online interactive mapping system. Dominant vegetation types were identified by the wetland ecologist during the field review.

The wetlands and waterways delineation did not identify any intermittent or perennial streams.

Pond

The boundary of a pond is determined by the extent of its water which is delineated and surveyed. A pond is an area of open standing or slow-moving water present for six or more months during the year. Ponds make up approximately 8 acres of the Study Area. Named ponds located within the Study Area are listed in Table 5-3.

Scrub-shrub and Forested Swamp

Swamps are defined as freshwater wetland areas dominated by woody vegetation, where groundwater is at or near the surface for a significant part of the growing season. Scrub-shrub swamps are areas dominated by broad-leaved woody shrubs less than 20 feet in height and often have an emergent herbaceous layer. Typical species in shrub swamps in the Study Area include sweet pepperbush (*Clethra alnifolia*), highbush blueberry (*Vaccinium corymbosum*), winterberry (*Ilex verticillata*), southern arrowwood (*Viburnum dentatum*), and silky dogwood (*Cornus amomum*). Drier portions of shrub swamps are often densely overgrown with greenbrier (*Smilax rotundifolia*), multiflora rose (*Rosa multiflora*) and blackberry (*Rubus allegheniensis*). Common species in the herbaceous layer include sensitive fern (*Onoclea sensibilis*), spotted touch-me-not (*Impatiens capensis*), and cinnamon fern (*Osmundastrum cinnamomeum*). There are approximately 32 acres of shrub swamp within the Study Area.

Forested swamps are dominated by trees over 20 feet in height and generally occupy low-lying terrain subject to periodic flooding by adjacent waterbodies or other areas with shallow groundwater. Forested swamps in the Study Area are dominated by red maple (*Acer rubrum*), willow (*Salix* sp.), and black gum (*Nyssa sylvatica*) trees with an understory of alder (*Alnus* sp.), silky dogwood, sweet pepperbush, winterberry, cinnamon fern, common reed (*Phragmites australis*), and peat moss (*Sphagnum* spp.). There are approximately 302 acres of forested swamp within the Study Area.

Marsh and Wet Meadow

Marshes are freshwater wetlands where water is generally above the surface of a mucky substrate and where the vegetation is dominated by emergent herbaceous species. Emergent marsh vegetation is dominated by hydrophytic species such as common reed (Phragmites australis), cattail (*Typha* sp.), burreeds (*Sparganiaceae*), arums (*Araceae*), and water lilies (*Nymphaeaceae*). Wet meadows are typically drier than emergent marshes and occupy seasonally saturated mineral substrates dominated by woolgrass (*Scirpus cyperinus*), soft rush (*Juncus effusus*), goldenrod (*Solidago* sp.), sensitive fern (*Onoclea sensibilis*), and reed canary grass (*Phalaris arundinacea*). Within the Study Area there are approximately 11 acres of marsh or wet meadows.

Salt Marsh

Salt marshes are estuarine intertidal wetland systems which occur on the bay side of barrier beaches and the outer mouth of tidal rivers where salinity is not much diluted by freshwater input (Enser et al. 2011). The typical salt marsh profile, from sea to land, features a low, regularly flooded marsh dominated by salt marsh cordgrass (*Spartina alterniflora*); a higher, irregularly flooded marsh dominated by salt meadow cordgrass (*Spartina patens*) and saltgrass (*Distichlis spicata*); low hypersaline pannes characterized by saltwort (*Salicornia* sp.); and a salt scrub ecotone characterized by marsh elder (*Iva frutescens*.), groundsel-tree (*Baccharis halimifolia*), and switchgrass (*Panicum* sp.). No salt marsh was identified during wetland surveys on the ROW.

River/Perennial Stream

A river is typically a named body of water designated as a perennial stream by the United States Geological Survey (USGS). A perennial stream maintains flow year-round and is also designated as a solid blue line on a USGS topographic map. Five perennial waterbodies are located within the Study Area based on a GIS analysis of National Hydrography Dataset. No perennial streams were identified during wetland surveys of the ROW.

Stream/Intermittent Stream

A stream is any flowing body of water or watercourse other than a river which flows during sufficient periods of the year to develop and maintain defined channels. Such watercourses carry groundwater discharge and/or surface water runoff. Such watercourses may not have flowing water during extended dry periods but may contain isolated pools of standing water. Four intermittent streams were identified within the Study Area based on a GIS analysis of National Hydrography Dataset. No intermittent streams were identified during wetland surveys along the ROW.

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. No floodplains were identified in the Study Area.

Area Subject to Storm Flowage

ASSF is 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. Two ASSFs were identified during wetland surveys on the ROW.

Area Subject to Flooding

ASF includes, but are not limited to, floodplains, depressions or low laying areas flooded by rivers, streams, intermittent streams, or areas subject to storm flowage which collect, hold, or meter out storm water and flood waters. ASFs do not connect to other freshwater or coastal wetlands as ASSFs do. No ASFs were identified during wetland surveys on the ROW.

Vernal Pools

A vernal pool is a depressional wetland basin that typically goes dry in most years and may contain inlets or outlets, typically of intermittent flow. Most vernal pools are shallow intermittent bodies of water that fill in fall or spring with rain or snowmelt and dry up by mid-summer because they lack a permanent source of water. Vernal pools can be isolated depressions or found within wetlands such as red maple swamps (RIDEM 2024).

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; these obligate vernal pool species include wood frog (*Lithobates sylvaticus*), spotted salamander (*Ambystoma maculatum*), marbled salamander (*L. opacum*), and fairy shrimp (*Eubranchipus* spp.).

Field investigations for potential vernal pools were performed during the wetland field surveys. The wetlands on the ROW were investigated to confirm the presence/absence of potential vernal pool habitats. One potential vernal pool was identified during wetland surveys on the ROW within wetland TTW01. Rhode Island has no publicly available mapping data for vernal pools.

TABLE 5-5 WETLANDS WITHIN SURVEY AREA

WETLAND ID	WETLAND CLASS[1]	MUNICIPALITY	HYDRIC SOIL RATING[2]	DOMINANT VEGETATION
TTW01	PFO	Tiverton, RI	No	Panicled hydrangea (*Hydrangea paniculata*), Red maple (*Acer rubrum*)
TTW02	PEM/PSS	Tiverton, RI	Yes	Common reed (*Phragmites australis*), Coastal sweet pepperbush (*Clethra alnifolia*)
TTW03	PEM/PSS	Tiverton, RI	No	Common reed (*Phragmites australis*), Coastal sweet pepperbush (*Clethra alnifolia*)
TTW04	PEM	Tiverton, RI	Yes	Sweet pepperbush (*Clethra alnifolia*), Common greenbrier (*Smilax rotundifolia*)
TTW05	PFO	Tiverton, RI	No	Red maple (*Acer rubrum*), Coastal sweet pepperbush (*Clethra alnifolia*)
TTW06	PFO	Tiverton, RI	No	Red maple (*Acer rubrum*), Coastal sweet pepperbush (*Clethra alnifolia*)
TTW07	PEM	Tiverton, RI	Yes	Common reed (*Phragmites australis*), Sensitive fern (*Onoclea sensibilis*)
TTW08	PEM	Tiverton, RI	Yes	Sheep laurel (*Kalmia angustifolia*), Highbush blueberry (*Vaccinium corymbosum*)
FTW01	PEM	Fall River, MA	Not rated	Shallow sedge (*Carex lurida*), Common reed (*Phragmites australis*)
FTW02	PEM	Fall River, MA	Not rated	Common reed (*Phragmites australis*), Speckled alder (*Alnus incana*)
FTW03	PEM/PSS	Fall River, MA	Not rated	Common reed (*Phragmites australis*), Smooth arrowwood (*Viburnum recognitum*)
FTW04	PEM	Fall River, MA	Not rated	Common reed (*Phragmites australis*), Multiflora rose (*Rosa multiflora*)
TW01E	PEM	Tiverton, RI	No	Soft rush (*Juncus effusus*), Woolgrass (*Scirpus cyperinus*)
TW02E	PSS	Tiverton, RI	Yes	Coastal sweet pepperbush (*Clethra alnifolia*), Devil's walkingstick (*Aralia spinosa*)
TW03E	PSS	Tiverton, RI	No	Coastal sweet pepperbush (*Clethra alnifolia*), Red maple (*Acer rubrum*)

Notes: Acronyms and abbreviations are listed at the beginning of this report.
[1] Wetlands classified according to Cowardin et al. 1979.
[2] Hydric soil data derived from the USDA Natural Resource Conservation Service's online Web Soil Survey tool (2023).

5.5.3 Groundwater Resources

The RIDEM classifies all the State's groundwater resources and establishes groundwater quality standards for each class. The four classes are designated GAA, GA, GB, and GC. Groundwater classified as GAA and GA is to be protected to maintain drinking water quality. Groundwater classified GB are those groundwater resources which may not be suitable for public or private drinking water use without treatment due to known or presumed degradation resulting from overlying land uses. Class GC groundwater is known to be unsuitable for drinking water use due to waste disposal practices such as landfills. Class GB and GC areas are served by a public water supply (RIDEM 2023). 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. Rhode Island groundwater resources within the Study Area include only GA. Because GAA and GA are suitable for drinking water use without treatment, both classes are subject to the same groundwater quality standards.

The United States Environmental Protection Agency (USEPA) has designated Sole Source Aquifer status to aquifers that supply at least 50% of the drinking water for its service area and for which there are no reasonably available alternative drinking water sources should the aquifer become contaminated. The purpose of sole source aquifer designation is to manage land use practices within the aquifer recharge area to protect groundwater quality. There are no sole source aquifers in the Study Area.

5.6 Vegetation

The Study Area contains a variety of vegetative cover typical of Southern New England, including ruderal and oak-dominated forests, ruderal grassland/shrubland, urban/recreational grass, and agricultural land. This section of the report focuses on upland communities. Wetland communities are discussed in Section 5.3.2 of this report.

Vegetation communities in Rhode Island have been affected by human activities for more than 10,000 years. Prior to European settlers in the seventeenth century, Rhode Island's land cover was >90% forested. Clearing land for farming and logging reduced forest cover to only 25% by the mid-1800s. By the mid-1960s, abandoned farmlands had reverted to early successional forests, which once again covered approximately 65% of the state. Since that time, conversion of forest to other community types or non-vegetated areas has occurred due to development and land use changes. According to the most recent Rhode Island Forest Inventory Analysis compiled by the United States Forest Service (USFS), approximately 47% of Rhode Island's land area is forested (USFS 2019). The remainder of the State's undeveloped upland vegetated land cover is primarily comprised of natural and ruderal open uplands, and urban/recreational grass.

Rhode Island forests are dominated by a variety of hardwoods, with red maple the most abundant tree species whereas the oak-hickory forest type assemblage comprises 61% of the state's forested land cover (RIDEM 2020). The oak-hickory forest type is dominant in the northern part of the state with patches of pine forest found in the southern part of the state. Going from north to south, oak-hickory forests decrease and pine-dominated forest types increase, with the central part of the state consisting mostly of mixed oak and pine (USFS 2002).

5.6.1 Oak Forests

Forested cover types within the Study Area are typically dominated by oaks (*Quercus* spp.) with or without an eastern 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 include black (*Q. velutina*), scarlet (*Q. coccinea*), and white oaks (*Q. alba*) as well as aspen and gray birch. The shrub/sapling understory includes such species as black cherry (*Prunus serotina*) and common greenbrier. Sheep laurel (*Kalmia angustifolia*) and sweet fern (*Comptonia peregrina*) occasionally occur in openings between oak stands with canopy openings and on rocky slopes. Understory herbaceous species include bracken fern (*Pteridium aquilinum*), tree clubmoss (*Dendrolycopodium 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 mid-slopes compared with dry hilltops. The increase in soil moisture produces this greater diversity in trees, shrubs and herbs. Mid-slope tree species in addition to oaks include black birch (*Betula lenta*), white ash (*Fraxinus americana*), American beech (*Fagus grandifolia*), maple (*Acer* sp.), and several species of hickory (*Carya* spp.). Shrubs include witch hazel (*Hamamelis virginiana*), sassafras (*Sassafras albidum*), highbush blueberry, sweet pepperbush, and ironwood (*Carpinus caroliniana*). Greenbrier, poison ivy (*Toxicodendron radicans*), and tree clubmoss are also common in this community. Mid-slope 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, primarily along the Tiverton Tap north of Tiverton Substation to the Massachusetts state border.

5.6.2 Ruderal Forest

Within the Study Area, ruderal forests are often associated with lands near residential subdivisions, commercial development, and highway corridors that have been subject to previous disturbance. Ruderal forests are often fragmented, undifferentiated upland forests, typically even-aged, resulting from succession following removal of native trees for agriculture, logging, or other land-clearing activities. Soil disturbance caused during native overstory removal tends to result in low-diversity regeneration, often with a non-native understory and early-succession tree species. Common crown species include red maple, eastern white pine, aspen (*Populus* sp.), and gray birch (*Betula populifolia*). Understory species are varied and may contain shrubs and vines such as multiflora rose, serviceberry (*Amelanchier canadensis*.), glossy buckthorn (*Rhamnus frangula*), ironwood (*Carpinus caroliniana*), common greenbrier, and grape (*Vitis* sp.).

5.6.3 Ruderal Grassland/Shrubland

Across Rhode Island, ruderal grasslands and shrublands occupy fallow farmlands, reverting woodlots, utility ROWs, and other areas maintained in an early successional ecological state. Ruderal grasslands and shrublands are anthropogenic communities of herbaceous or mixed herb/shrub vegetation resulting from succession following removal of tree cover. Within the Study Area, most ruderal grassland/shrubland habitat is associated with cleared and maintained portions of electric transmission ROWs.

Periodic vegetation management through mowing, selective cutting, or other methods to remove tree saplings within cleared and maintained ROWs favors the establishment and persistence of grasses, herbs, and shrubs. The species assembly and structure may vary considerably within a cleared and maintained ROW from low growing sparsely vegetated herbaceous fields to very dense shrub cover. Sweet fern (*Comptonia peregrina*), bayberry (*Myrica pensylvanica*), highbush blueberry, sheep laurel (*Kalmia angustifolia*), sweet, and arrowwoods (*Viburnum* sp.) are shrub species commonly found within the Study Area. On the mid-slope, common greenbrier and blackberry form dense, impenetrable thickets. Numerous herbs including goldenrod, asters (*Aster* sp.), bracken fern, hay scented fern, deer-tongue grass (*Dichanthelium clandestinum*), pokeweed (*Phytolacca americana*), and mullein (*Verbascum thapsus*) are also common.

Forest vegetation abuts managed ROWs in many places within the Study Area. Over time, pioneer species and/or saplings from adjacent forested areas may become established in ROWs, eventually triggering management activities. Maintenance of low-growing vegetation communities within ROWs is imperative to maintaining system reliability and safety.

5.6.4 Urban/Recreational Grass

Urban/recreational grass areas are managed grasslands planted in developed settings for recreation, erosion control, aesthetic, or other purposes and are prevalent in the residential and commercially developed portions of the Study Area. Urban/recreational grass areas include residential and commercial lawns, golf courses, playing fields, parks, and highway shoulders and medians. Typically, these areas consist of a continuous grass cover which may include Kentucky bluegrass (*Poa pratensis*), red fescue (*Festuca rubra*), clover (*Trifolium* sp.), and plantains (*Plantago* sp.). Ornamental shrubs may also occur within the residential and parkland areas.

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. Typical wildlife species found commonly in the habitat types within the Study Area may include the following:

- Mammals such as white-tailed deer, foxes, raccoons, weasels, squirrels, and bats.
- A variety of birds such as passerine songbirds, waterfowl, birds of prey, and gamebirds.
- Amphibians and reptiles such as salamanders, frogs, toads, turtles, and snakes.
- Many different species of invertebrates.

During initial field activities in 2023, a potential nest of an osprey (*Pandion haliaetus*) was discovered and documented on the top of existing structure L14 Tap-27 in Fall River, Massachusetts. Osprey are protected under the Migratory Bird Treaty Act and a permit from the USFWS must be obtained prior to relocating active nests if deemed necessary for Project activities.

5.7.1 Fisheries

RIDEM has listed Designated Trout Waters for the 2023/24 season, which include Adamsville Brook and Pond, Eight Rod Farm Pond, Stafford Pond, and Tiverton Trout Pond in Tiverton, Rhode Island (RIDEM 2023). No Designated Trout Waters occur within the Study Area.

Refer to Table 5-1 for the warm and cold-water fishery designations associated with the surface water bodies within the Study Area. Although Rhode Island does not have a formal definition of cold-water fishery, the term generally means the waterbody has the capacity to support, on a year-round basis, wild or stocked brook trout (*Salvelinus fontinalis*). Warm-water fisheries are waters which cannot support brook trout populations but have the capacity to support species such as brown bullhead (*Ameriurus nebulosus*), bluegill (*Lepomis macrochirus*), smallmouth bass (*Micropterus dolomieu*), largemouth bass (*M. salmoides*), and yellow perch (*Perca flavescens*).

5.7.2 Rare and Endangered Species

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

Federally Listed Species

The current USFWS Endangered Species Consultation Procedure makes use of the online Information for Planning and Conservation Form (https://ecos.fws.gov/ipac/) which streamlines the USFWS environmental review process. POWER completed and submitted the Information for Planning and Conservation (IPaC) Form on May 30, 2024. Results indicated that one federally endangered species, the northern long-eared bat (*Myotis septentrionalis*); one proposed endangered species, the tricolored bat (*Perimyotis subflavus*); and one candidate species, the monarch butterfly (*Danaus plexippus*), may occur in the Project ROW (Appendix E). Results also indicated that no federally designated Critical Habitat occurs in the Project ROW or Study Area. Species descriptions and habitat requirements for the northern long-eared bat, roseate tern, and monarch butterfly are further described below.

Northern Long-eared Bat

The northern long-eared bat (*Myotis septentrionalis*) has suffered severe population declines across its habitat range from white- nose syndrome, a fungal disease that is most often fatal. This disease can spread rampantly through winter hibernacula, disrupt hibernation, and lead to starvation and death. The northern long-eared bat was listed by the USFWS as endangered under the federal Endangered Species Act (ESA) on November 29, 2022.

In the winter, northern long-eared bats hibernate in caves and mines called hibernacula. Within the hibernacula, they have been found hibernating in small crevices and cracks. During the summer, northern long-eared bats 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.

Tricolored Bat

Like the northern long-eared bat, the tricolored bat (*Perimyotis subflavus*) has experienced severe population decline as a result of white-nose syndrome. On September 13, 2022, the USFWS announced a proposal to list the tricolored bat as endangered.

During the winter, tricolored bats hibernate in caves and mines; during the spring, summer and fall, tricolored bats are found in forested habitats where they roost in trees, primarily among leaves. As its name suggests, the tricolored bat is distinguished by its unique tricolored fur that appears dark at the base, lighter in the middle and dark at the tip.

Monarch Butterfly

Due to declining populations resulting from habitat loss and degradation, continued exposure of pesticides, and climate change, the monarch butterfly (*Danaus plexippus*) was listed as a candidate species for listing under the federal ESA on December 17, 2020. The USFWS conducted a 12-month review of the monarch's status and determined listing is warranted but precluded as of the 2022 notification of review (USFWS 2022). The USFWS continues to evaluate the monarch butterfly at the species level. As a candidate species, there are currently no Section 7 consultation requirements for federal agency actions (USFWS 2020b).

Monarchs use milkweed as their host plant to lay their eggs. Larvae emerge after two to five days and develop over nine to 18 days using the milkweed to feed on. Larvae then pupate into a chrysalis and emerge six to 14 days later as an adult butterfly. During the breeding season, multiple generations of monarchs are produced with a life span of approximately two to five weeks.

In some regions, monarchs will breed year-round but in temperate climates such as the northeastern United States, monarchs will migrate and live for an extended period (six to nine months). Monarchs who overwintered in Mexico begin their northward migration in March and breed. Generation one monarchs, offspring of the overwintering generation, are born in the south and begin to migrate north in April to May. After an additional one or two generations, northward migrating monarchs arrive on their New England summer breeding grounds in June-July. These individuals will reproduce one or two additional generations over the summer into early fall. The last offspring of the northern population begin their southerly migration to Mexico in late summer through October. These monarchs, which originally migrated to Mexico, will overwinter and fly back to the southern breeding grounds at which point their offspring will start the generational migration cycle over again (USFWS 2021).

State-Listed Species

Based on correspondence and follow up communication with the RIDEM (Appendix E), the following Rhode Island state-listed species have been documented on or near the Project ROW (Tables 5-6 and 5-7):

TABLE 5-6 RHODE ISLAND STATE LISTED SPECIES DOCUMENTED ON OR WITHIN 500 FEET OF THE PROJECT ROW

COMMON NAME	SCIENTIFIC NAME	REFERENCES FOR IDENTIFICATION
Tall Scouring-rush	*Equisetum hyemale* ssp. *affine*	Native Plant Trust, Go Botany. *Equisetum hyemale*. https://gobotany.nativeplanttrust.org/species/equisetum/hyemale/. Accessed February 13, 2024.

TABLE 5-7 RHODE ISLAND STATE LISTED SPECIES DOCUMENTED ON OR WITHIN 2,500 FEET OF THE PROJECT ROW

COMMON NAME	SCIENTIFIC NAME	REFERENCES FOR IDENTIFICATION
Plymouth Rose-Gentian	*Sabatia kennedyana*	Native Plant Trust, Go Botany. *Sebatia kennedyana*. https://gobotany.nativeplanttrust.org/species/sabatia/kennedyana/. Accessed February 13, 2024.
Ringed Bog-Haunter	*Williamsonia lintneri*	MassWildlife's Natural Heritage & Endangered Species Program, Mass.gov. *Williamsonia lintneri*. https://www.mass.gov/doc/ringed-boghaunter. Accessed February 13, 2024.

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6.0 DESCRIPTION OF AFFECTED SOCIAL ENVIRONMENT

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

6.1 Land Use

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

Predominant land uses making up approximately 80% of the Study Area include deciduous, softwood and mixed forest; medium and high density residential; transportation; industrial; and commercial uses as shown in Figure 6-1 (RIGIS 2024a).

6.1.1 Land Use Along the Transmission Line Corridor

The Tiverton Tap ROW begins approximately 0.1 miles west of Route 24 at the Tiverton, Rhode Island/Fall River, Massachusetts border. The ROW extends approximately 600 feet southeast then turns southwest, paralleling Route 24 for approximately 0.87 miles through Pocasset Cedar Swamp and a commercial area to Eagleville Road. Continuing southwest, the ROW corridor parallels forested areas for approximately 0.75 miles, paralleling State Route 24. The ROW then turns west for approximately 1,000 feet traversing forested areas adjacent to a sand and gravel operation, before turning south into the Tiverton Substation.

6.1.2 Open Space and Recreation

The location of the Project, adjacent to Route 24 and within largely undeveloped forest and commercial/industrial areas, limit the public open space and recreational areas. The Project ROW does not cross recreational areas directly and none are located within the Study Area.

6.1.3 Future Land Use

In order to assess future land use, an analysis of current zoning was undertaken. Typically, towns and cities manage future growth through zoning regulations which provide a degree of control over a community. The majority of the Study Area is zoned industrial, highway commercial, or residential in varying densities. No high-density residential areas were identified within the Study Area. The Town of Tiverton developed the Town of Tiverton Rhode Island Comprehensive Community Plan affirmed April 30, 2018. After a review of the Town of Tiverton Comprehensive Community Plan, electric transmission lines are mentioned as critical infrastructure potentially vulnerable to hazards like severe storms and lightning strikes. No actions are proposed related to electrical facilities as the plan notes

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

current electrical equipment is operational and currently protected from floods, lightning, and power failure.

6.2 Visual Resources

According to the Rhode Island Scenic Landscape Inventory list (RIGIS 2024b), no designated scenic areas are located immediately adjacent to or crossed by the Project. There are no National Recreational, National Scenic, or National Historic Trails within the Project Study Area. Additionally, none of the water bodies in the Project Study Area are listed as wild, scenic or recreational rivers. As described above, there are no areas of public open space, or recreational areas, present within the Project Study Area.

6.3 Historic and Archaeological Resources

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 National Register of Historic Places (NRHP). Once a review has been initiated, the agency, in consultation with the State Historic Preservation Officer and appropriate Tribal authorities, must identify historic properties, assess whether effects to the properties will be adverse, and then work to avoid, minimize, or mitigate any 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 Part 60). In order to be eligible, historic resources must:

- be "associated with events that have made a significant contribution to the broad patterns of our history";
- be "associated with the lives of persons significant in our past";
- "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
- "have yielded, or may be likely to yield, information important in prehistory or history" (United States National Park Service 1990).

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.

The Company contracted POWER to conduct a cultural resources due diligence literature review for the Project in the fall of 2023. POWER coordinated with the Rhode Island Historical Preservation & Heritage Commission (RIHPHC) to identify previously recorded archaeological resources and is currently undertaking a review of publicly available records to identify historic above-ground resources, within the Project survey area. These reviews included both above-ground historic resources and archaeological resources that are listed or evaluated as eligible for listing in the State or National Registers as well as surveyed properties that have not been evaluated or listed, within a study area determined in consultation with the RIHPHC (1.0 kilometer for archaeology, 0.25 miles for above-ground structures). POWER archaeologists also conducted a pedestrian survey in the

Project corridor, and completed an archaeological sensitivity assessment of the Project ROW to provide information about cultural resources that could be affected by the proposed Project.

6.3.1 Architectural Resources

The due diligence review identified eight total listings on the NRHP within the town of Tiverton. In addition, there are 74 properties in Tiverton registered with RIHPHC. There are no listings on the NRHP within one kilometer of the Project corridor. POWER consulted with RIHPHC regarding the study radius for historic above-ground resources (both previously recorded and unrecorded) and is currently inventorying resources within 0.25 miles of the project centerline. Preliminary results indicate that there are eight historic above-ground resources within the study radius. POWER will make recommendations to RIHPHC about the NRHP eligibility of all inventoried resources.

6.3.2 Archeological Resources

The due diligence review identified seven previously recorded archaeological sites within the survey area: three Pre-Contact Native American sites, two historical period archaeological sites, and two sites with both Pre- and Pose-Contact materials. POWER obtained a permit from RIHPHC to conduct Phase 1 subsurface archaeological survey in the Project corridor where construction impacts are proposed within areas determined to be of moderate or high archaeological sensitivity and has completed intensive archaeological field investigations. A draft Archaeological Site Avoidance and Protection Plan (ASAPP), to include compression controls, was prepared for one identified site on the ROW and this plan has been submitted to the USACE and the RIHPHC.

Tribal Historic Preservation Offices for the Narragansett Indian Tribe, Mashpee Wampanoag Tribe, and Wampanoag Tribe of Gayhead (Aquinnah), received POWER's Phase 1 permit application from RIHPHC in December 2023 and they did not issue any comments on the research design. The RIHPHC issued a State Archaeologist's Permit to POWER to conduct the Phase 1 survey when weather and ground conditions allow. Representatives of the Tribal Historic Preservation Offices have been notified of the field work schedule and will be kept informed of the work progress through regular email updates by POWER.

6.4 Transportation

The transportation needs of the Project are served by a network of federal, state (State Route 24), and local roads and highways. The Project crosses one town road, Eagleville Road.

6.5 Electric and Magnetic Fields

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

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

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

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

Magnetic fields are measured in units called Gauss. For the low levels normally encountered during daily activities, the field strength is expressed in a much smaller unit, the milliGauss (mG), which is one thousandth of a Gauss. Table 6-1 lists common household devices and typical magnetic field levels measured at the distances indicated from the source.

TABLE 6-1 COMMON SOURCES OF MAGNETIC FIELDS

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

Note: Different makes and models of appliances, tools, or fixtures will produce different levels of magnetic fields. These are generally-accepted ranges.

Source: Public Service Commission of Wisconsin 2017.

Table 6-2 is provided to illustrate guidelines suggested by various national and international health organizations for exposure to both electric and magnetic fields.

TABLE 6-2 60 HZ EMF GUIDELINES ESTABLISHED BY HEALTH AND SAFETY ORGANIZATIONS

ORGANIZATION	MAGNETIC FIELD	ELECTRIC FIELD
American Conference of Governmental and Industrial Hygienists (ACGIH) (occupational)	10,000 mG[a] 1,000 mG[b]	25 kV/m[a] 1.0 kV/m[b]
International Commission on Non-Ionizing Radiation Protection (ICNIRP) (general public, continuous exposure)	2,000 mG	4.2 kV/m
Non-Ionizing Radiation Committee of the American Industrial Hygiene Assoc. endorsed (in 2003) ICNIRP's occupational EMF levels for workers	4,170 mG	8.3 kV/m

ORGANIZATION	MAGNETIC FIELD	ELECTRIC FIELD
International Committee on Electromagnetic Safety	9,040 mG	5.0 kV/m
U.K., National Radiological Protection Board [now Health Protection Agency]	2,000 mG	4.2 kV/m
Australian Radiation Protection and Nuclear Safety Agency, Draft Standard, Dec. 2006[c]	3,000 mG	4.2 kV/m

Notes:

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

6.6 Noise

The noise impacts associated with the Project are limited to temporary construction noise. No new noise generating equipment that would result in continuous noise is proposed.

The potential for noise impacts from Project construction is a function of the specific receptors along the route as well as the equipment and proposed hours of operation. The State of Rhode Island does not have regulations that set community noise exposure criteria or abatement measurements. Instead, noise abatement criteria are instituted by municipalities of Rhode Island. Project construction is anticipated to occur during typical work hours, though in specific instances, at some locations, or at the request of a municipality, the Company may seek municipal approval to work at night.

The Tiverton noise ordinance is shown in Table 6-3.

TABLE 6-3 MUNICIPAL NOISE ORDINANCE SUMMARY

MUNICIPALITY CODE	ALLOWED CONSTRUCTION HOURS		EXCEPTIONS
	Weekday	Weekend	
Tiverton	7:00 a.m. - 9:00 p.m.	7:00 a.m. - 9:00 p.m.	Town Council may grant sound variances after public hearing.

Noise generated by construction is generally temporary and intermittent. Sound levels from construction activity typically are dominated by the loudest piece of equipment operating at the time. Therefore, at any given point along the work corridor, the loudest piece of equipment will be the most representative of the expected sound levels in the area.

Table 6-4 identifies the types of equipment to be used for each phase of the construction sequence and provides a range of typical sound levels from the equipment. The typical sound levels are provided at a distance of 50 feet from the source and have also been extrapolated for noise levels at 100, 200, and 300 feet. The estimated noise levels range from 80 A-weighted decibels (dBA) to 98 dBA at a distance of 50 feet from the construction activity. The closest residence along the Project ROW is approximately 100 feet away from the separated transmission lines, resulting in intermittent noise of up to 92 dBA during vegetation removal and ROW mowing, with lower levels of noise during other phases of Project construction. Typical sound levels of construction noise experienced at any given residence will be sporadic and of limited duration.

TABLE 6-4 TYPICAL CONSTRUCTION SOUND LEVELS

DESCRIPTION OF ACTIVITY	TYPES OF EQUIPMENT	TYPICAL SOUND LEVELS AT 50 FEET (dBA)	ESTIMATED SOUND LEVELS (dBA) AT VARIOUS DISTANCES FROM NOISE SOURCES		
			100 Feet	200 Feet	300 Feet
Vegetation Removal and ROW Mowing	• Grapple trucks • Bulldozers • Track-mounted mowers • Motorized tree shears • Log forwarders • Chippers, Chain saws • Box trailers	84 to 98	78 to 92	72 to 86	69 to 83
Erosion/Sediment Controls and Access Road Improvements and Maintenance	• Dump trucks • Bulldozers, excavators, backhoes • Graders, Forwarders • 10-wheel trucks with grapples, Cranes	80 to 93	74 to 87	68 to 81	65 to 78
Removal and Disposal of Existing Transmission Line Components	• Cranes • Flatbed trucks • Pullers with take-up reel • Excavators	80 to 90	74 to 84	68 to 78	65 to 75
Installation of Foundations and Structures	• Backhoes and excavators • Rock drills mounted on excavators • Cluster drills with truck mounted compressors • Concrete trucks • Cranes • Aerial lift equipment • Tractor trailers	80 to 90	74 to 84	68 to 78	65 to 75
Conductor and Shield Wire Installation	• Puller-tensioners • Conductor reel stands • Cranes • Bucket trucks • Flatbed trucks	80 to 93	74 to 87	68 to 81	65 to 78
Restoration of the ROW	• Bulldozers, Excavators • Tractor-mounted York rakes • Straw blowers • Hydro-seeders	80 to 90	74 to 84	68 to 78	65 to 75

Source: https://www.fhwa.dot.gov/environment/noise/construction_noise/handbook/handbook09.cfm

At the Tiverton Substation, construction activities will be limited to the replacement of line taps. Audible noise levels in residential areas are typically around 55 dBA during the day; the nearest resident to the substation may experience intermittent noise up to 75 dBA during construction activities in and around the substation.

The Company expects construction to occur over a period of approximately eight months, dependent upon the available outage windows. Temporary noise impacts from construction equipment will be mitigated by maintaining equipment in good working condition and by use of appropriate mufflers. Noise sources that may operate continually during the day, such as generators or air compressors, will be located away from populated areas to the extent possible. The Company and its contractors will also comply with RIDEM Diesel Engine Anti-Idling Program[4] and other Rhode Island anti-idling laws[5], which limit vehicle idling to no more than five minutes, to the greatest extent feasible based upon the construction task, type of equipment/vehicle and weather conditions. Only necessary equipment will run during construction to minimize engine noise. With the implementation of these measures, noise impacts associated with the Project will be minimized.

[4] 250-Rhode Island Code of Regulations-120-05-45 Title 250 Part 45 - Rhode Island Diesel Engine Anti-Idling Program
[5] Rhode Island General Laws (RIGL)§ 23-23-29.2. (Diesel motor vehicle engine idling), RIGL § 23-23-29.3. (Non-road diesel engine idling), and RIGL § 31-16.1-3. (Restrictions on idling for diesel engines)

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7.0 IMPACT ANALYSIS

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

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

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

7.1 Summary of Environmental Effects and Mitigation

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

7.2 Summary of Social Effects and Mitigation

The Project involves existing transmission lines within existing 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 temporary and localized. No visual impacts will result from the Project. Traffic control plans will be employed as necessary at the ROW access points off local and state roads, and for the installation of conductors across roadways. The Project will not adversely impact the social and economic conditions in the Project area. To the contrary, the Project will ensure the continued reliability of the electric system.

7.3 Soils

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

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

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

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

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

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

7.4 Water Resources

7.4.1 Major Surface Waters

Potential impacts to surface waters if sediment transport is not controlled include temporary increased turbidity and sedimentation (locally and downstream) and subsequent alterations of benthic substrates, decreases in primary production and dissolved oxygen concentrations, releases of toxic substances and/or nutrients from sediments, and destruction of benthic invertebrates. For this Project, however, any impact of the Project upon major surface waters will be minor and temporary. Construction activities temporarily increase risks for soil erosion and sedimentation that may temporarily degrade existing water quality; however, appropriate BMPs will be implemented and maintained to effectively control sediment. Temporary construction mats will be used to access structure locations within or adjacent to surface water features as conditions warrant. Sedimentation and turbidity within these watercourses will be minimized through the implementation and installation of BMPs prior to construction activities.

7.4.2 Wetlands and Waterbodies

The Company has planned and designed the Project to minimize and avoid potential impacts to wetlands. However, due to site constraints, construction logistics, and engineering constraints, minor impacts to wetlands are unavoidable. To minimize these potential impacts, wetland crossings were chosen to cross at previously impacted locations or at narrow points of the wetland. Construction mats will be used at all unavoidable wetland crossings. Where structures are located in or near wetland areas, erosion control measures in addition to construction mats, will be employed as needed to reduce sedimentation impacts on the wetland.

On the Tiverton Taps, there are 18 new transmission structures to be installed in regulated freshwater wetlands and 10 existing transmission structures to be removed from regulated freshwater wetlands. The existing structures being replaced will be removed and the wetland areas restored with hydric soils obtained from its replacement foundation hole(s) resulting in no net loss of wetland.

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

TABLE 7-1 SUMMARY OF POTENTIAL IMPACTS TO FRESHWATER WETLANDS

WETLAND ID (WETLAND CLASS)	IMPACT TYPE	TEMPORARY IMPACT (SF)[1]	PERMANENT IMPACT (SF)	MUNICIPALITY
TTW02 (PEM/PSS)	Temporary Construction Mats & Larger Diameter Transmission Foundations and Structures	87,522	50	Tiverton
TTW04 (PEM)	Temporary Construction Mats & Larger Diameter Transmission Foundations and Structures	398	0	Tiverton
TTW07 (PEM)	Temporary Construction Mats & Larger Diameter Transmission Foundations and Structures	49,473	365	Tiverton
TTW08 (PEM)	Temporary Construction Mats & Larger Diameter Transmission Foundations and Structures	114,356	454	Tiverton
	Total	**415,483.6**	**1,815.4**	

7.4.3 Groundwater Resources

The only potential impact to groundwater resources would result from inadvertent spillage or release of fuel, petroleum, hydraulic fluid, or other products. Potential impacts to groundwater resources within the Project ROW as a result of construction activity on the transmission line facilities will be negligible. Equipment used for construction will be properly inspected, maintained and operated to reduce the chances of spill occurrences of petroleum products. Within primary groundwater recharge areas, special safeguards will be implemented to assure the protection of groundwater resources. Construction equipment will be required to carry emergency 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 an equipment malfunction. In some scenarios, refueling in place will be allowed for equipment that cannot be moved from a fixed location. Appropriate precautions must be utilized, and the Company's Environmental representatives must be consulted prior to initiating the refueling, such as secondary containment devices. Following construction, the normal operation and maintenance of the transmission line facilities will have no impact on groundwater resources.

7.5 Vegetation

Along most of the ROW and at structure sites, vegetation mowing will be required prior to construction of the Project. Vegetation removal and mowing occurred in Q4 2023 and Q1 2024 to facilitate access on the ROW to advance the Company subsurface geotechnical program to support the planning and engineering design for the Project. These activities will be limited to those areas necessary to provide access to existing and proposed Project structure locations, to facilitate safe equipment passage, to provide safe work sites for personnel within the ROW, and to maintain safe clearances between vegetation and transmission line conductors for reliable operation of the transmission facilities. Pruning and individual tree removal will be required in certain locations along the ROW to ensure adequate safety and operational clearances for the new transmission line. Tree removal and vegetation management (e.g., mowing) is to occur within the Company's existing ROW easement to maintain minimum clearances from energized lines. Tree removal activities will take place within the Company's existing and approved ROW easement or on the Company fee-owned property. During and following construction, danger trees that have been determined to present a potential hazard to the integrity of the line will be marked and pruned or removed. Vegetative species compatible with the use of the ROW for transmission line purposes are expected to regenerate naturally, over time.

Off-ROW trees located just outside the maintained ROW edge will be assessed for their potential to damage the transmission lines. To ensure the safety and reliability of the line, danger and hazard trees may have to be pruned or removed. A danger tree is a tree located either on or off the ROW, which may contact electric lines if it were to fall, and hazard trees are danger trees that are structurally weak, broken, damaged, decaying or infested and that could contact the structures or conductors (or violate the conductor clearance zones).

After completion of work on the transmission facilities, the Company will stabilize, seed and mulch impacted areas with appropriate grass-type mixes and straw mulch. The Applicant will promote the re-growth of desirable species by implementing vegetative maintenance practices to control tall-growing trees and incompatible, invasive species that conflict with line clearances, thereby enabling native plants to dominate.

7.6 Wildlife

Minor, temporary disturbances of wildlife may result from equipment travel and construction crews working in the Project corridor. During construction, displacement of wildlife may occur due to disturbance associated with ROW mowing, tree removal, and the operation of construction equipment. Wildlife currently utilizing the forested edge of the cleared ROW may be affected by construction of the Project.

Larger, more mobile species, such as eastern white-tailed deer or red fox, will temporarily leave the construction area. Individuals of some bird species will also be temporarily displaced. Depending on the time of year of these operations, this displacement could affect breeding and nesting activities. Smaller and less mobile animals such as small mammals, reptiles, and amphibians may be affected during vegetation mowing/removal and the transmission line construction. The species impacted during the refurbishment of the transmission line are expected to be limited in number. Effects will be localized to the immediate area of construction around structure locations and along existing access roads. However, this is anticipated to be a temporary effect as it is expected that existing wildlife utilization patterns will resume, and population sizes will recover once work activities are completed.

Minor tree cutting and trimming is required for the Project. Based on communication with RIDEM, there are no maternity roost trees or hibernaculum located in the Project area; therefore, no impacts to northern long-eared bats are anticipated. The Company will take steps necessary to minimize disturbance to preferred pollinator habitat throughout the construction period, such as selecting non-milkweed dominated areas for on-site foundation spoils management. In-situ restoration of disturbed soils will allow natural revegetation, including recolonization of milkweed and other important nectar sources used by monarchs. No long-term impacts to general wildlife are expected to result from the Project.

7.7 Air Quality

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

The Company will take measures to limit vehicle idling times and to reduce air emissions during construction. The Company will also implement construction best management practices to suppress dust generation and fugitive dust emissions. Due to the transitory nature of construction activities, air quality in the Tiverton area will not be significantly affected by construction within the ROW.

Typical construction equipment will be used for construction of the Project. During all upgrade components, the Company will comply with the use of ultra-low sulfur diesel-powered equipment and restricted vehicle idling times during construction. the Company will also take measures to limit vehicle idling times and to reduce air emissions, including the following:

- In Rhode Island, any diesel-powered non-road construction equipment with engine horsepower ratings of 50 and above to be used for 30 or more days over the course of construction will either be USEPA Tier 4-compliant or will be retrofitted with USEPA-verified (or equivalent) emission control devices such as oxidation catalysts or other comparable technologies (to the extent that they are commercially available) installed on the exhaust system side of the diesel combustion engine.
- The Company requires the use of ultra-low sulfur diesel fuel in its diesel-powered construction equipment and limits idling time to five minutes except when engine power is necessary for the delivery of materials or to operate accessories to the vehicle such as power lifts.

- Vehicle idling is to be minimized during construction activities, in compliance with the Rhode Island Anti-idling Law, R.I. Gen. Laws § 31-16.1, § 23-23-29.2, and § 23-23-29.3, and the Company's Environmental Guidance (EG-802RI) Vehicle Idling – Rhode Island.
- Require strict compliance with the RIDEM Diesel Engine Anti-Idling Program[1] and other Rhode Island anti-idling laws to prevent equipment from idling and producing unnecessary noise while not in productive use.
- Exposed soils and access roads will be wetted and stabilized, as necessary, to suppress dust generation during construction.

There are no anticipated long-term impacts on air quality associated with the operation of the transmission lines.

Importantly, Rhode Island does not have any air quality nonattainment counties under the standards of the USEPA. The USEPA, under the Clean Air Act of 1970, 42 U.S.C. § 7401 *et seq.*, amended in 1977 and 1990, developed National Ambient Air Quality Standards (NAAQS) that include primary standards to protect human health and the health of sensitive subpopulations, including children, elderly, and those with chronic respiratory problems. NAAQS also contain secondary standards designed to protect public welfare, including economic interests, visibility, vegetation, animal species, and other concerns not related to human health. Standards developed by the USEPA for the NAAQS involving carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO_2), ozone (O_3), particulate matter (PM), and sulfur dioxide (SO_2).

7.8 Social and Economic

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

7.8.1 Land Use

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

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

7.8.2 Consistency with Local Planning

The Town of Tiverton has a Comprehensive Community Plan which describes the local direction regarding future development and growth in each community. The Comprehensive Plan was evaluated with regard to expressed town-wide goals. Because the Project consists of refurbishment and upgrades that will occur entirely within an existing cleared transmission line ROW, it will not alter existing land use patterns and will not adversely impact future planned development. The Project will provide a continued reliable supply of electricity for the growth and development envisioned by the Comprehensive Plan.

7.9 Visual Resources

Visual resources include elements of the surrounding area that may be sensitive to changes to their visual setting; including historic sites, scenic landscapes, lighthouses, state parks/beaches, wildlife refuges, designated scenic areas, and other recreation and tourism areas. Effects to visual resources can be perceived by both residents (year-round and seasonal) and tourists.

Overall, the Project's visual impacts are limited by the location of the Project within an already-developed transmission ROW, and by the relatively limited need for tree removal in locations near sensitive receptors. New pole structures have been sited adjacent to existing structures, where feasible, to minimize the potential for visual impact. The Company will work with abutting landowners who experience a material change in view to identify reasonable and practical screening that could be provided on their properties, in "soft" form (e.g., compatible vegetation), "hard" form (e.g., fencing), or a combination of the two. With the implementation of these measures, the visual impacts of the Project will be minimized.

The heights of existing transmission structures range from 31 to 71 feet. The heights of the replacement structures will range in heights from 47 to 97 feet, with the average structure height being approximately 75 feet.

A representative viewpoint location was selected along the Project route for development of visual simulations in order to demonstrate how the constructed Project would appear to future viewers (proposed conditions). The location of the visual simulation for the Tiverton Tap lines is located off of Eagleville Road with a view to the north into the ROW (Appendix E)

Overall, the potential for visual impact on landscape character and sensitive viewers has been minimized through use of an existing and primarily cleared transmission line ROW and replacement of existing transmission structures that would create weak or no visual contrast. Therefore, the Project will not materially change the existing appearance of the ROW, and no significant impacts to visual resources are anticipated as a result of the Project.

7.10 Cultural and Historic Resources

No architectural above-ground resources were identified within the Project ROW. Accordingly, the Project will not directly affect architectural above-ground resources. Potential visual impacts to NRHP eligible or listed resources will be assessed by RIHPHC using data provided by POWER in a historic above-ground resources inventory. This inventory was completed in June, 2024 and will be submitted to RIHPHC for review and comment.

POWER began Phase 1 archaeological survey in January 2024 for the Project at the locations of proposed geotechnical borings in moderate to high sensitivity areas; the results of this testing have not been fully reviewed by RIHPHC, but no significant cultural materials were recovered and RIHPHC agreed to the Company commencing with the geotechnical boring program.

On behalf of the Company, POWER received a permit from the RIHPHC to conduct Phase 1 archaeological field survey in areas of proposed impacts on January 9, 2024. Intensive archaeological surveys commenced in early Q2 and were completed in June 2024 . The results of these surveys will be communicated to RIHPHC. POWER cultural resources staff have maintained a dialogue with Tribal cultural resource monitors throughout the Project in order to identify and address Tribal concerns and to enable a collaborative approach to investigation strategy.

POWER identified some low-density Native material around one existing transmission structure – where there is already a known site. POWER is recommending ASAPP measures at this location in the form of compression controls to reduce ground disturbance by construction vehicles and equipment. The ASAPP will be filed with the RIHPHC and the USACE as part of the Section 106 of the National Historic Preservation Act consultation process.

7.11 Noise

Noise impacts are expected to be negligible. Temporary construction noise may be generated by the Project that will occur during normal daytime working hours. Proper mufflers will be required to control noise levels generated by construction equipment. Some work tasks such as concrete pours and transmission line stringing, once started, must be continued through to completion and may go beyond normal work hours. Work requiring scheduled outages and crossings of certain transportation and utility corridors may need to be performed on a limited basis outside of normal work hours, including on Sundays and holidays. Prior to and during construction, the Company will notify landowners, abutting property owners, municipal officials, and local police and fire chiefs of the details of planned construction including the normal work hours and any extended work hours.

7.12 Transportation

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

7.13 Safety and Public Health

Following construction of the facilities, the new transmission line structures will be clearly marked with warning signs to alert the public to potential hazards if climbed. Trespassing on the ROW will be discouraged by using existing gates and/or barriers at entrances from public roads. Because the proposed facilities will be designed, built and maintained in accordance with the standards and codes as described in Section 3.3.6, the public health and safety will be protected.

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

7.14 Electric and Magnetic Fields

Magnetic field levels were calculated for two loading scenarios: expected annual average and annual peak loading. Magnetic field levels for average and peak loading conditions are summarized in Table

7-2 and 7-3, respectively. Table 7-4 summarizes electric field levels. Please refer to the ROW cross-sections Schematic 1 below. Along much of the Tiverton Tap route, the magnetic field remains approximately the same or decreases when compared with calculated pre-construction magnetic field levels. Electric field levels were calculated to not change by more than 0.5 kilovolts per meter (kV/m) at the ROW edges. The EMF levels from the existing and rebuilt transmission lines decrease rapidly with distance from the ROW.

The magnetic field at average loading decreases by 8 mG on the northern edge of the ROW and decreases by 3.8 mG on the southern edge of the ROW. For a very small segment of the route at cross section XS-05, the magnetic field at average loading experiences a small increase of 0.7 mG on the northern edge of the ROW due to the phase-phase spacing. Magnetic field levels decrease rapidly with distance from the edges of the ROW. At a distance of 100 feet from the ROW edges, calculated magnetic field levels were less than 1 mG for all rebuilt configurations, as summarized in Table 7-2.

At both average and peak loading, EMF levels at the ROW edges are calculated to slightly increase or not appreciably change as a result of the Project rebuild. The Company has selected optional phasing of the configuration of the conductors to minimize the magnetic field at either ROW edge. At both average and peak loading, all calculated EMF levels are far below the guidelines of international scientific and health agencies for electric fields (4.2 kV/m or greater) and magnetic fields (2,000 mG or greater).

A discussion of the Current Status of Research on Extremely Low Frequency Electric and Magnetic Fields and Health: Rhode Island Energy Transmission Line Projects – The Narragansett Electric Company (June 2, 2022) was prepared by Exponent, Inc. and is attached as Appendix G.

TABLE 7-2 MAGNETIC FIELD LEVELS (MG) AT AVERAGE LOADING

SEGMENT NUMBER	CONFIGURATION	–ROW EDGE (FACING TIVERTON TAP LINES)	+ROW EDGE (FACING TIVERTON TAP LINES)
XS-04	Existing	5	19
	Rebuilt (2025)	1.2	11
	Rebuilt (2030)	1.2	11
XS-05	Existing	0.3	1.9
	Rebuilt (2025)	0.1	2.6
	Rebuilt (2030)	0.1	2.2

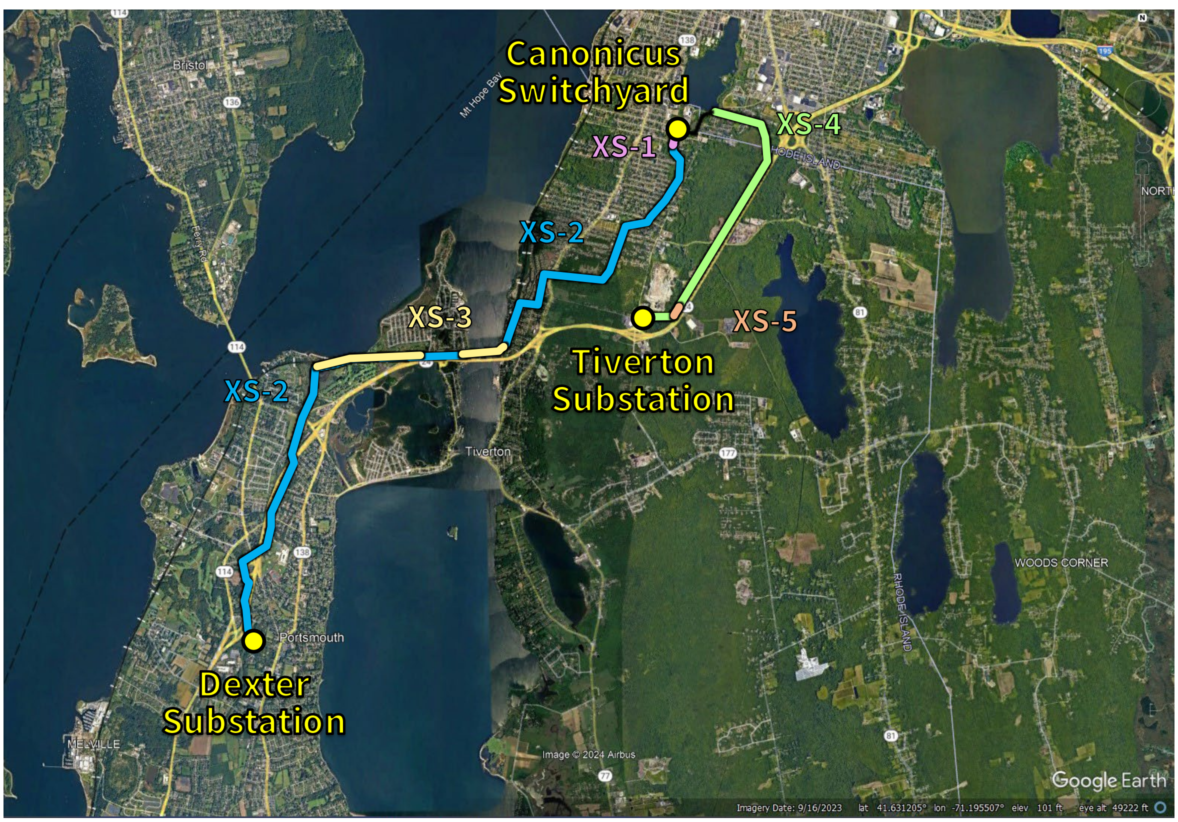
TABLE 7-3 MAGNETIC FIELD LEVELS (MG) AT PEAK LOADING

SEGMENT NUMBER	CONFIGURATION	–ROW EDGE (FACING TIVERTON TAP LINES)	+ROW EDGE (FACING TIVERTON TAP LINES)
XS-04	Existing	7.6	30
	Rebuilt (2025)	1.8	15
	Rebuilt (2030)	1.8	16
XS-05	Existing	0.8	4.6
	Rebuilt (2025)	0.2	4.9
	Rebuilt (2030)	0.1	4.5

It is important to note that the EMF levels are all far below the guidelines reference levels recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the International Committee on Electromagnetic Safety (2019).

TABLE 7-4 ELECTRIC FIELD LEVELS (KV/M) AT AVERAGE LOADING

SEGMENT NUMBER	CONFIGURATION	–ROW EDGE (FACING TIVERTON TAP LINES)	+ROW EDGE (FACING TIVERTON TAP LINES)
XS-04	Existing	>0.1	0.3
	Rebuilt (2025)	>0.1	>0.1
	Rebuilt (2030)	>0.1	>0.1
XS-05	Existing	>0.1	0.5
	Rebuilt (2025)	0.1	0.7
	Rebuilt (2030)	0.1	0.7



SCHEMATIC 1. TIVERTON TAP IS REPRESENTED BY CROSS-SECTIONS XS-04 AND XS-05.

8.0 MITIGATION MEASURES

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

8.1 Construction Phase

The construction phase of the Project will include the replacement of existing structures, conductor, and OPGW within an existing ROW. This work will require only minor disturbances to the surrounding natural environment.

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

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

Vegetation management and tree removal will be necessary along access routes and work pad locations. These activities will require minor vegetation maintenance including brush removal up to a width of 20 feet centered on the access road and pruning limbs to a height of 12 to 15 feet to maintain clearances and allow safe passage of construction equipment and vehicles.

The Company will adhere to a site-specific invasive species control plan which will require that all equipment and temporary construction matting brought on-site will be certified as clean. Temporary matting will be removed upon completion of the Project and the area under jurisdiction of the Rhode Island Freshwater Wetlands Act will be restored back to pre-existing conditions and contours to the extent practicable.

8.1.1 Erosion and Sedimentation Control

Erosion and sediment control devices will be installed along the perimeter of identified wetland resource areas prior to the onset of soil disturbance activities to ensure that soil stockpiles and other disturbed soil areas are confined and do not result in downslope sedimentation of sensitive areas. Low growing tree species, shrubs and grasses will only be mowed along access roads, structure locations, and pull areas as necessary. As part of Rhode Island Pollution Discharge Elimination System permitting, a site-specific Soil Erosion and Sediment Control Plan will be developed and implemented during the construction phase of the Project. The Soil Erosion and Sediment Control Plan will be maintained on-site and updated throughout the Project to reflect environmental inspection reporting and BMPs. Construction crews will be responsible for conducting daily inspections and identifying erosion controls that must be maintained or replaced as necessary.

Access roads and work pads located in uplands and within 100-foot and 200-foot regulated contiguous areas will be left in-place and will be stabilized with a top dressing of topsoil and seed.

8.1.2 Supervision and Monitoring

Throughout the entire construction process, the Company will retain the services of an environmental compliance monitor. The primary responsibility of the monitor will be to oversee construction activities, including the installation and maintenance of erosion and sedimentation controls, on a routine basis to ensure compliance with all federal and state permit requirements, the Company's policies, and other commitments. The environmental compliance monitor will be a trained environmental scientist responsible for supervising construction activities relative to environmental issues. The environmental compliance monitor will be experienced in the erosion control techniques described in this report and will have an understanding of wetland resources to be protected. During periods of prolonged or heavy precipitation and after excessive snow melt, the monitor will inspect the environmental controls to confirm they are functioning properly.

In addition to retaining the services of an environmental monitor, the Company will require the construction team to designate an individual to be responsible for the daily inspection and upkeep of environmental controls. This person will also be responsible for providing direction to the other members of the construction crew regarding matters of wetland access and appropriate work methods. Additionally, all construction personnel will be briefed on Project environmental compliance issues and obligations prior to the start of construction, as part of the Project environmental training program. Regular construction progress meetings will provide the opportunity to reinforce the construction team's awareness of these issues.

8.1.3 Air Quality

During earth disturbing activities, the construction team will deploy dust mitigation measures as described in the Company's EG-303NE. 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.

The Company requires the use of ultra-low sulfur diesel fuel exclusively in the construction team's diesel-powered construction equipment. Vehicle idling is to be minimized during the construction phase of the Project, in compliance with the Rhode Island Diesel Engine Anti-Idling Program, Air Pollution Control Regulation No. 45, authorized pursuant to R.I. Gen. Laws § 31-16.1-3, § 23-23-29.2, and § 23-23-29.3. Vehicle idling for diesel and non-diesel-powered vehicles is limited to five minutes except for powering auxiliary equipment, for heating/defrosting purposes in cold weather, and for cooling purposes in hot weather. The construction team is responsible for complying with the state regulatory requirements along with the Company Environmental Guidance (EG-802RI) Vehicle Idling – Rhode Island.

- In Rhode Island, any diesel-powered non-road construction equipment with engine horsepower ratings of 50 and above to be used for 30 or more days over the course of construction will either be USEPA Tier 4-compliant or will be retrofitted with USEPA-verified (or equivalent) emission control devices such as oxidation catalysts or other comparable technologies (to the extent that they are commercially available) installed on the exhaust system side of the diesel combustion engine.

- The Company requires the use of ultra-low sulfur diesel fuel in its diesel-powered construction equipment and limits idling time to five minutes except when engine power is necessary for the delivery of materials or to operate accessories to the vehicle such as power lifts.
- Vehicle idling is to be minimized during construction activities, in compliance with the Rhode Island Anti-idling Law, R.I. Gen. Laws § 31-16.1-3, § 23-23-29.2, and § 23-23-29.3, and the Company's Environmental Guidance (EG-802RI) Vehicle Idling – Rhode Island.
- Require strict compliance with the RIDEM Diesel Engine Anti-Idling Program[1] and other Rhode Island anti-idling laws to prevent equipment from idling and producing unnecessary noise while not in productive use.
- Exposed soils and access roads will be wetted and stabilized, as necessary, to suppress dust generation during construction.

8.1.4 Noise Quality

To minimize the effects of construction noise to abutters to the ROW and to the general public, the Company will implement that following mitigation measures:

- Requiring well-maintained equipment with functioning mufflers.
- Requiring muffling enclosures on continuously operating equipment such as air compressors and welding generators.
- Using a low-noise generator (e.g., WhisperWattTM or equivalent) to reduce noise impacts.
- Requiring strict compliance with the Massachusetts Anti-Idling Law to prevent equipment from idling and producing unnecessary noise while not in productive use.
- If applicable, mitigating the impact of noisy equipment on sensitive locations by using shielding or buffering distance to the extent practicable.

8.1.5 Mitigation of Social Resource Impacts

The Company will minimize social resource impacts during construction by incorporating several standard mitigation measures. By use of an established transmission line ROW rather than creating a new ROW, the potential for disruption due to construction activities will be limited to an area already dedicated to transmission line uses. Construction generated noise will be limited by the use of mufflers on all construction equipment and by limiting construction activities to the hours specified in the local ordinances. Dust will be controlled by wetting and stabilizing access road surfaces, as necessary, and by maintaining crushed stone aprons at the intersections of access roads with paved roads. The Company will minimize the potential for disturbance from the construction by notifying landowners and abutters of planned construction activities before and during construction of the line. Some short-term impacts are unavoidable, even though they have been minimized. By carrying out the work on the transmission lines in a timely fashion, the Company will keep these impacts to a minimum. The Company's contractors will prepare Traffic Management Plans, as necessary, which will minimize impacts associated with increased construction traffic on local roadways.

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

8.2 Post-Construction Phase

Following the completion of construction, the Company will use standard mitigation measures to minimize the impacts of the Project 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 will be used on a site-specific basis. The Company will implement the following standard and site-specific mitigation measures for the Project.

8.2.1 Restoration of Natural Resource Impacts

Restoration efforts, including final grading and installation of permanent erosion control devices, and seeding of disturbed areas, will be completed following construction. Construction debris will be removed from the Project site and disposed of at an appropriate landfill. Pre-existing grades, 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. The Company’s ROW vegetation maintenance practices encourage the growth of low-growing shrubs and other vegetation which provides a degree of natural vegetation control. In addition to reducing the need to remove tall growing tree species from the ROW, the vegetation maintained on the ROW inhibits erosion.

8.2.2 Mitigation of Social Resource Impacts

The Company will continue to coordinate with property owners to limit unwarranted access and trespass onto the ROW by installing permanent gates and barriers where not already installed along access roads entering the ROW from public ways.

In cases where an off-ROW tree needs to be pruned or removed for the Project, the Company will work with landowners to address the hazardous tree situation(s). Property owners who have a danger or hazard tree which poses a risk to the transmission line will be notified prior to tree removal and landscape or other type of visual mitigation may be provided, as necessary.

Recognizing the varying needs of its stakeholders, the Company is developing various communication methods to inform stakeholders throughout construction, including as needed: work area signage; advance notification of scheduled construction; personal contact with residents, community groups and businesses; and regular e-mail updates to residents (upon request) and local officials that will include information on upcoming construction activity.

The Company will assign dedicated personnel to the Project who will be responsible for continuing outreach responses during construction and who will provide a consistent point of contact for the public. As noted above, the Project website will be updated during the construction phase, and once a construction commencement date has been selected.

Major construction impacts are confined entirely within the existing 115 kV transmission line ROW, with only some minor construction impacts occurring immediately adjacent to the ROW, ensuring that the Project will not result in prolonged disruption to residential or business activities.

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Rhode Island Energy Facility Siting Board
Project Siting Report

The Narragansett Electric Company
Tiverton Tap Rebuild Project

Tiverton, Rhode Island

VOLUME II

June 2024

APPENDIX A PROJECT FIGURES

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- Project Centerline
- Transmission Line
- Existing or Proposed Power Facility
- Town Boundary

REVISIONS:

POWER ENGINEERS

POWER Engineers, Inc
2 Hampshire Street Suite 301
Foxborough, MA 02035

NOTES:
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FIGURE 1-1 PROJECT LOCUS

Scale 1"=2000' when printed at 11" by 17"

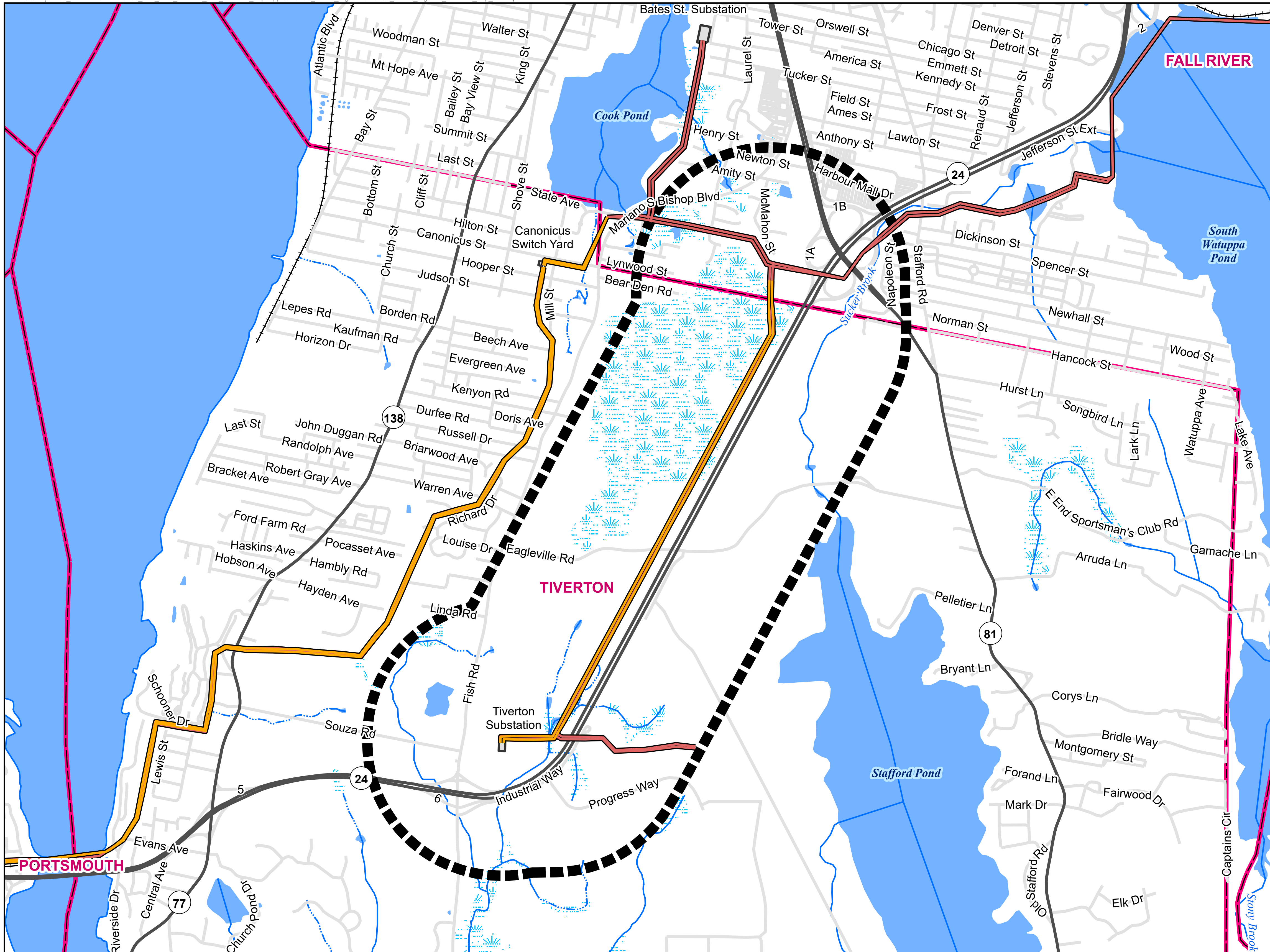
0 500 1,000 Meters

0 2,000 4,000 Feet

Rhode Island Energy
280 Melrose Street
Providence, RI 02907

Project Locus Map
L14 & M13 Tiverton Tap Rebuild Project
Rhode Island Energy
Towns of Portsmouth and Tiverton, Rhode Island

SCALE	JOB NO.	DATE:	SHEET
AS NOTED	249458	5/30/2024	1 of 1



- Existing Transmission Line
- Proposed Transmission Line
- 5000 Foot Study Area
- Substation or Switching Station
- State Highway
- Minor Road
- Railroad
- Town Boundary
- Perennial River or Stream (NHD)
- Intermittent Stream (NHD)
- Swamp/Marsh (NHD)
- Lake, Pond, or Reservoir (NHD)

REVISIONS:

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POWER Engineers, Inc
2 Hampshire Street Suite 301
Foxborough, MA 02035

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FIGURE 5-1 STUDY AREA

Scale 1"=2000' when printed at 11" by 17"

0 500 1,000 1,500 Meters

0 1,000 2,000 3,000 4,000 Feet

Rhode Island Energy™ a PPL company

Rhode Island Energy
280 Melrose Street
Providence, RI 02907

Study Area
L14 & M13 Tiverton Tap Rebuild Project
Rhode Island Energy
City of Fall River, Town of Tiverton
Bristol and Newport Counties
Commonwealth of Massachusetts, State of Rhode Island

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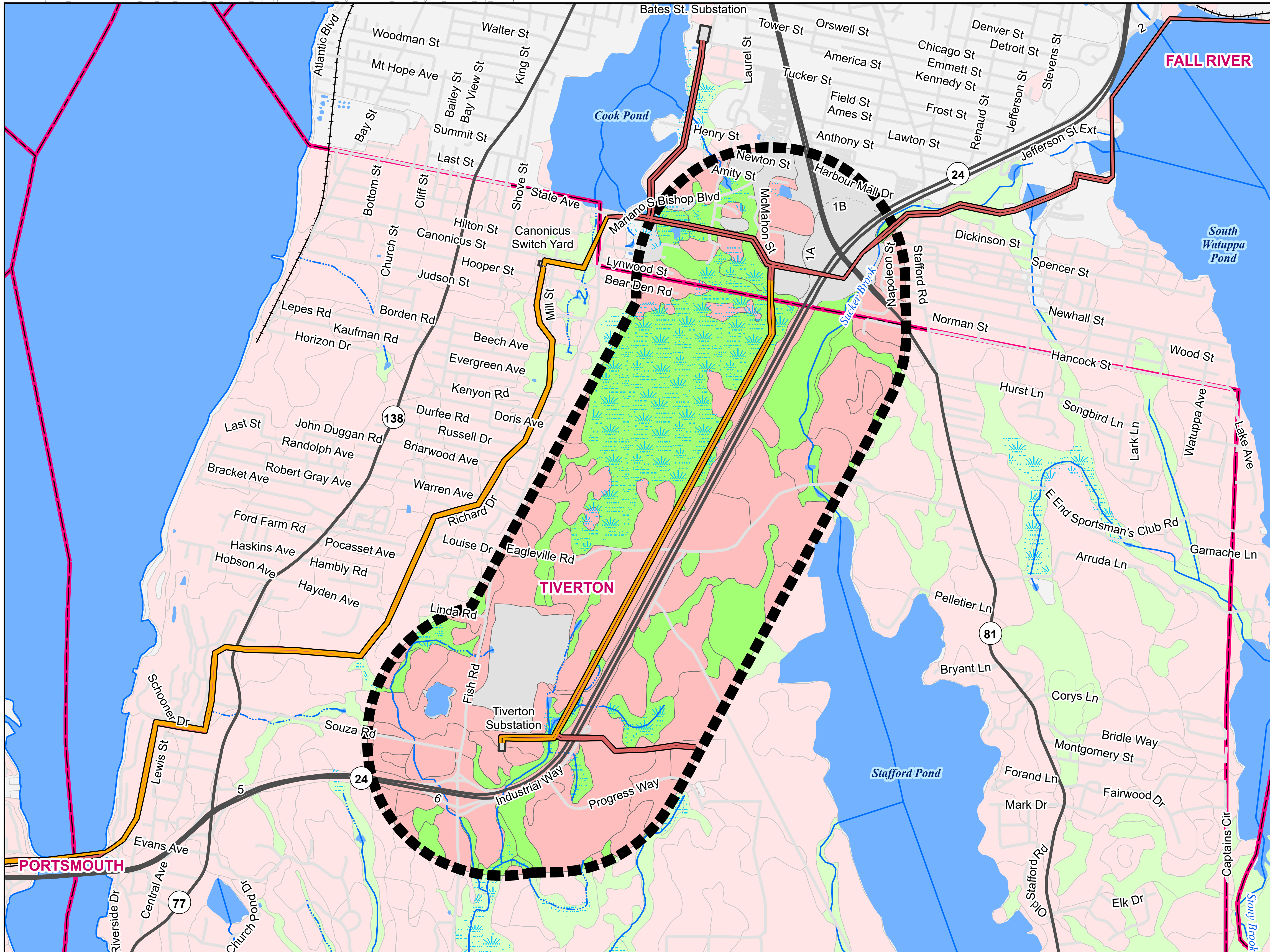

- Existing Transmission Line
- Proposed Transmission Line
- 5000 Foot Study Area
- Substation or Switching Station
- State Highway
- Minor Road
- Railroad
- Town Boundary
- Perennial River or Stream (NHD)
- Intermittent Stream (NHD)
- Swamp/Marsh (NHD)
- Lake, Pond, or Reservoir (NHD)

Hydric Soils

- Yes
- No
- Unranked

REVISIONS:

POWER ENGINEERS

POWER Engineers, Inc
2 Hampshire Street Suite 301
Foxborough, MA 02035

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FIGURE 5-2 HYDRIC SOILS

Scale 1"=2000' when printed at 11" by 17"

0 500 1,000 1,500 Meters

0 1,000 2,000 3,000 4,000 Feet

Rhode Island Energy
a PPL company

Rhode Island Energy
280 Melrose Street
Providence, RI 02907

Hydric Soils
L14 & M13 Tiverton Tap Rebuild Project
Rhode Island Energy
City of Fall River, Town of Tiverton
Bristol and Newport Counties
Commonwealth of Massachusetts, State of Rhode Island

SCALE	JOB NO.	DATE:	SHEET
AS NOTED	249458	5/30/2024	1 of 1

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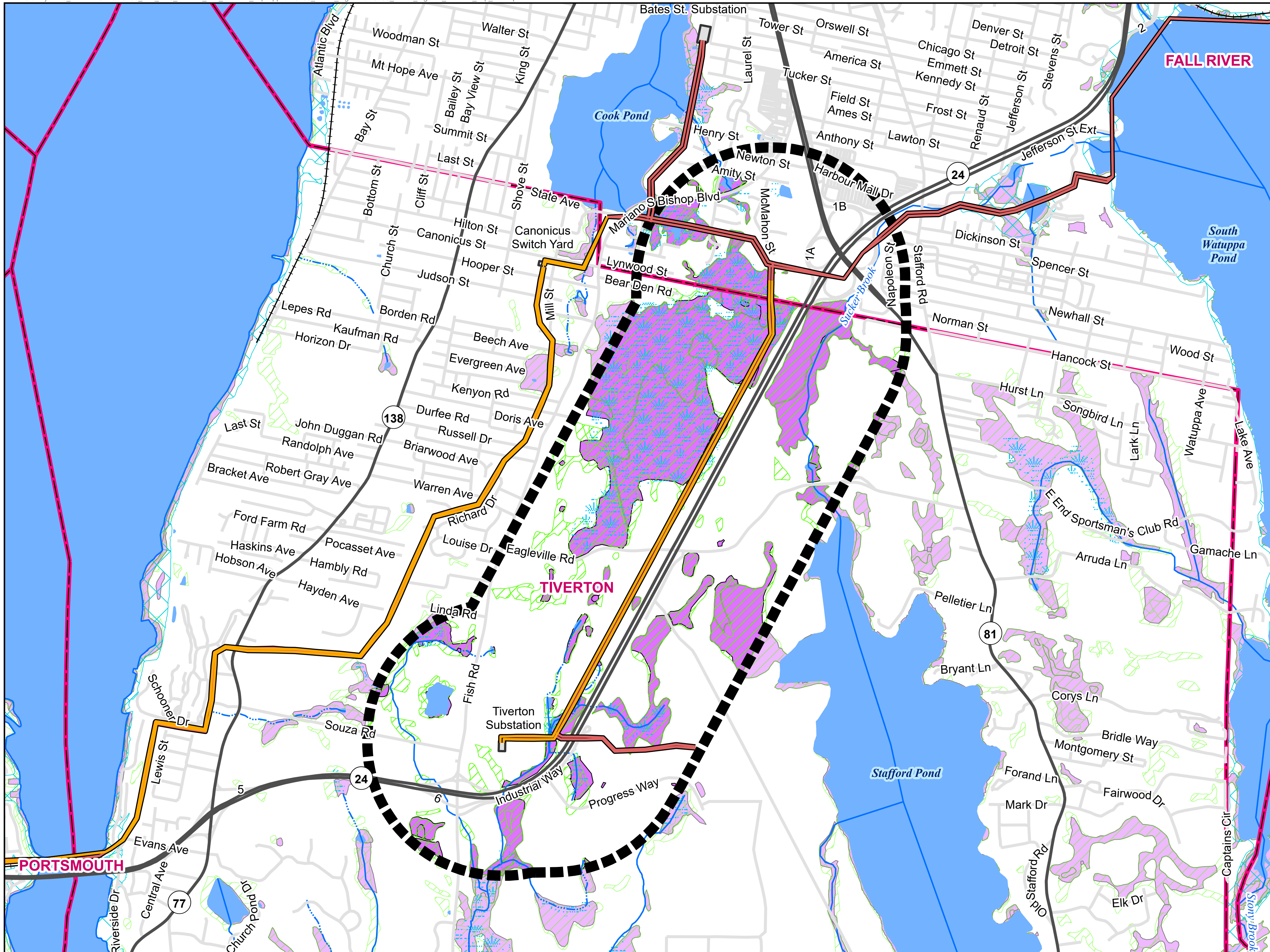

- Existing Transmission Line
- Proposed Transmission Line
- 5000 Foot Study Area
- Substation or Switching Station
- State Highway
- Minor Road
- Railroad
- Town Boundary
- Perennial River or Stream (NHD)
- Intermittent Stream (NHD)
- Swamp/Marsh (NHD)
- Lake, Pond, or Reservoir (NHD)
- FEMA - 100 Year Floodplain
- NWI Wetland
- Wetlands (State Agency)

REVISIONS:

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POWER Engineers, Inc
2 Hampshire Street Suite 301
Foxborough, MA 02035

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FIGURE 5-3 WETLAND RESOURCES

Scale 1"=2000' when printed at 11" by 17"

0 500 1,000 1,500 Meters

0 1,000 2,000 3,000 4,000 Feet

Rhode Island Energy
a PPL company

Rhode Island Energy
280 Melrose Street
Providence, RI 02907

Wetland Resources
L14 & M13 Tiverton Tap Rebuild Project
Rhode Island Energy
City of Fall River, Town of Tiverton
Bristol and Newport Counties
Commonwealth of Massachusetts, State of Rhode Island

SCALE	JOB NO.	DATE:	SHEET
AS NOTED	249458	5/30/2024	1 of 1

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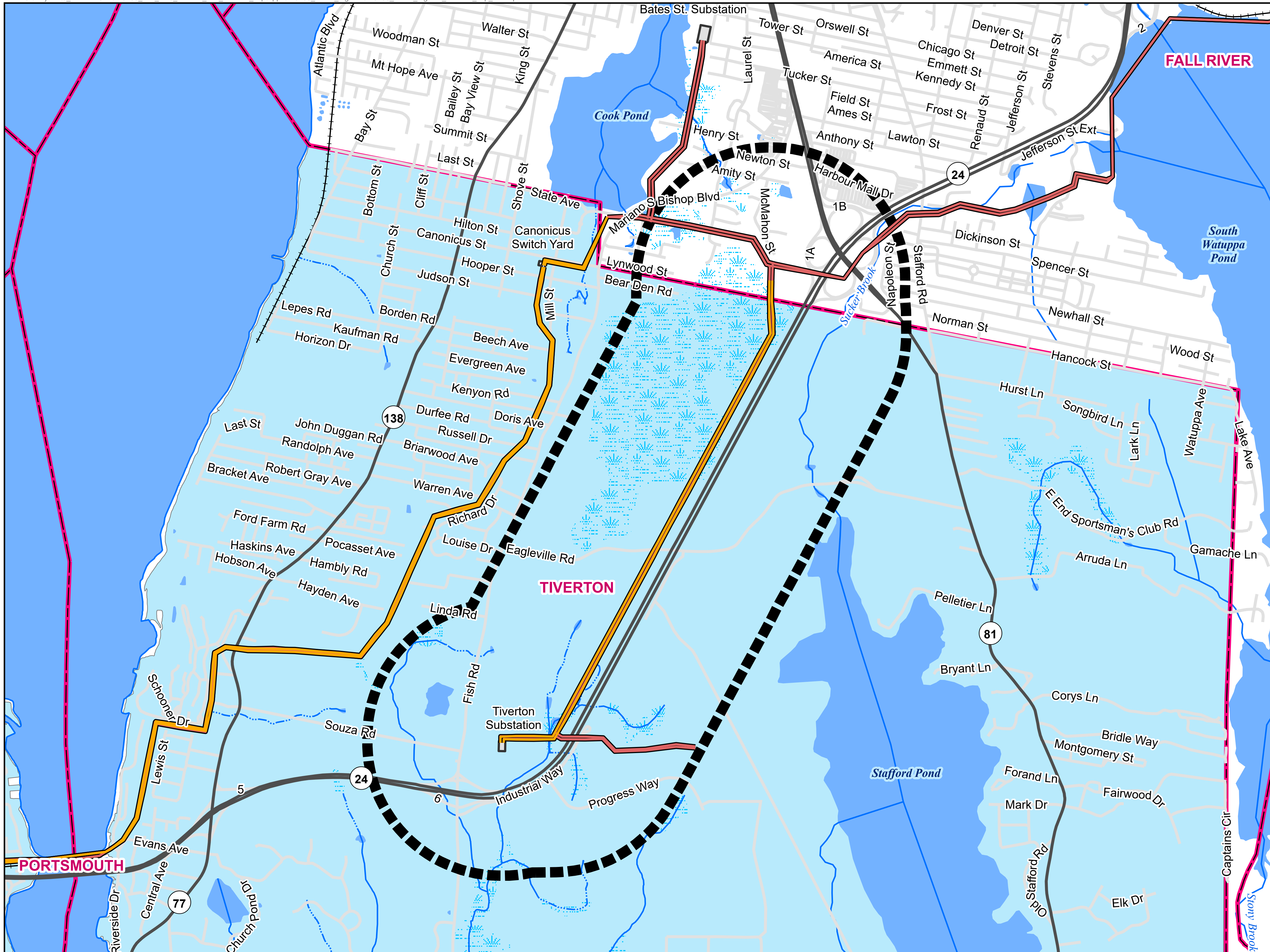

Existing Transmission Line
Proposed Transmission Line
5000 Foot Study Area
Substation or Switching Station
State Highway
Minor Road
Railroad
Town Boundary
Perennial River or Stream (NHD)
Intermittent Stream (NHD)
Lake, Pond, or Reservoir (NHD)
Water Area
Swamp/Marsh (NHD)
Groundwater Quality Standard
GA

REVISIONS:

POWER ENGINEERS
POWER Engineers, Inc
2 Hampshire Street Suite 301
Foxborough, MA 02035

NOTES:

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FIGURE 5-4 GROUNDWATER RESOURCES

Scale 1"=2000' when printed at 11" by 17"

0 500 1,000 1,500 Meters

0 1,000 2,000 3,000 4,000 Feet

Rhode Island Energy
280 Melrose Street
Providence, RI 02907

Groundwater Resources
L14 & M13 Tiverton Tap Rebuild Project
Rhode Island Energy
City of Fall River, Town of Tiverton
Bristol and Newport Counties
Commonwealth of Massachusetts, State of Rhode Island

SCALE	JOB NO.	DATE:	SHEET
AS NOTED	249458	5/30/2024	1 of 1

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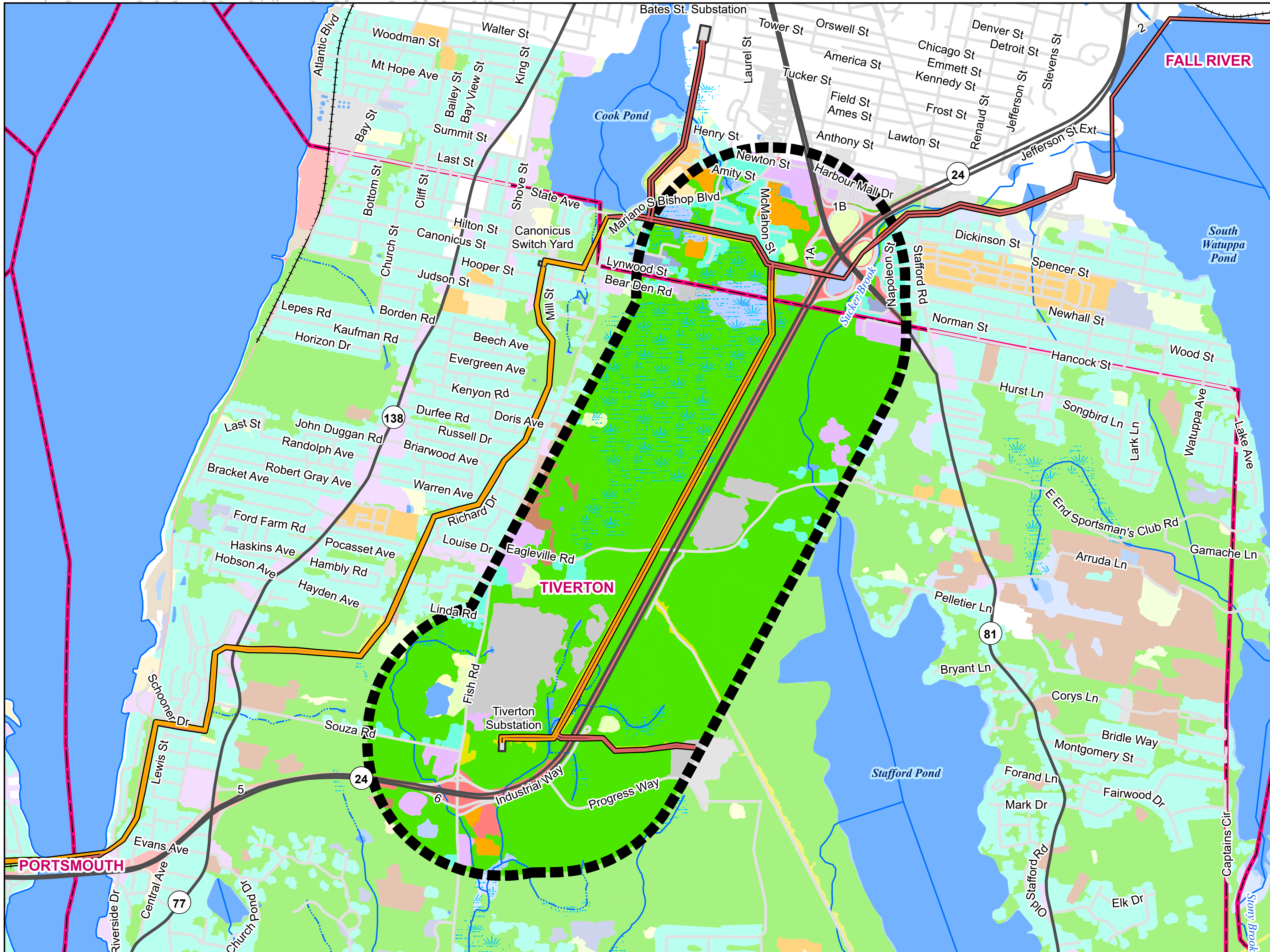

Existing Transmission Line
Proposed Transmission Line
5000 Foot Study Area
Substation or Switching Station
State Highway
Minor Road
Railroad
Town Boundary
Perennial River or Stream (NHD)
Intermittent Stream (NHD)
Swamp/Marsh (NHD)
Lake, Pond, or Reservoir (NHD)

Land Use / Land Cover

Residential
Commercial
Industrial, Mines, or Waste Disposal
Institutional (schools, hospitals, churches, cemeteries, etc.)
Transitional Areas
Transportation
Agriculture, Pasture, or Orchard
Recreation
Brushland
Forest
Utility Easement
Vacant Land
Wetland
Water

REVISIONS:

POWER ENGINEERS
POWER Engineers, Inc
2 Hampshire Street Suite 301
Foxborough, MA 02035

NOTES:

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FIGURE 6-1 LAND USE / LAND COVER

Scale 1"=2000' when printed at 11" by 17"

0 500 1,000 1,500 Meters

0 1,000 2,000 3,000 4,000 Feet

Rhode Island Energy
280 Melrose Street
Providence, RI 02907

Land Use / Land Cover
L14 & M13 Tiverton Tap Rebuild Project
Rhode Island Energy
City of Fall River, Town of Tiverton
Bristol and Newport Counties
Commonwealth of Massachusetts, State of Rhode Island

SCALE	JOB NO.	DATE:	SHEET
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APPENDIX B PROJECT EROSION & SEDIMENT CONTROL PLANS

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This document has been reviewed for Critical Energy Infrastructure Information (CEII). [June 2024]

- Project Centerline
- Transmission Line
- Existing or Proposed Power Facility
- Town Boundary

REVISIONS:

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Foxborough, MA 02035

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N

PROJECT LOCUS MAP
Scale 1"=2000' when printed at 11" by 17"

0 500 1,000 Meters

0 2,000 4,000 Feet

Rhode Island Energy
a PPL company

Rhode Island Energy
280 Melrose Street
Providence, RI 02907

PROJECT LOCUS MAP
Tiverton Tap Rebuild Project
Rhode Island Energy
City of Fall River, Massachusetts; Towns of Portsmouth and Tiverton, Rhode Island

SCALE	JOB NO.	DATE:	SHEET
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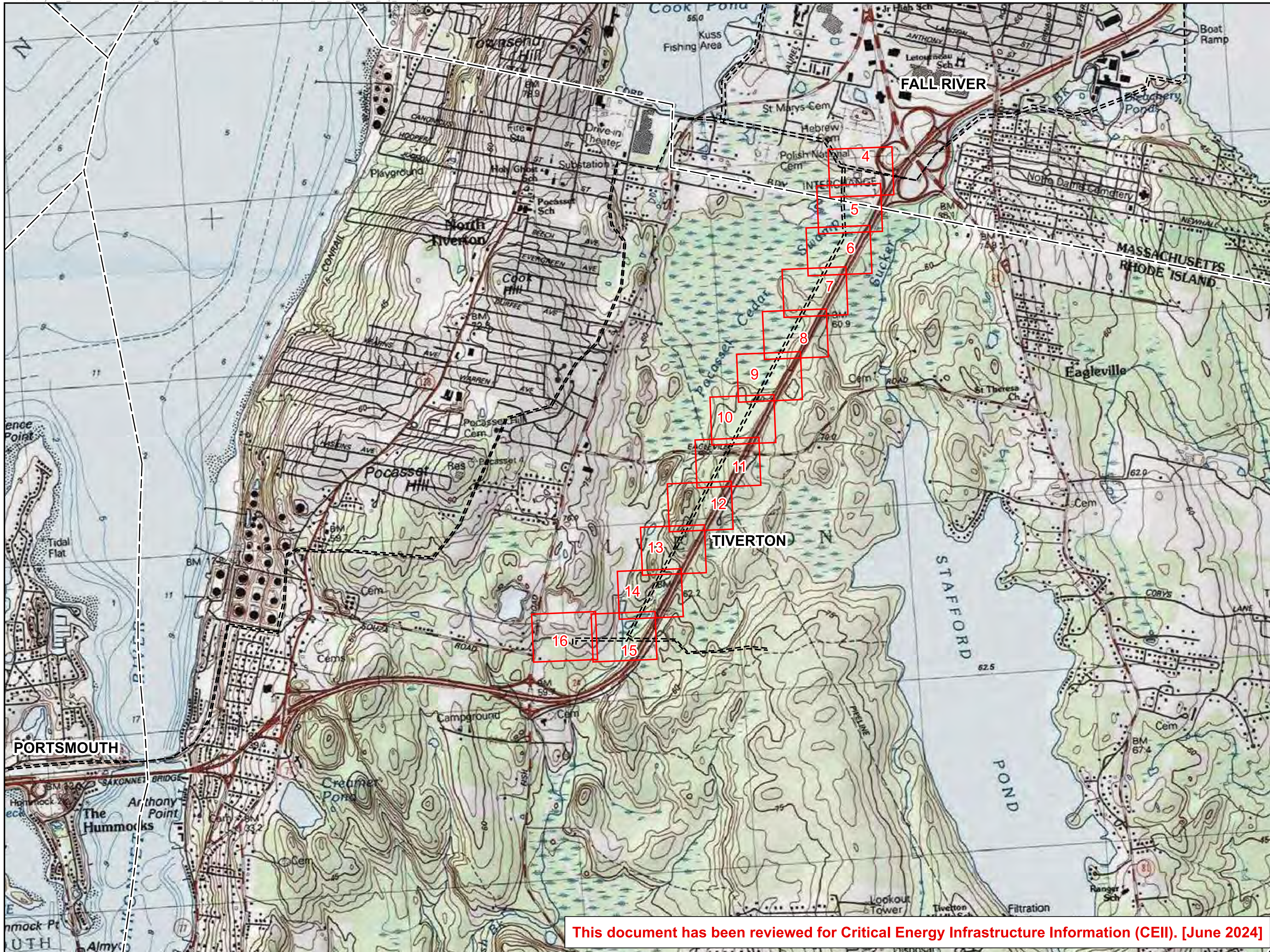

Page Boundary
Transmission Line
Existing or Proposed Power Facility
Town Boundary

REVISIONS:

POWER ENGINEERS

POWER Engineers, Inc
2 Hampshire Street Suite 301
Foxborough, MA 02035

NOTES:

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N

ESC PLAN MAP BOOK KEY

Scale 1"=2000' when printed at 11" by 17"

0 500 1,000 Meters

0 2,000 4,000 Feet

Rhode Island Energy
a PPL company

Rhode Island Energy
280 Melrose Street
Providence, RI 02907

SOIL EROSION AND SEDIMENT CONTROL PLAN INDEX
Tiverton Tap Rebuild Project
Rhode Island Energy
City of Fall River, Massachusetts; Towns of Portsmouth and Tiverton, Rhode Island

SCALE	JOB NO.	DATE:	SHEET
AS NOTED	249458	6/7/2024	2 of 16

General Notes:

1. Plans/Drawings are issued for permitting and soil erosion control measures.

2. Property and boundary information and existing overhead and underground utilities shown are from publicly available data and are provided for reference purposes only. POWER Engineers makes no representation or warranty as to the accuracy of location of the information shown.

3. Limits of Disturbance (LOD) are depicted as a typical work corridor within the existing electric transmission ROW, railroad ROW and public roadway ROW. Limits of Disturbance equate to the boundaries of the access routes and work pads shown on the figures.

4. Construction practices will conform with the following standards, as applicable:
   a. Rhode Island Soil Erosion and Sediment Control Handbook
   b. Rhode Island Storm Water Design and Installation Standards Manual
   c. Rhode Island Department of Environmental Management Wetland BMP Manual
   d. Rhode Island Energy ROW Access Maintenance and Construction Best Management Practices (EG-303NE)

Erosion and Sediment Control Measures:

1. Areas inside the Limits of Disturbance will be restored by the Contractor to their original condition at the Contractor's expense, to the satisfaction of Rhode Island Energy.

2. Install temporary inlet protection where catch basins are present within the work zone, including oil absorbent socks.

3. Contractor will be solely responsible for site security and job safety. All construction activity shall be in accordance with OSHA regulations and local and state requirements.

4. All materials are to be disposed of per applicable laws and regulations.

5. Dewatering activities shall occur outside of wetlands and watercourses with approved dewatering controls such as filter bags, filter socks, weir tanks or dewatering basins. Where this is not possible, dewatering effluent shall be transported offsite.

6. All wetland and waterways shall be flagged prior to commencing work activities at the site.

7. Maintain undisturbed vegetated buffers between work areas and wetlands/waterways wherever possible.

8. Limit removal of, and damage to, existing vegetation wherever possible.

9. Avoid unnecessary disturbance of site soils wherever possible.

10. Upon completion of construction in a given location (structure, work area, etc.), disturbed or exposed soils will be immediately stabilized with mulch, blankets or similar temporary erosion and sediment control practice adequate for providing temporary stabilization while vegetation becomes established.

11. Where temporary erosion control, or permanent seed mixes are placed, appropriate temporary measures will be taken to prevent soil erosion while seed is germinating.

12. Mulch will not be used as a temporary erosion control practice in drainageways. Mulch placement on steep slopes (>3:1) will be limited to hydraulic mulch or rolled erosion control products (e.g., erosion control blankets, etc.).

13. Seeding shall occur only during specified planting seasons unless otherwise directed by Rhode Island Energy.

14. Seed mixes will be approved by the Rhode Island Energy Environmental Scientist prior to placement. Seed mixes will be appropriate for the site conditions (e.g. wetland, upland, etc.).

15. Low growing, woody plant species and root systems will be retained in locations where work pads and access roads are not proposed. Care will be taken to protect such plants and their root systems from damage and compaction.

16. Perimeter sediment control locations shown on the plans contained herein are approximations, and may change depending on field conditions at the time of construction or as directed by the Rhode Island Energy Environmental Scientist. Perimeter sediment controls will not be installed directly in wetlands without prior written approval from the Rhode Island Energy Environmental Scientist.

17. Where coastal and freshwater resource areas occur immediately adjacent to and down gradient from the work, sediment perimeter controls (e.g. straw wattles, compost filter socks, excelsior sediment logs, straw bales, reinforced silt fence, etc.) will be placed between the resource area and the work zone prior to the commencement of work. Perimeter controls will be installed as close to the area of disturbance as possible. Perimeter control selection should occur in coordination with the Rhode Island Energy Environmental Scientist.

18. Perimeter sediment controls will be placed along the down slope edge of unpaved access roads as indicated on the plans wherever wetlands resource areas are closer than 50' to the edge of road and/or adjacent to slopes exceeding a grade of 3:1, or as directed by the Rhode Island Energy Environmental Scientist.

19. If required, alternatives to silt fence and/or straw bales (e.g., compost socks, wattles, excelsior sediment logs, etc.) are preferred within wetlands adjacent to the edge of the construction pad. Care should be taken to avoid disturbing wetland soils outside of limits of the construction pad and/or area while installing perimeter controls.

20. Mud box/drill cutting box locations, dewatering areas, concrete washout areas, and temporary soil stockpile areas shown on the plan indicate only that such devices and practices may be required and do not approximate locations. Final locations for such devices and practices will be determined during construction as field conditions require and allow. Dewatering may be required in additional locations depending on field conditions or weather during construction.

21. Where water bars are installed on improved access roads, they should be installed such that runoff is directed to a level spreader, stabilized outlet, or other feature designed to prevent concentrated flows from eroding adjacent locations. Wherever possible, runoff should be directed away from wetlands, waterways, and waterbodies.

22. When construction mats are used in locations where excavations/mud boxes are required for structure installation, the construction mat surface will be adequately protected to prevent siltation through the construction mats to wetlands below.

23. Where necessary, or as directed by the Rhode Island Energy Environmental Scientist, stone transition ramps shall be installed in association with construction mats.

24. All erosion and sediment controls, devices, and practices will be properly maintained, replaced, supplemented, or modified as necessary throughout the life of the project in order to minimize soil erosion and to prevent sediment from being deposited in any wetlands, or coastal features.

25. Soil stockpiles will be contained within approved construction work pads or designated stockpiling areas.

26. Where possible, soil stockpiles will not exceed 5 feet high in height. Soil stockpiles will be covered with matting, tarp, or other similar material and weights at the end of each construction day if necessary. Install perimeter controls around all stockpiles in close proximity to wetlands and contiguous areas.

27. No vehicle or equipment refueling shall occur within 100 feet of a wetland, waterbody, or waterway.

28. Stone, soil, or other fill materials will not be placed in any wetlands, waterbodies, or waterways beyond permitted areas.

29. Where work will occur in wetlands, or where waterway crossings are proposed, construction mats, or construction mat bridges will be installed respectively prior to commencing construction.

30. Upon permanent stabilization of all disturbed soils, temporary erosion and/or sediment controls and construction mats will be removed from, and disposed of properly, off-site.

31. Unless otherwise directed, all erosion and sediment controls shall be installed in accordance with, and work shall conform to Rhode Island Energy's Environmental Guidance-303NE.

32. Any potentially impacted soils or water encountered during construction activities will be managed in accordance with applicable local, state and federal regulations.

33. Mud Boxes will be used to contain and handle wetland soils and saturated soils on temporary construction work pads in wetlands.

34. Stabilized construction entrances will be installed at access route entrances onto the ROW, and will be installed with clean stone over geotextile fabric.

Erosion and Sediment Control Maintenance During Construction:

1. All Erosion and sediment control measures will be inspected for stability and proper function after every runoff producing storm event, or at least weekly. All necessary repairs will be made immediately.

2. Trapped sediment will be removed from behind perimeter control devices before the deposits reach 50 percent (1/2) of the above-ground height of the device, unless otherwise noted, or according to manufacturer's specifications.

3. Sediment will be removed from sediment traps when design capacity has been reduced by 50 percent (50%).

4. In disturbed areas where adequate seed stock is not present, or where topsoil has been displaced, soils will be prepared in a manner suitable for supporting plant growth prior to placing seed, mulch, and or other erosion control practices appropriate for the site.

Wetland Invasive Species Control Notes:

1. All construction equipment, vehicles, and materials (i.e., construction mats) must be clean and free of excess soil, debris, and vegetation before being mobilized to the Project area.

2. Construction mats or equivalent will be used in wetlands and other coastal resources during clearing and other construction operations to minimize the spread of invasive species within a wetland or coastal resource by avoiding equipment and vehicles directly traversing wetlands or coastal resources.

3. To minimize the potential for spreading invasive plant species from wetland-to-wetland, any equipment or vehicles working in or traversing a wetland will be cleaned prior to relocating to another work site. Cleaning of vehicles and equipment (including the tracks and tires) will involve removal of visible dirt, debris, and vegetation through the use of brooms, shovels, and if needed, compressed air.

4. Construction mats will be cleaned prior to relocation to other work areas, wetlands, or coastal resources. Cleaning of matting will involve systematically dropping the mats one on top of another to shake loose any sediment and debris. The matting will then be swept to remove loose soil and any plant material.

POWER ENGINEERS
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Rhode Island Energy a PPL company
Rhode Island Energy
280 Melrose Street
Providence, RI 02907

SOIL EROSION AND SEDIMENT CONTROL PLAN GENERAL NOTES
Tiverton Tap Rebuild Project
Rhode Island Energy
City of Fall River, Massachusetts; Towns of Portsmouth and Tiverton, Rhode Island

SCALE	JOB NO.	DATE:	SHEET
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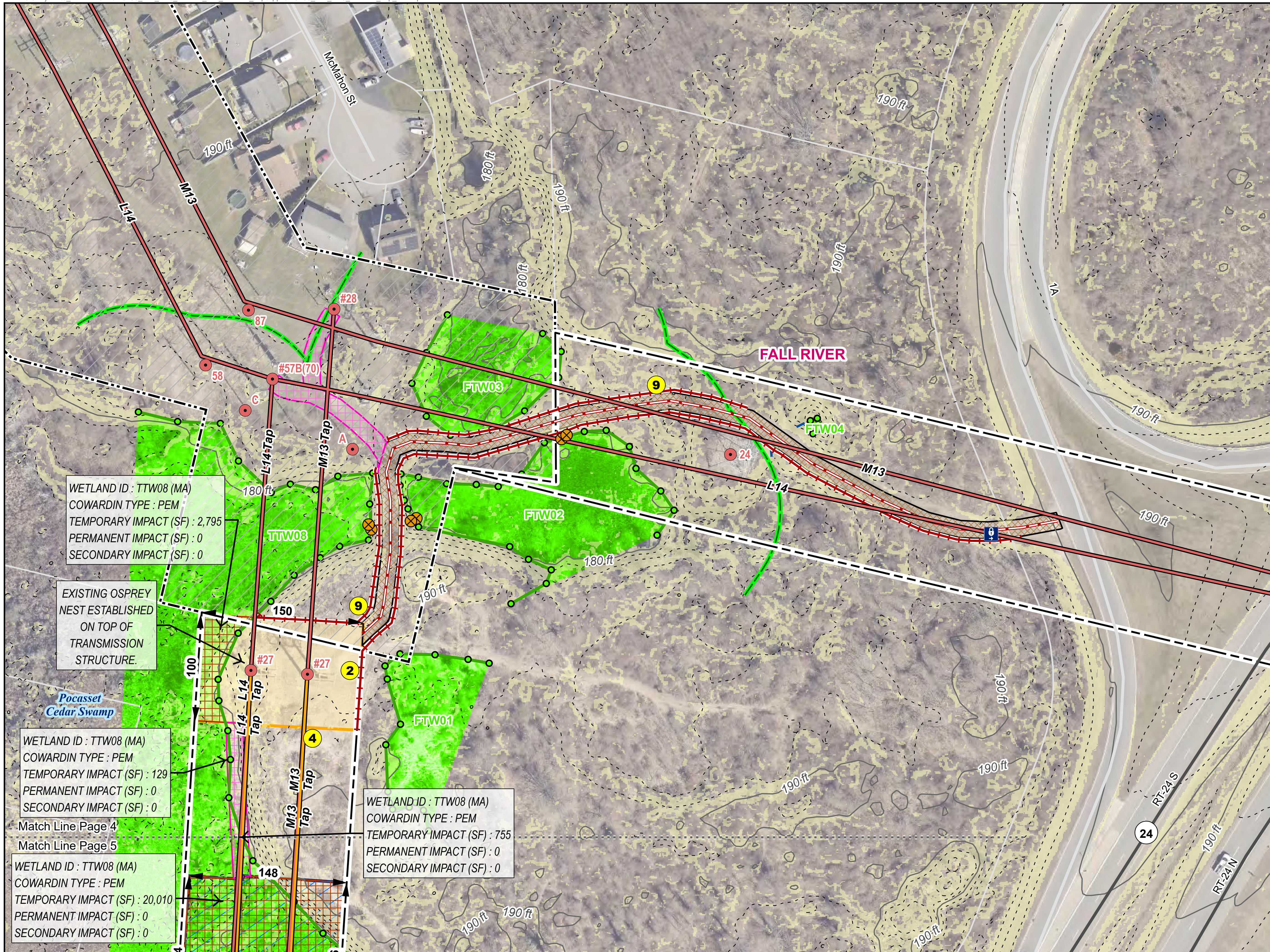

- Existing Structure
- Proposed Structure with Concrete Foundation
- Existing Transmission Line
- Proposed Transmission Line
- National Grid Owned Land
- Existing Right of Way
- Type R - Refresh/Cap Existing Sub-base
- Perimeter Sediment Control
- Type R - Refresh/Cap Existing Sub-base
- Temporary Work Area - Mow Only
- Pull Site - Mow Only and Matting
- Alternative Type Matting
- Construction Matting
- State Highway
- Minor Road
- Index Contour (10' Interval)
- Contour (2' Interval)
- 0 - 15% Slope
- > 15% Slope
- Parcel Boundary
- Culvert
- Gate
- Wetland Flag
- Wetland Border
- Isolated Wetland Border
- Ditch
- 100 ft Buffer Wetland
- Field Delineated Wetland
- 2 Install temporary concrete wash station.
- 4 Dewatering Area
- 9 Perimeter Sediment Controls

REVISIONS:

The project Limit of Disturbance (LOD) are comprised of the outer edge of all work pads, pull pads, grading areas, and road improvements within the right-of-way (ROW) shown on these plans.

Final determinations will be made in the field by Rhode Island Energy as to the extent of grading that is required for access roads and work pads, so as to minimize rock removal and earth disturbance.

POWER ENGINEERS

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2 Hampshire Street Suite 301
Foxborough, MA 02035

NOTES:

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N

ESC PLAN MAP BOOK 4

Scale 1”=100’ when printed at 11” by 17”

0 10 20 30 Meters

0 25 50 75 100 Feet

Rhode Island Energy a PPL company

Rhode Island Energy
280 Melrose Street
Providence, RI 02907

SOIL EROSION AND SEDIMENT CONTROL PLAN
Tiverton Tap Rebuild Project
Rhode Island Energy
City of Fall River
Commonwealth of Massachusetts

SCALE	JOB NO.	DATE:	SHEET
AS NOTED	249458	6/7/2024	4 of 16

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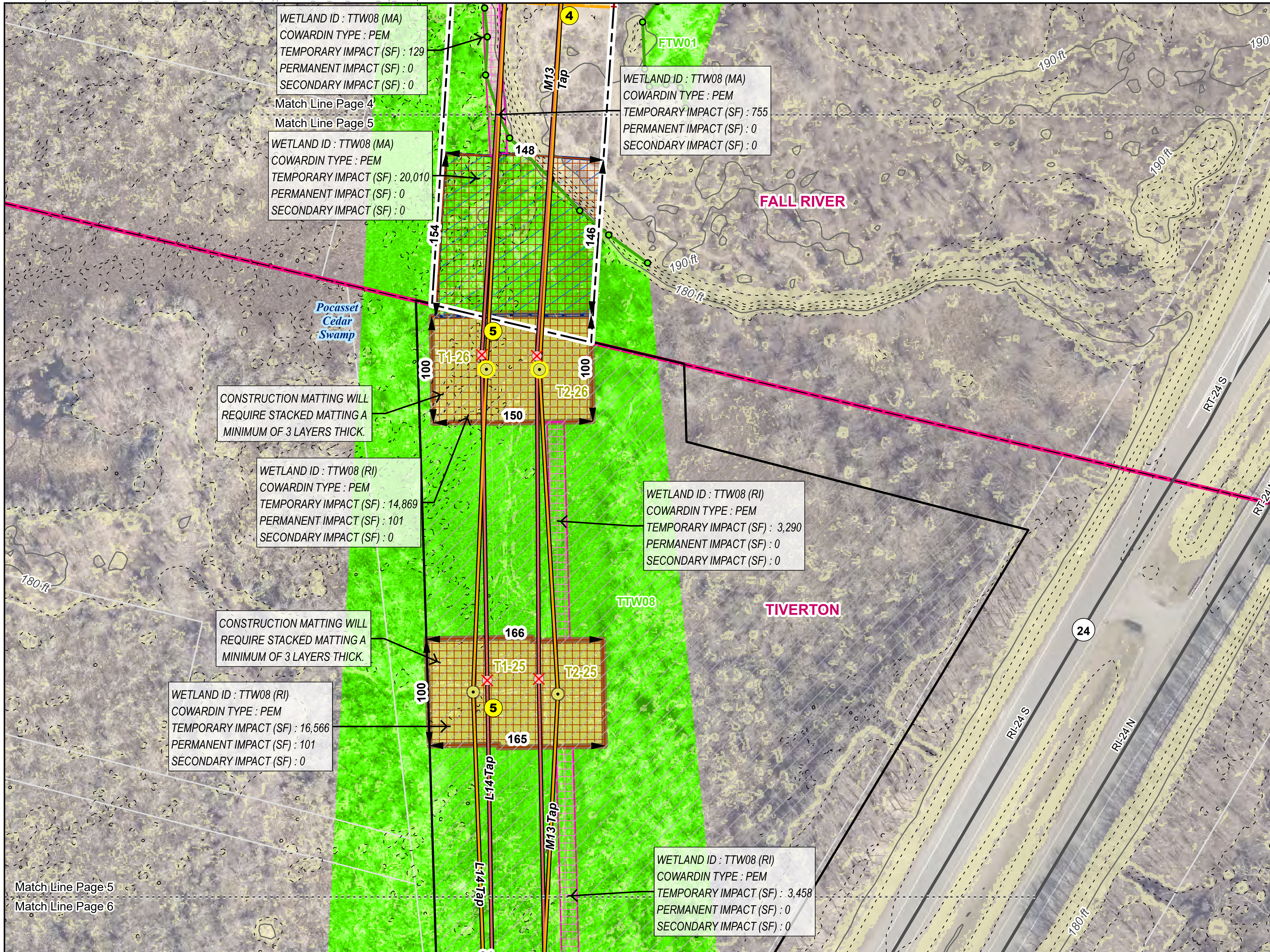

- Proposed Structure
- Structure To Be Removed
- Proposed Structure with Concrete Foundation
- Existing Transmission Line
- Proposed Transmission Line
- RIE Owned Land
- Existing Right of Way
- Perimeter Sediment Control
- Temporary Work Area - Mow Only
- Pull Site - Mow Only and Matting
- Matted Work Pad - Stacked Mats
- Alternative Type Matting
- Construction Matting
- State Highway
- Minor Road
- Index Contour (10' Interval)
- Contour (2' Interval)
- 0 - 15% Slope
- > 15% Slope
- Town Boundary
- Parcel Boundary
- Wetland Flag
- Wetland Border
- Field Delineated Wetland
- 4 Dewatering Area
- 5 Install temporary mud box.

REVISIONS:

The project Limit of Disturbance (LOD) are comprised of the outer edge of all work pads, pull pads, grading areas, and road improvements within the right-of-way (ROW) shown on these plans.

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Foxborough, MA 02035

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ESC PLAN MAP BOOK 5

Scale 1"=100' when printed at 11" by 17"

0 10 20 30 Meters

0 25 50 75 100 Feet

Rhode Island Energy
280 Melrose Street
Providence, RI 02907

SOIL EROSION AND SEDIMENT CONTROL PLAN
Tiverton Tap Rebuild Project
Rhode Island Energy
City of Fall River, Town of Tiverton
Comm. of Massachusetts and State of Rhode Island

SCALE	JOB NO.	DATE:	SHEET
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Proposed Structure
Structure To Be Removed
Proposed Structure with Concrete Foundation
Existing Transmission Line
Proposed Transmission Line
RIE Owned Land
Matted Work Pad - Stacked Mats
Alternative Type Matting
Construction Matting
State Highway
Index Contour (10' Interval)
Contour (2' Interval)
0 - 15% Slope
> 15% Slope
Parcel Boundary
Field Delineated Wetland
Rhode Island Natural Heritage Areas
5 Install temporary mud box.

REVISIONS:

The project Limit of Disturbance (LOD) are comprised of the outer edge of all work pads, pull pads, grading areas, and road improvements within the right-of-way (ROW) shown on these plans.

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ESC PLAN MAP BOOK 6

Scale 1"=100' when printed at 11" by 17"

0 10 20 30 Meters

0 25 50 75 100 Feet

Rhode Island Energy
280 Melrose Street
Providence, RI 02907

SOIL EROSION AND SEDIMENT CONTROL PLAN
Tiverton Tap Rebuild Project
Rhode Island Energy
Town of Tiverton
State of Rhode Island

SCALE	JOB NO.	DATE:	SHEET
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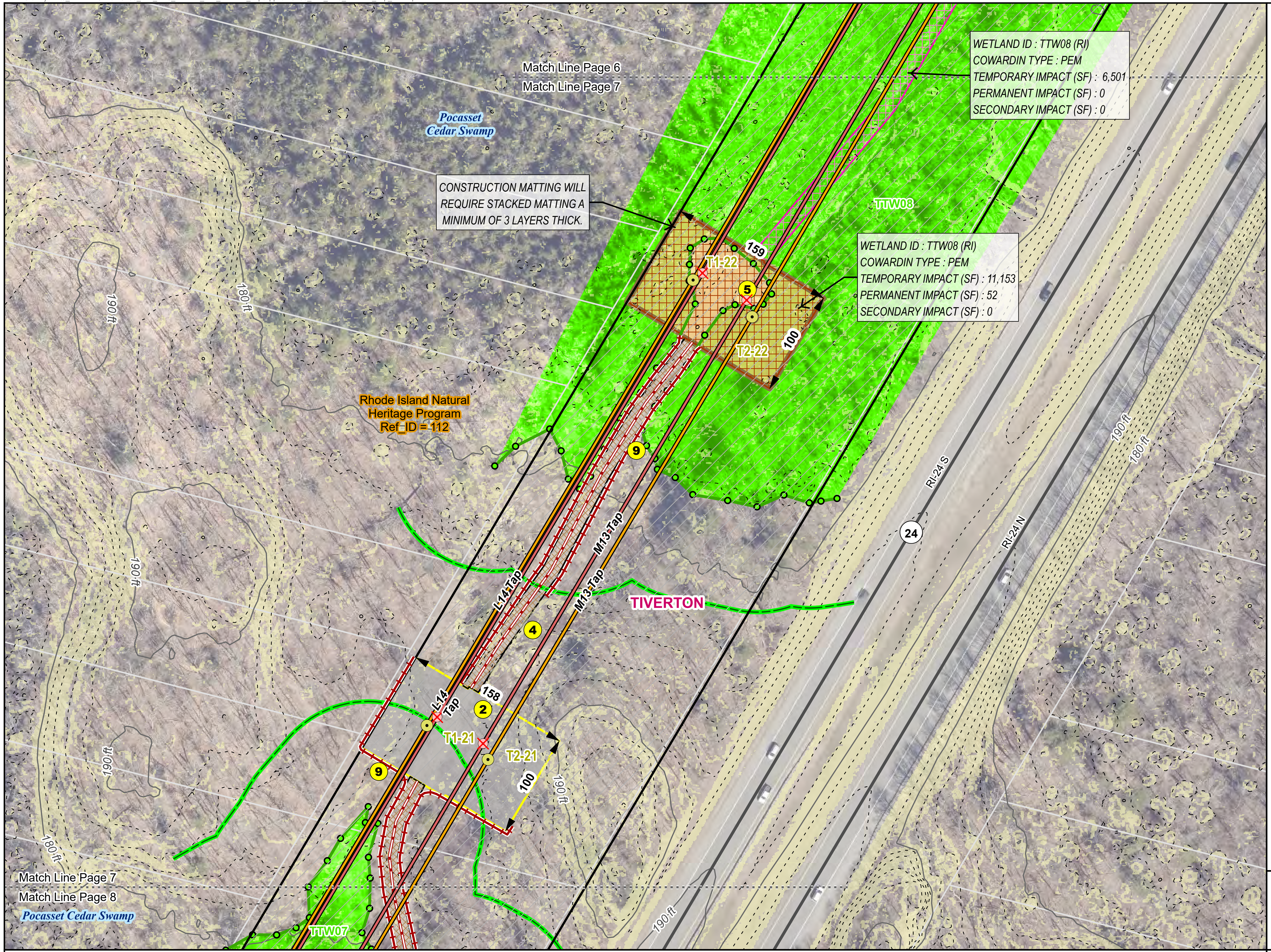

- Proposed Structure
- Structure To Be Removed
- Proposed Structure with Concrete Foundation
- Existing Transmission Line
- Proposed Transmission Line
- RIE Owned Land
- Type R - Refresh/Cap Existing Sub-base
- Perimeter Sediment Control
- Type R - Refresh/Cap Existing Sub-base
- Temporary Work Area - Stone - Cover with Top Soil and Stabilize Following Construction Work
- Matted Work Pad - Stacked Mats
- Alternative Type Matting
- Construction Matting
- State Highway
- Index Contour (10' Interval)
- Contour (2' Interval)
- 0 - 15% Slope
- > 15% Slope
- Parcel Boundary
- Wetland Flag
- Wetland Border
- Wetland Jurisdictional Area (100')
- Field Delineated Wetland
- Rhode Island Natural Heritage Areas
- 2 Install temporary concrete wash station.
- 4 Dewatering Area
- 5 Install temporary mud box.
- 9 Perimeter Sediment Controls

REVISIONS:

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ESC PLAN MAP BOOK 7

Scale 1"=100' when printed at 11" by 17"

0 10 20 30 Meters

0 25 50 75 100 Feet

Rhode Island Energy (a PPL company)

Rhode Island Energy
280 Melrose Street
Providence, RI 02907

SOIL EROSION AND SEDIMENT CONTROL PLAN
Tiverton Tap Rebuild Project
Rhode Island Energy
Town of Tiverton
State of Rhode Island

SCALE	JOB NO.	DATE:	SHEET
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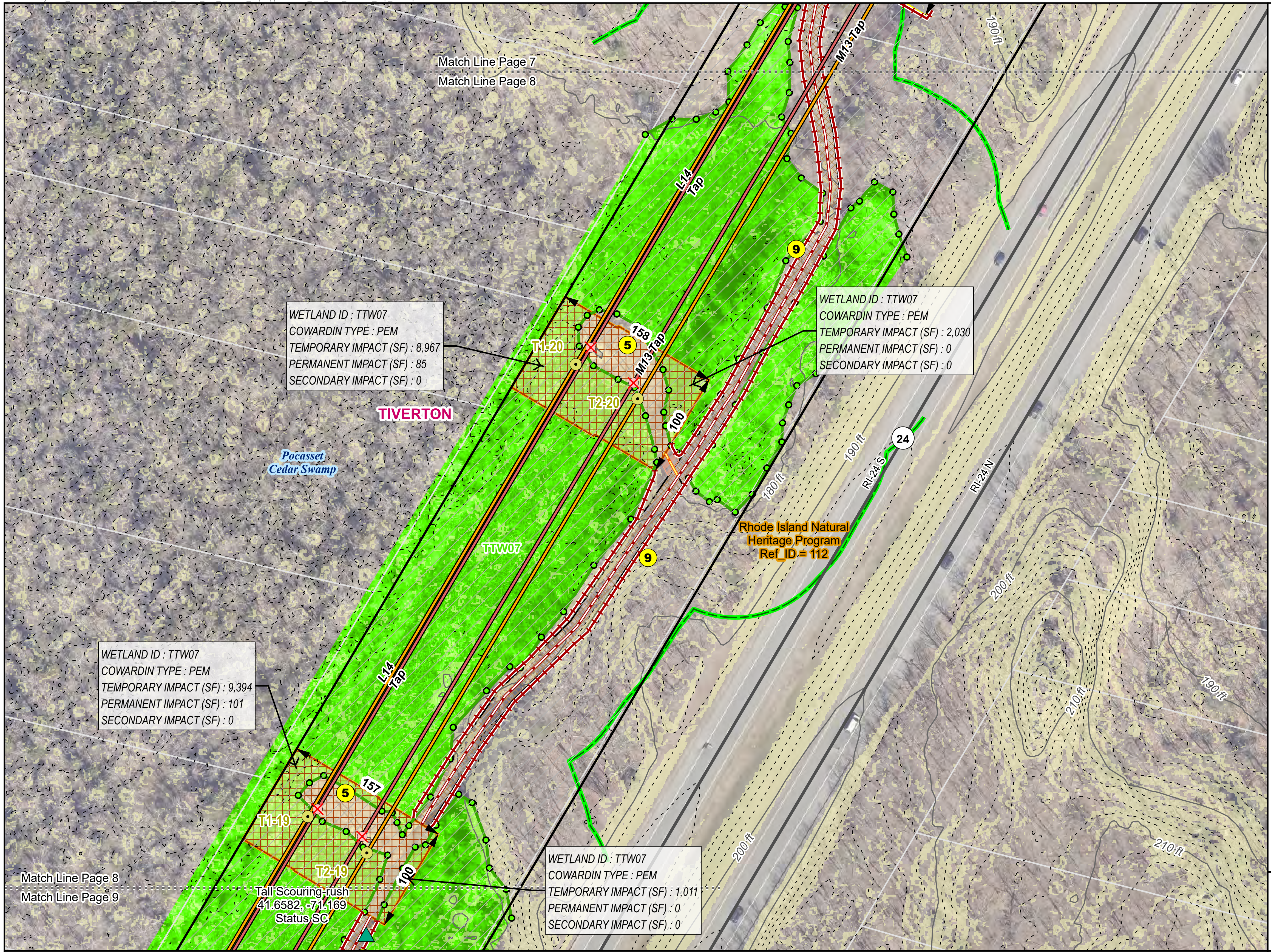

Proposed Structure
Structure To Be Removed
Proposed Structure with Concrete Foundation
Existing Transmission Line
Proposed Transmission Line
RIE Owned Land
Minor Improvements - "Type 1 - RIE Standard Road", grade and scrape per specifications (15-feet and 6 inches either side) and add depth of stone per standard Type-1 specifications
Type R - Refresh/Cap Existing Sub-base
Perimeter Sediment Control
Minor Improvements - "Type 1 - RIE Standard Road", grade and scrape per specifications (15-feet and 6 inches either side) and add depth of stone per standard Type-1 specifications
Type R - Refresh/Cap Existing Sub-base
Temporary Work Area - Stone - Cover with Top Soil and Stabilize Following Construction Work
Temporary Work Area - Mow Only
Construction Matting
State Highway
Index Contour (10' Interval)
Contour (2' Interval)
0 - 15% Slope
> 15% Slope
Parcel Boundary
Wetland Flag
Wetland Border
Wetland Jurisdictional Area (100')
Field Delineated Wetland
State Concern
Rhode Island Natural Heritage Areas
5 Install temporary mud box.
9 Perimeter Sediment Controls

REVISIONS:

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POWER ENGINEERS

POWER Engineers, Inc
2 Hampshire Street Suite 301
Foxborough, MA 02035

NOTES:

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ESC PLAN MAP BOOK 8

Scale 1"=100' when printed at 11" by 17"

0 10 20 30 Meters

0 25 50 75 100 Feet

Rhode Island Energy
a PPL company

Rhode Island Energy
280 Melrose Street
Providence, RI 02907

SOIL EROSION AND SEDIMENT CONTROL PLAN
Tiverton Tap Rebuild Project
Rhode Island Energy
Town of Tiverton
State of Rhode Island

SCALE	JOB NO.	DATE:	SHEET
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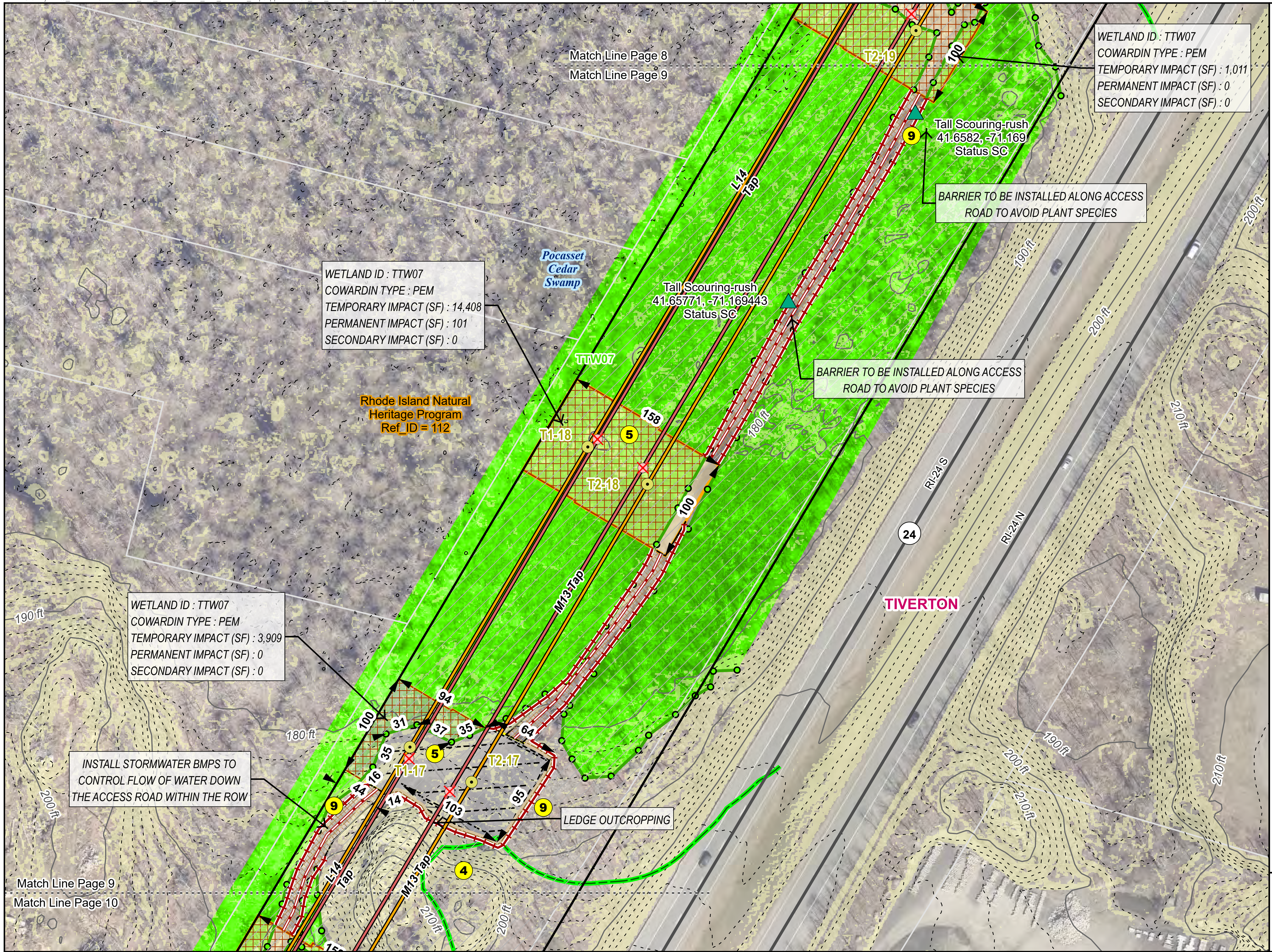

- Proposed Structure
- Structure To Be Removed
- Proposed Structure with Concrete Foundation
- Existing Transmission Line
- Proposed Transmission Line
- RIE Owned Land
- Type R - Refresh/Cap Existing Sub-base
- Perimeter Sediment Control
- Reinforced Silt Fence
- Type R - Refresh/Cap Existing Sub-base
- Temporary Work Area - Stone - Cover with Top Soil and Stabilize Following Construction Work
- Temporary Work Area - Mow Only
- Construction Matting
- State Highway
- Index Contour (10' Interval)
- Contour (2' Interval)
- Preliminary Grading Contour
- 0 - 15% Slope
- > 15% Slope
- Parcel Boundary
- Wetland Flag
- Wetland Border
- Wetland Jurisdictional Area (100')
- Field Delineated Wetland
- State Concern
- Rhode Island Natural Heritage Areas
- 4 Dewatering Area
- 5 Install temporary mud box.
- 9 Perimeter Sediment Controls

REVISIONS:

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N

ESC PLAN MAP BOOK 9

Scale 1"=100' when printed at 11" by 17"

0 10 20 30 Meters

0 25 50 75 100 Feet

Rhode Island Energy™ a PPL company

Rhode Island Energy
280 Melrose Street
Providence, RI 02907

SOIL EROSION AND SEDIMENT CONTROL PLAN
Tiverton Tap Rebuild Project
Rhode Island Energy
Town of Tiverton
State of Rhode Island

SCALE	JOB NO.	DATE:	SHEET
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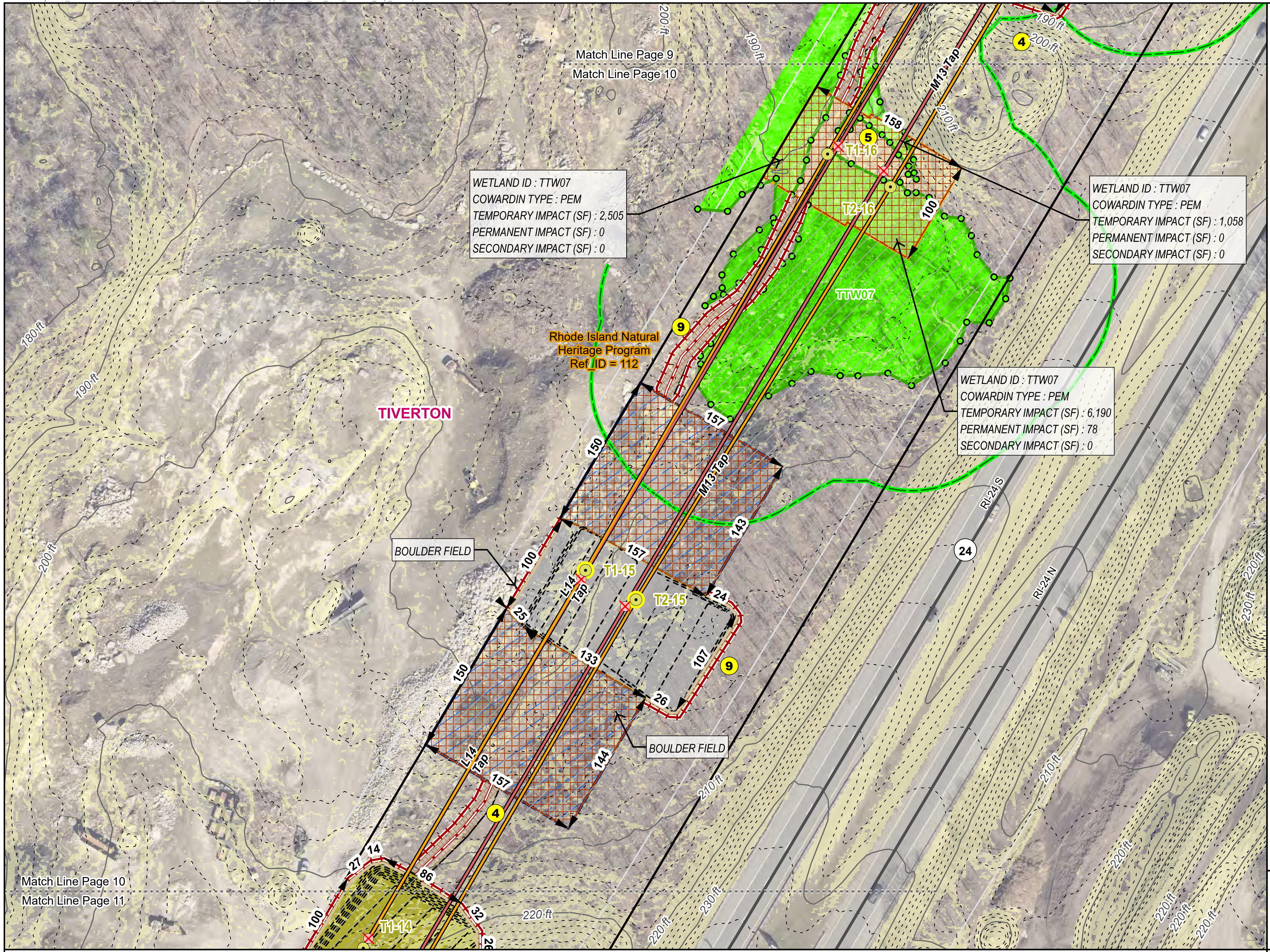

Proposed Structure
Structure To Be Removed
Proposed Structure with Concrete Foundation
Existing Transmission Line
Proposed Transmission Line
RIE Owned Land
Type R - Refresh/Cap Existing Sub-base
Perimeter Sediment Control
Reinforced Silt Fence
Type R - Refresh/Cap Existing Sub-base
Temporary Work Area - Stone - Cover with Top Soil and Stabilize Following Construction Work
Temporary Work Area - Mow Only
Pull Site - Mow Only and Matting
Tiered Work Pad
Construction Matting
State Highway
Index Contour (10' Interval)
Contour (2' Interval)
Preliminary Grading Contour
0 - 15% Slope
> 15% Slope
Parcel Boundary
Wetland Flag
Wetland Border
Wetland Jurisdictional Area (100')
Field Delineated Wetland
Rhode Island Natural Heritage Areas
4 Dewatering Area
5 Install temporary mud box.
9 Perimeter Sediment Controls

REVISIONS:

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ESC PLAN MAP BOOK 10

Scale 1"=100' when printed at 11" by 17"

0 10 20 30 Meters

0 25 50 75 100 Feet

Rhode Island Energy
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Rhode Island Energy
280 Melrose Street
Providence, RI 02907

SOIL EROSION AND SEDIMENT CONTROL PLAN
Tiverton Tap Rebuild Project
Rhode Island Energy
Town of Tiverton
State of Rhode Island

SCALE	JOB NO.	DATE:	SHEET
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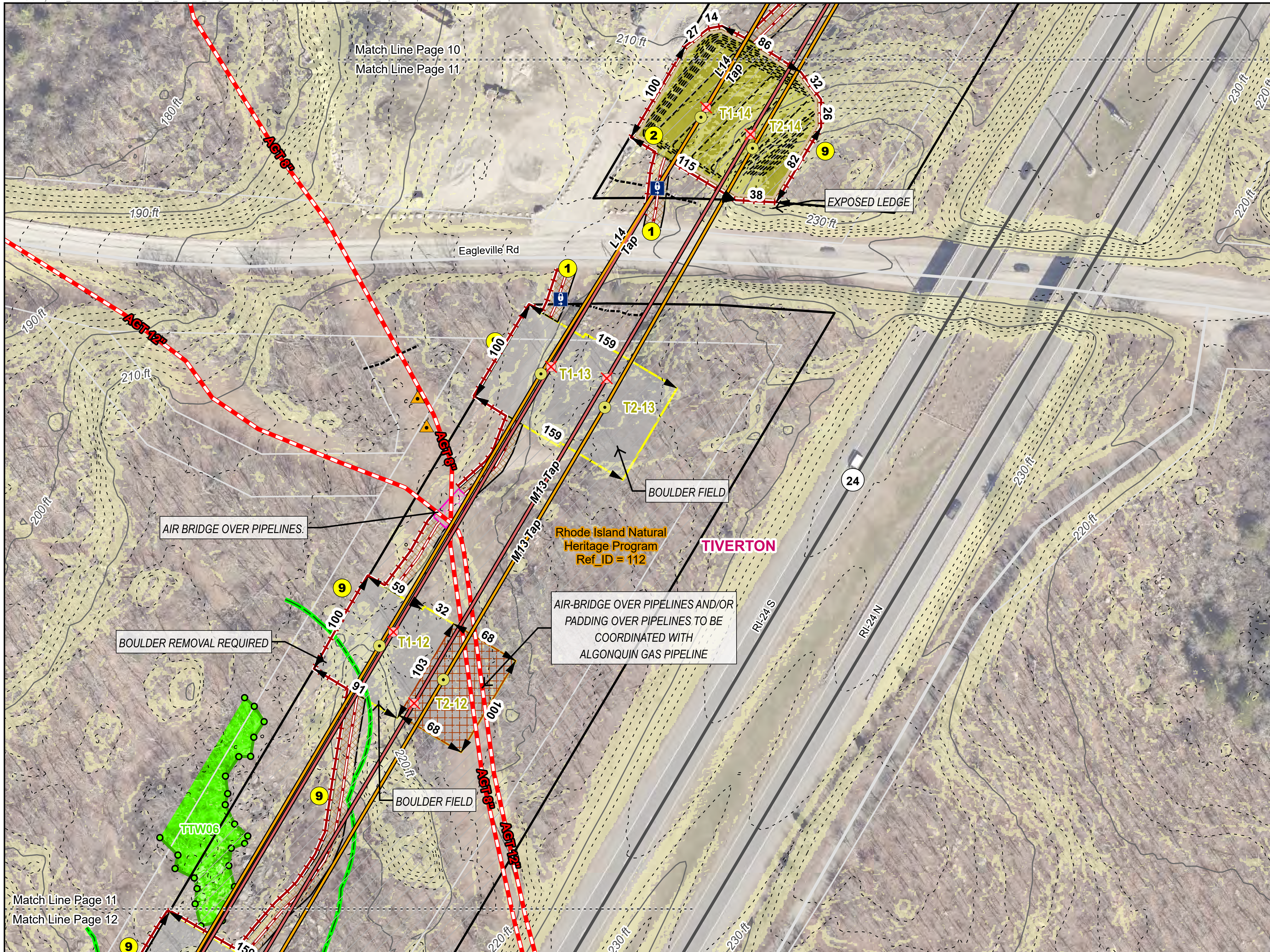

Proposed Structure
Structure To Be Removed
Proposed Structure with Concrete Foundation
Existing Transmission Line
Proposed Transmission Line
Natural Gas Pipeline
RIE Owned Land
Type R - Refresh/Cap Existing Sub-base
Perimeter Sediment Control
Reinforced Silt Fence
Type R - Refresh/Cap Existing Sub-base
Temporary Work Area - Stone - Cover with Top Soil and Stabilize Following Construction Work
Tiered Work Pad
Alternative Type Matting
Construction Matting
State Highway
Minor Road
Index Contour (10' Interval)
Contour (2' Interval)
Preliminary Grading Contour
0 - 15% Slope
> 15% Slope
Parcel Boundary
Pipeline Marker
Gate
Wetland Flag
Stone Wall
Wetland Border
Wetland Jurisdictional Area (100')
Field Delineated Wetland
Rhode Island Natural Heritage Areas
1 Install Stabilized construction ingress/egress
2 Install temporary concrete wash station.
9 Perimeter Sediment Controls

REVISIONS:

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ESC PLAN MAP BOOK 11

Scale 1"=100' when printed at 11" by 17"

0 10 20 30 Meters

0 25 50 75 100 Feet

Rhode Island Energy
280 Melrose Street
Providence, RI 02907

SOIL EROSION AND SEDIMENT CONTROL PLAN
Tiverton Tap Rebuild Project
Rhode Island Energy
Town of Tiverton
State of Rhode Island

SCALE	JOB NO.	DATE:	SHEET
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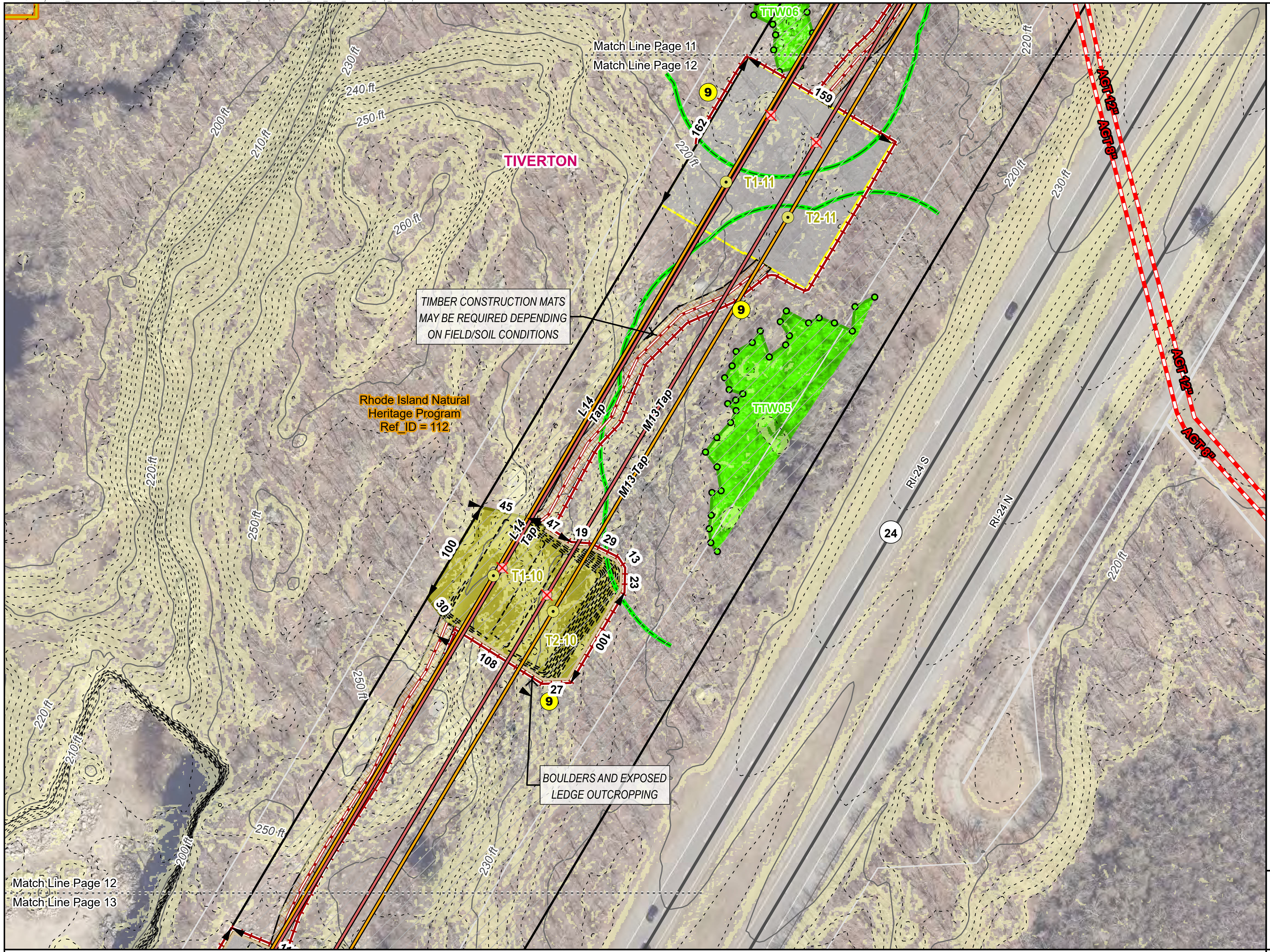

Proposed Structure
Structure To Be Removed
Proposed Structure with Concrete Foundation
Existing Transmission Line
Proposed Transmission Line
Natural Gas Pipeline
RIE Owned Land
Type R - Refresh/Cap Existing Sub-base
Perimeter Sediment Control
Reinforced Silt Fence
Type R - Refresh/Cap Existing Sub-base
Temporary Work Area - Stone - Cover with Top Soil and Stabilize Following Construction Work
Tiered Work Pad
State Highway
Minor Road
Index Contour (10' Interval)
Contour (2' Interval)
Preliminary Grading Contour
0 - 15% Slope
> 15% Slope
Parcel Boundary
Wetland Flag
Wetland Border
Wetland Jurisdictional Area (100')
Field Delineated Wetland
Rhode Island Natural Heritage Areas
Perimeter Sediment Controls

REVISIONS:

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ESC PLAN MAP BOOK 12

Scale 1"=100' when printed at 11" by 17"

0 10 20 30 Meters

0 25 50 75 100 Feet

Rhode Island Energy
280 Melrose Street
Providence, RI 02907

SOIL EROSION AND SEDIMENT CONTROL PLAN
Tiverton Tap Rebuild Project
Rhode Island Energy
Town of Tiverton
State of Rhode Island

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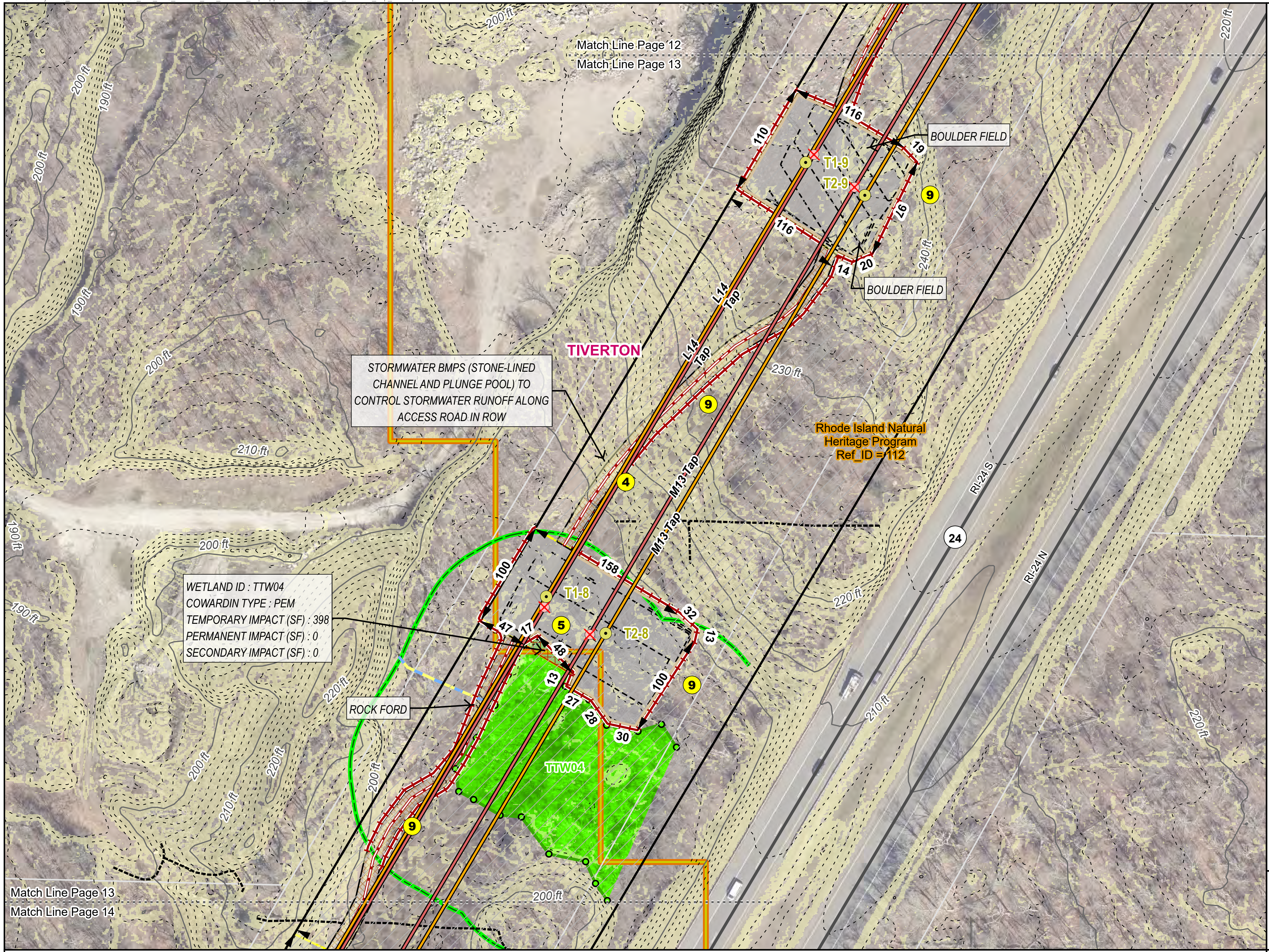

Proposed Structure
Structure To Be Removed
Proposed Structure with Concrete Foundation
Existing Transmission Line
Proposed Transmission Line
RIE Owned Land
Type R - Refresh/Cap Existing Sub-base
Perimeter Sediment Control
Reinforced Silt Fence
Type R - Refresh/Cap Existing Sub-base
Temporary Work Area - Stone - Cover with Top Soil and Stabilize Following Construction Work
Construction Matting
Rock Ford
State Highway
Index Contour (10' Interval)
Contour (2' Interval)
Preliminary Grading Contour
0 - 15% Slope
> 15% Slope
Parcel Boundary
Wetland Flag
Stone Wall
Wetland Border
Area Subject to Storm Flowage (ASSF)
Wetland Jurisdictional Area (100')
Field Delineated Wetland
Rhode Island Natural Heritage Areas
4 Dewatering Area
5 Install temporary mud box.
9 Perimeter Sediment Controls

REVISIONS:

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ESC PLAN MAP BOOK 13

Scale 1"=100' when printed at 11" by 17"

0 10 20 30 Meters

0 25 50 75 100 Feet

Rhode Island Energy
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Rhode Island Energy
280 Melrose Street
Providence, RI 02907

SOIL EROSION AND SEDIMENT CONTROL PLAN
Tiverton Tap Rebuild Project
Rhode Island Energy
Town of Tiverton
State of Rhode Island

SCALE	JOB NO.	DATE:	SHEET
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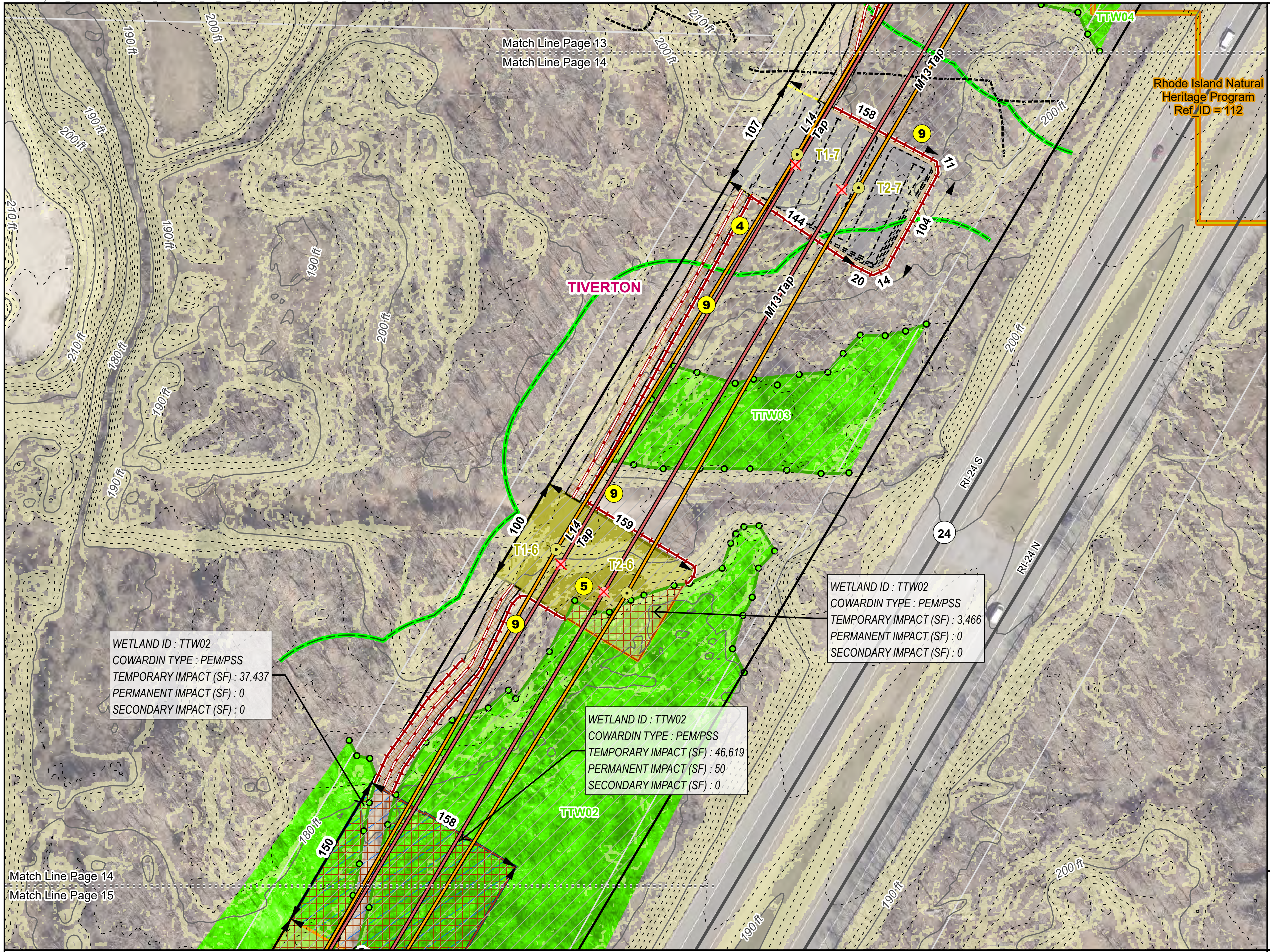

Proposed Structure
Structure To Be Removed
Proposed Structure with Concrete Foundation
Existing Transmission Line
Proposed Transmission Line
RIE Owned Land
Type R - Refresh/Cap Existing Sub-base
Perimeter Sediment Control
Reinforced Silt Fence
Type R - Refresh/Cap Existing Sub-base
Temporary Work Area - Stone - Cover with Top Soil and Stabilize Following Construction Work
Temporary Work Area - Mow Only
Pull Site - Mow Only and Matting
Tiered Work Pad
Construction Matting
State Highway
Index Contour (10' Interval)
Contour (2' Interval)
Preliminary Grading Contour
0 - 15% Slope
> 15% Slope
Parcel Boundary
Wetland Flag
Stone Wall
Wetland Border
Wetland Jurisdictional Area (100')
Field Delineated Wetland
Rhode Island Natural Heritage Areas
4 Dewatering Area
5 Install temporary mud box.
9 Perimeter Sediment Controls

REVISIONS:

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ESC PLAN MAP BOOK 14

Scale 1"=100' when printed at 11" by 17"

0 10 20 30 Meters

0 25 50 75 100 Feet

Rhode Island Energy
280 Melrose Street
Providence, RI 02907

SOIL EROSION AND SEDIMENT CONTROL PLAN
Tiverton Tap Rebuild Project
Rhode Island Energy
Town of Tiverton
State of Rhode Island

SCALE	JOB NO.	DATE:	SHEET
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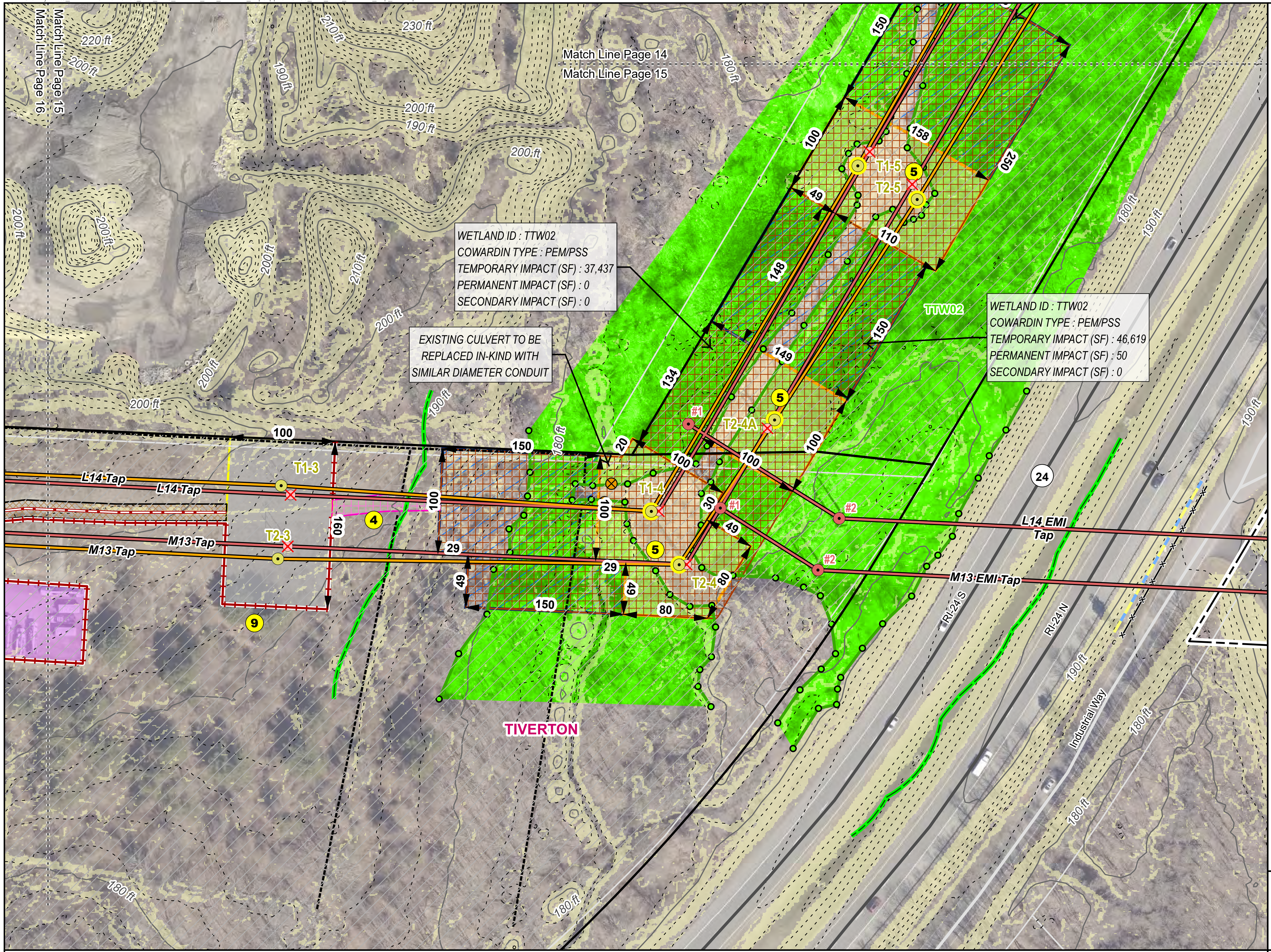

Existing Structure
Proposed Structure
Structure To Be Removed
Proposed Structure with Concrete Foundation
Existing Transmission Line
Proposed Transmission Line
RIE Owned Land
Existing Right of Way
Type R - Refresh/Cap Existing Sub-base
Perimeter Sediment Control
Type R - Refresh/Cap Existing Sub-base
Temporary Work Area - Stone - Cover with Top Soil and Stabilize Following Construction Work
Temporary Work Area - Mow Only
Pull Site - Mow Only and Matting
Laydown Area
Alternative Type Matting
Construction Matting

State Highway
Minor Road
Index Contour (10' Interval)
Contour (2' Interval)
0 - 15% Slope
> 15% Slope
Parcel Boundary
Culvert
Wetland Flag
Fence
Stone Wall
Wetland Border
Area Subject to Storm Flowage (ASSF)
Wetland Jurisdictional Area (100')
Field Delineated Wetland
4 Dewatering Area
5 Install temporary mud box.
9 Perimeter Sediment Controls

REVISIONS:

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ESC PLAN MAP BOOK 15
Scale 1"=100' when printed at 11" by 17"

0 10 20 30 Meters
0 25 50 75 100 Feet

Rhode Island Energy
a PPL company

Rhode Island Energy
280 Melrose Street
Providence, RI 02907

SOIL EROSION AND SEDIMENT CONTROL PLAN
Tiverton Tap Rebuild Project
Rhode Island Energy
Town of Tiverton
State of Rhode Island

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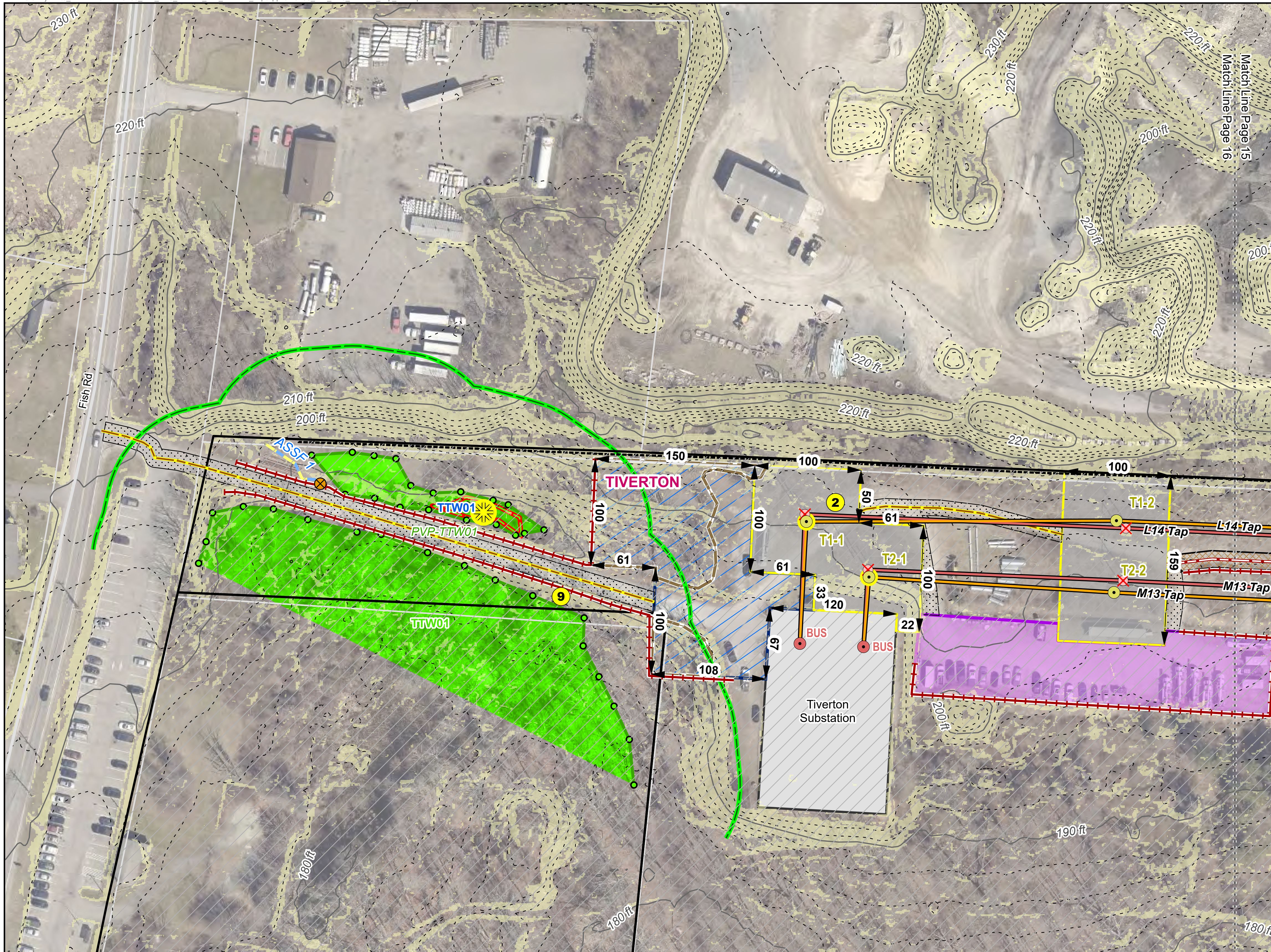

Existing Structure
Proposed Structure
Structure To Be Removed
Proposed Structure with Concrete Foundation
Existing Transmission Line
Proposed Transmission Line
Substation or Switching Station
RIE Owned Land
No Improvements - Existing Access (15' Wide)
Type R - Refresh/Cap Existing Sub-base
Perimeter Sediment Control
Type R - Refresh/Cap Existing Sub-base
No Improvements - Existing Access (15' Wide)
Temporary Work Area - Stone - Cover with Top Soil and Stabilize Following Construction Work
Pull Site - Mow Only and Matting
Laydown Area
Tree Trimming or Removal
Minor Road
Index Contour (10' Interval)
Contour (2' Interval)
0 - 15% Slope
> 15% Slope
Parcel Boundary
Field Documented Potential Vernal Pool
Culvert
Wetland Flag
Stone Wall
Wetland Border
Area Subject to Storm Flowage (ASSF)
Wetland Jurisdictional Area (100')
Field Delineated Wetland
Potential Vernal Pool
Install temporary concrete wash station.
Perimeter Sediment Controls

REVISIONS:

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NOTES:

SITE INFORMATION PROVIDED BY PPL ELECTRIC UTILITIES CORPORATION (2023); INCLUDING, BUT NOT LIMITED TO PROPERTY LINES, MUNICIPAL LINES, AND PROPERTY INFORMATION. AERIALS, AND CONTOURS, RECEIVED FROM RIGIS (HTTPS://WWW.RIGIS.ORG/ (2000-2023)) AND GOOGLE EARTH (2023). ALL INFORMATION IS APPROXIMATE.

CONTRACTOR SHALL NOT CONDUCT EARTH DISTURBANCE BEYOND THE LIMITS SHOWN ON THESE DRAWINGS WITHOUT PRIOR APPROVAL BY RI ENERGY CORPORATION'S REPRESENTATIVE RESPONSIBLE FOR EROSION & SEDIMENTATION CONTROL ON SITE. THE REVIEWING AGENCY SHALL BE NOTIFIED BY PPL ELECTRIC UTILITIES CORPORATIONS REPRESENTATIVE RESPONSIBLE FOR EROSION & SEDIMENTATION CONTROL ON SITE OF ANY CHANGES TO THE APPROVED PLAN PRIOR TO THE IMPLEMENTATION OF THOSE CHANGES.

N

ESC PLAN MAP BOOK 16

Scale 1"=100' when printed at 11" by 17"

0 10 20 30 Meters

0 25 50 75 100 Feet

Rhode Island Energy
a PPL company

Rhode Island Energy
280 Melrose Street
Providence, RI 02907

SOIL EROSION AND SEDIMENT CONTROL PLAN
Tiverton Tap Rebuild Project
Rhode Island Energy
Town of Tiverton
State of Rhode Island

SCALE	JOB NO.	DATE:	SHEET
AS NOTED	249458	6/7/2024	16 of 16

APPENDIX C ROW CROSS SECTIONS

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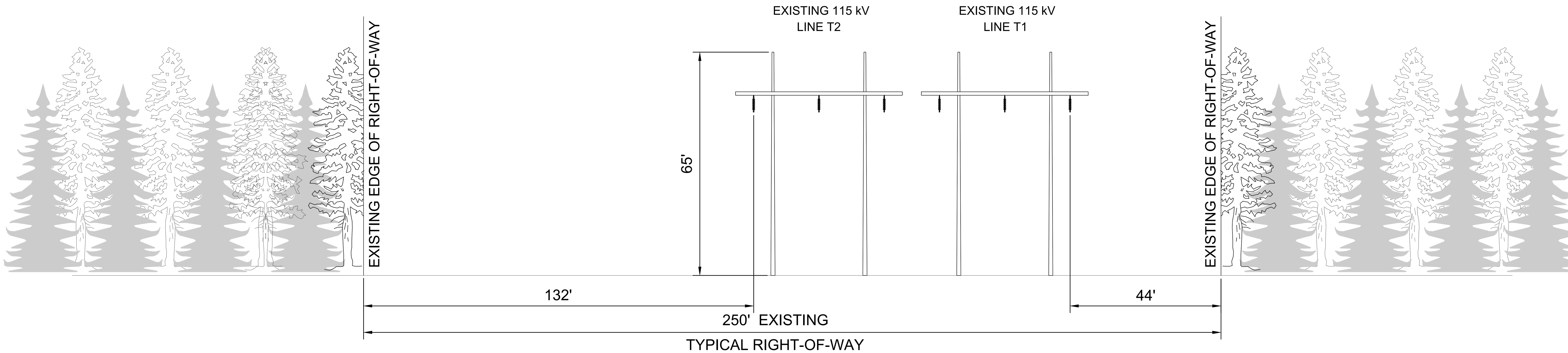
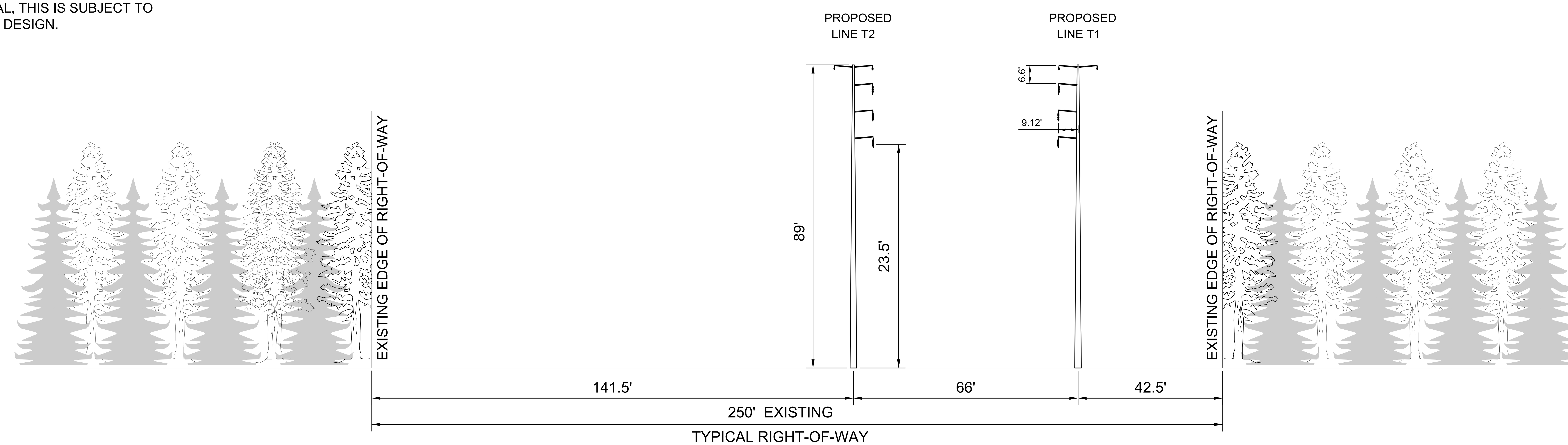


NOTES:

1. STRUCTURE HEIGHTS ARE TYPICAL OF THE SEGMENT.
2. CROSS SECTIONS ARE TYPICAL OF SEGMENT. VARIATIONS ALONG SEGMENT MAY OCCUR.
3. EDGE OF VEGETATION MANAGEMENT WILL MATCH EDGE OF RIGHT-OF-WAY.
4. STRUCTURE CONFIGURATION, HEIGHT, SPACING AND LOCATION ARE CONCEPTUAL, THIS IS SUBJECT TO CHANGE DURING DETAILED DESIGN.



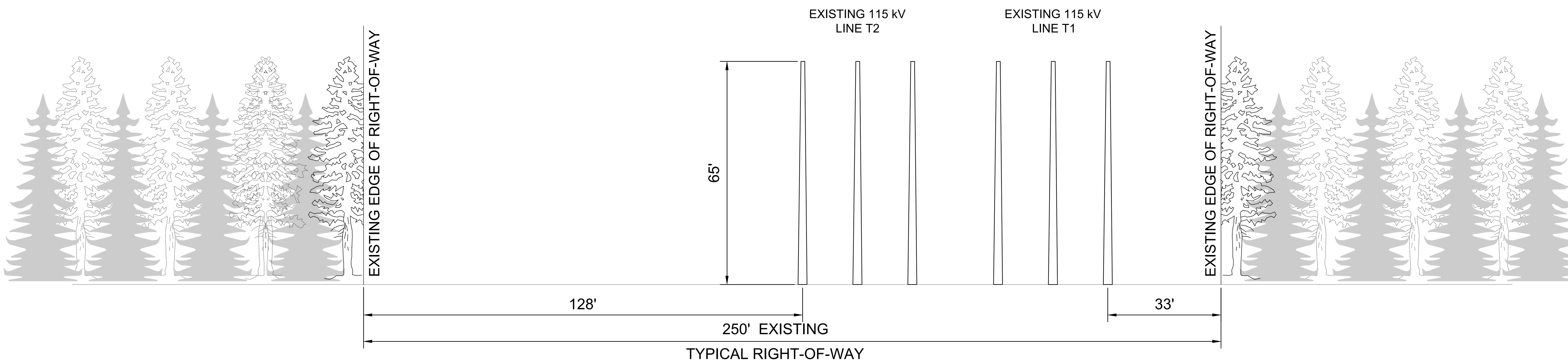
ACCT.-	M13 L14 115KV MAINLINE REBUILD
ECN #- ECN-	CROSS SECTION
SCALE-	TIVERTON TAP
BY- BMcD/NDL	TYPICAL STRUCTURE CONFIGURATION
REV'D- BMcD/CH	
CEII CONFIDENTIAL	APPROVED / DATE / PPL ELECTRIC UTILITIES
CAD ID / FORMAT: D	DRAWING NO.: XXXXXXXX1 / SHEET NO.: 4 / REVISION: 0

REFERENCE TITLE	NUMBER	REFERENCE TITLE	NUMBER	NO.	DATE	ACCT.	ECN/FCN	REVISION	BY	REV'D	APPR.

PLAN & PROFILE PRIMARY | PLAN & PROFILE NO. | PRIMARY LOC CODE | LOC CODE | LOC CODE | LOC CODE | SORTS | N SHARE

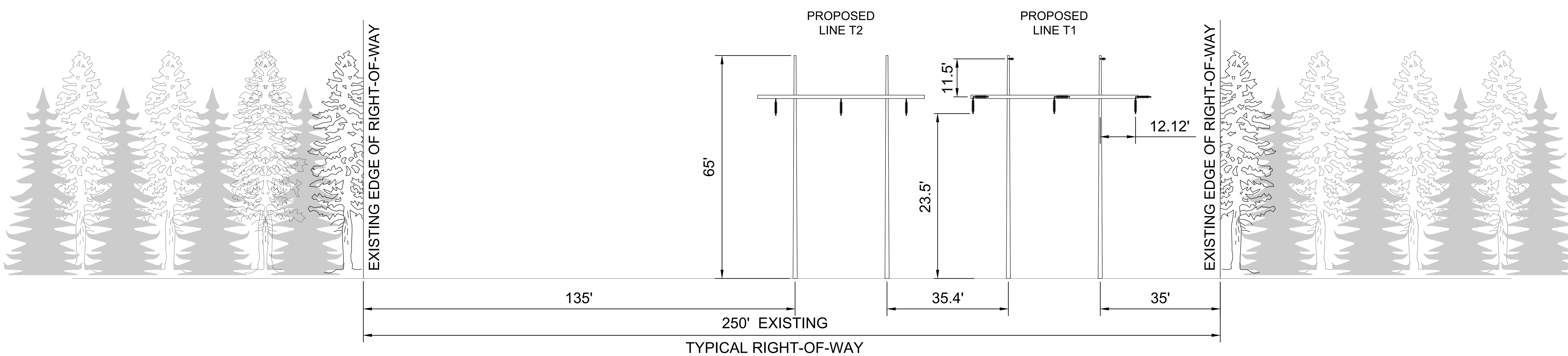
THIS FORMAT CONTAINS REQUIRED METADATA ATTRIBUTES

PPL ELECTRIC UTILITIES FORM 4877 (02/16)



NOTES:

1. STRUCTURE HEIGHTS ARE TYPICAL OF THE SEGMENT.
2. CROSS SECTIONS ARE TYPICAL OF SEGMENT. VARIATIONS ALONG SEGMENT MAY OCCUR.
3. EDGE OF VEGETATION MANAGEMENT WILL MATCH EDGE OF RIGHT-OF-WAY.
4. STRUCTURE CONFIGURATION, HEIGHT, SPACING AND LOCATION ARE CONCEPTUAL, THIS IS SUBJECT TO CHANGE DURING DETAILED DESIGN.



PPL ELECTRIC UTILITIES

ACCT.-	M13 L14 115KV MAINLINE REBUILD
ECN #- ECN-	CROSS SECTION
SCALE-	TIVERTON TAP
BY- BMcD/NDL	H-FRAME CONFIGURATION
REV'D- BMcD/CH	
CEII CONFIDENTIAL	APPROVED / DATE / PPL ELECTRIC UTILITIES
CAD ID / FORMAT: D	DRAWING NO.: XXXXXXXX1 / SHEET NO.: 5 / REVISION: 0

REFERENCE TITLE	NUMBER	REFERENCE TITLE	NUMBER	NO.	DATE	ACCT.	ECN/FCN	REVISION	BY	REV'D	APPR.

PLAN & PROFILE PRIMARY | PLAN & PROFILE NO. | PRIMARY LOC CODE | LOC CODE | LOC CODE | LOC CODE | SORTS | N SHARE

THIS FORMAT CONTAINS REQUIRED METADATA ATTRIBUTES

PPL ELECTRIC UTILITIES FORM 4877 (02/16)

APPENDIX D TYPICAL STRUCTURE DETAILS

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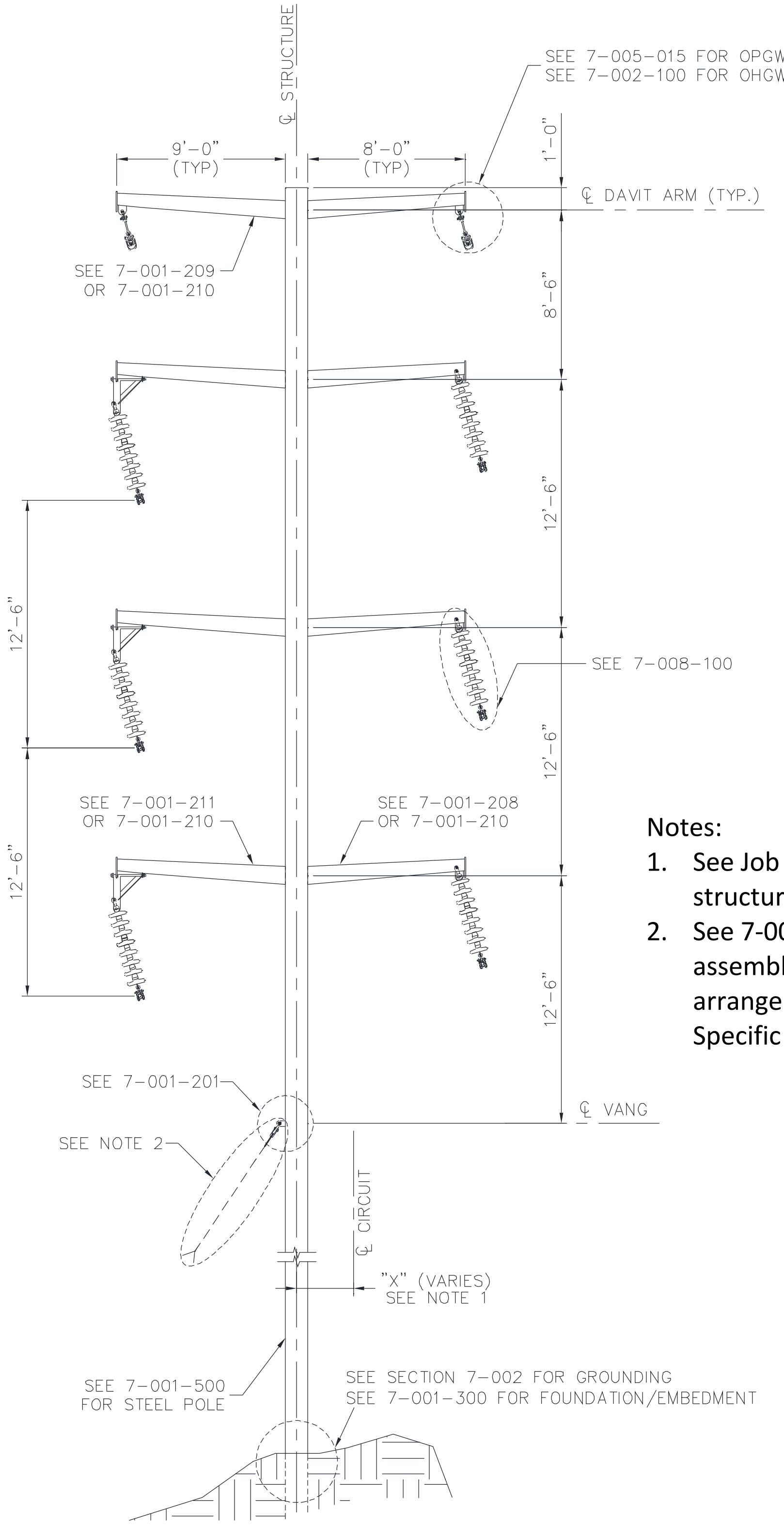
T-7-008-002



Notes:

1. See Job Specific Drawings for structure layout dimensions.
2. See 7-001 for guy wire and anchor assemblies. Guy and anchor arrangement may vary per Job Specific Drawings.

Rev	Date	ECN	Sponsor	Reviewer	Transmission Construction Standards PPL Corporate
00	03/18/2016	ECN-6316	MSD	SDS	
01	02/14/2022	ECN-15222	JAK	KEL	Approved: Kyle Supinski
02	05/21/2023	ECN-16828	JMB	JFK	Manager T&S Standards

Approved: E171459 Pepper, Maxwell Huntington

T-7-008-004

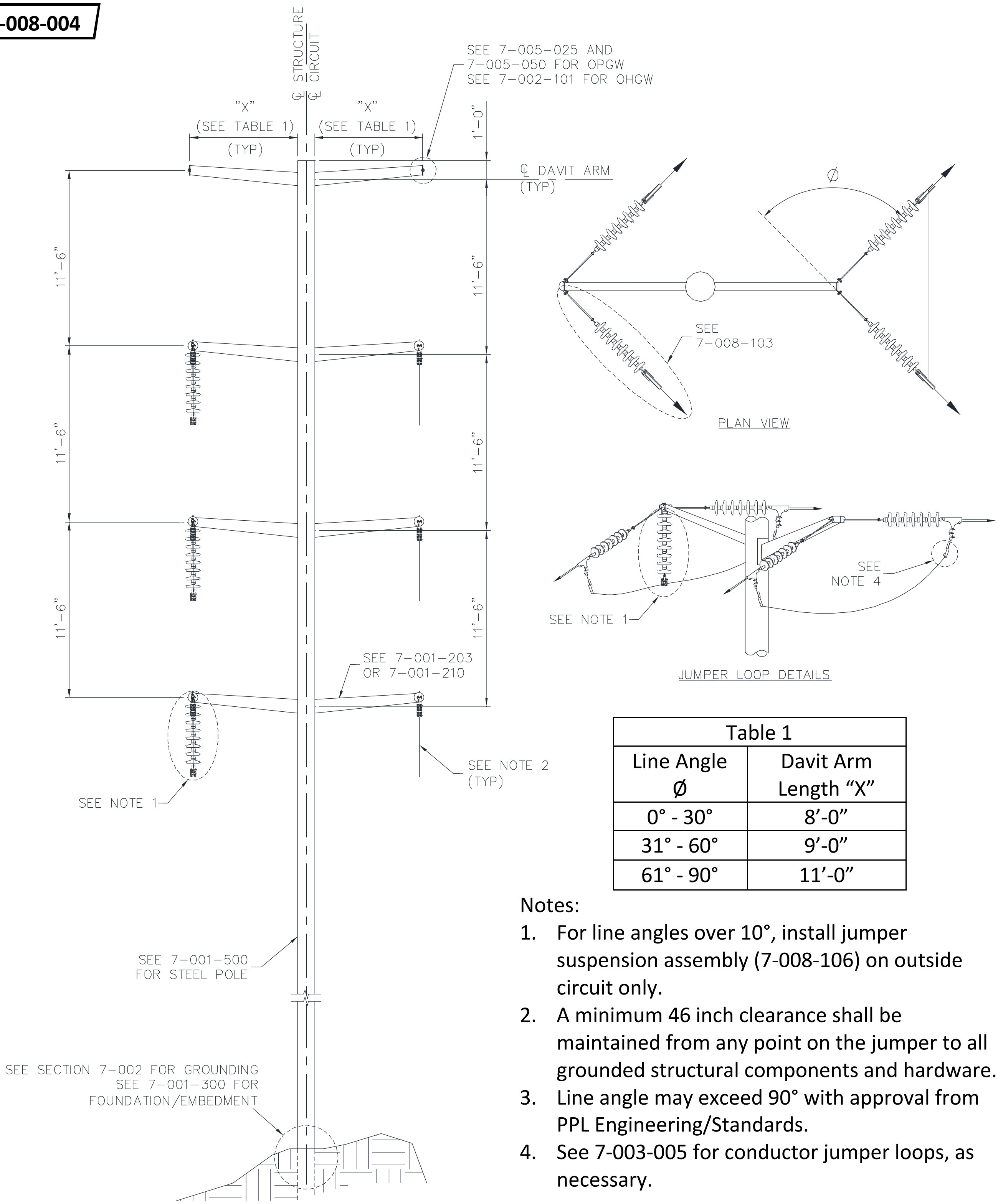
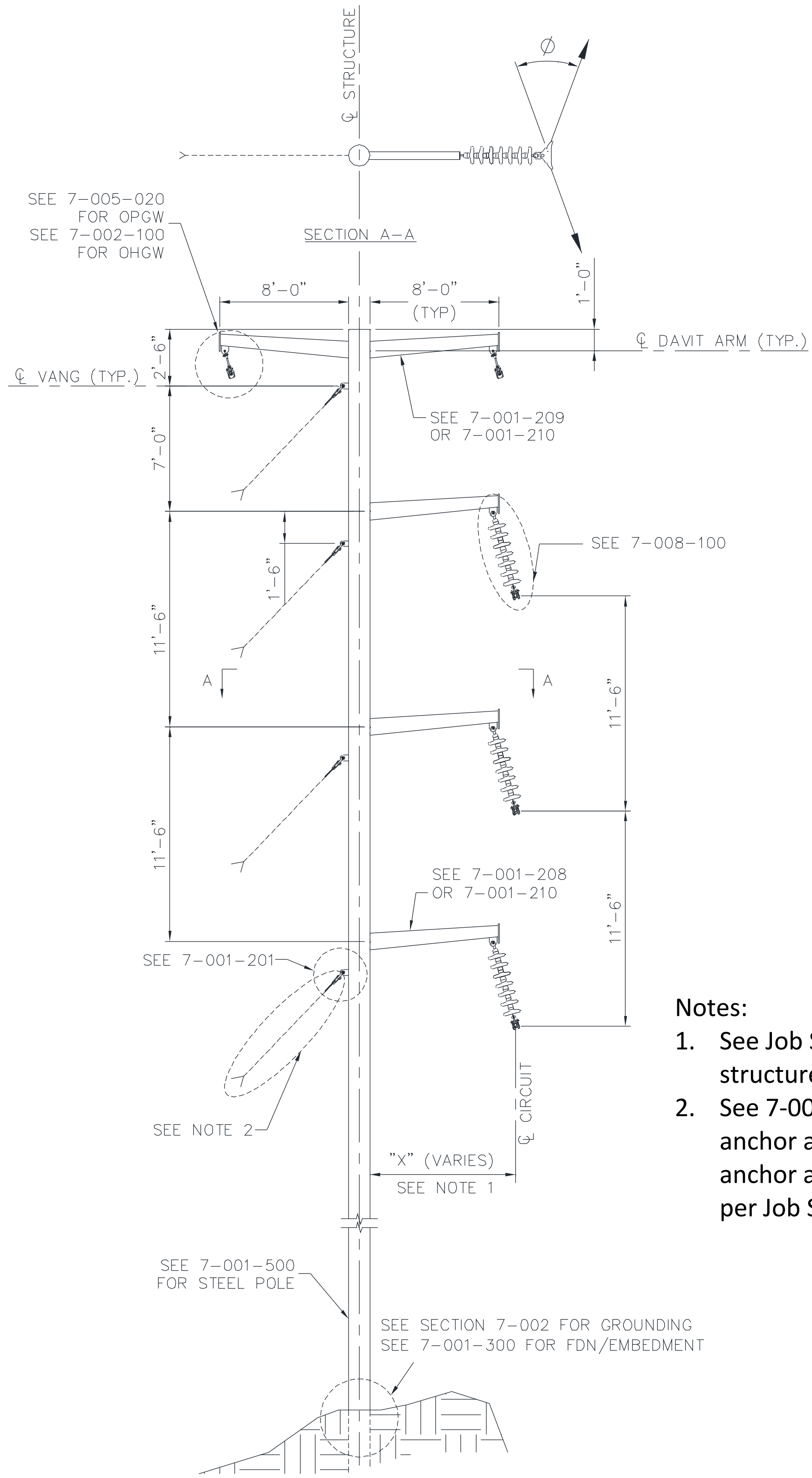


Table 1	
Line Angle Ø	Davit Arm Length "X"
0° - 30°	8'-0"
31° - 60°	9'-0"
61° - 90°	11'-0"

Notes:

1. For line angles over 10°, install jumper suspension assembly (7-008-106) on outside circuit only.
2. A minimum 46 inch clearance shall be maintained from any point on the jumper to all grounded structural components and hardware.
3. Line angle may exceed 90° with approval from PPL Engineering/Standards.
4. See 7-003-005 for conductor jumper loops, as necessary.

T-7-008-011



Notes:

1. See Job Specific Drawings for structure layout dimensions.
2. See 7-001 for guy wire and anchor assemblies. Guy and anchor assemblies may vary per Job Specific Drawings.

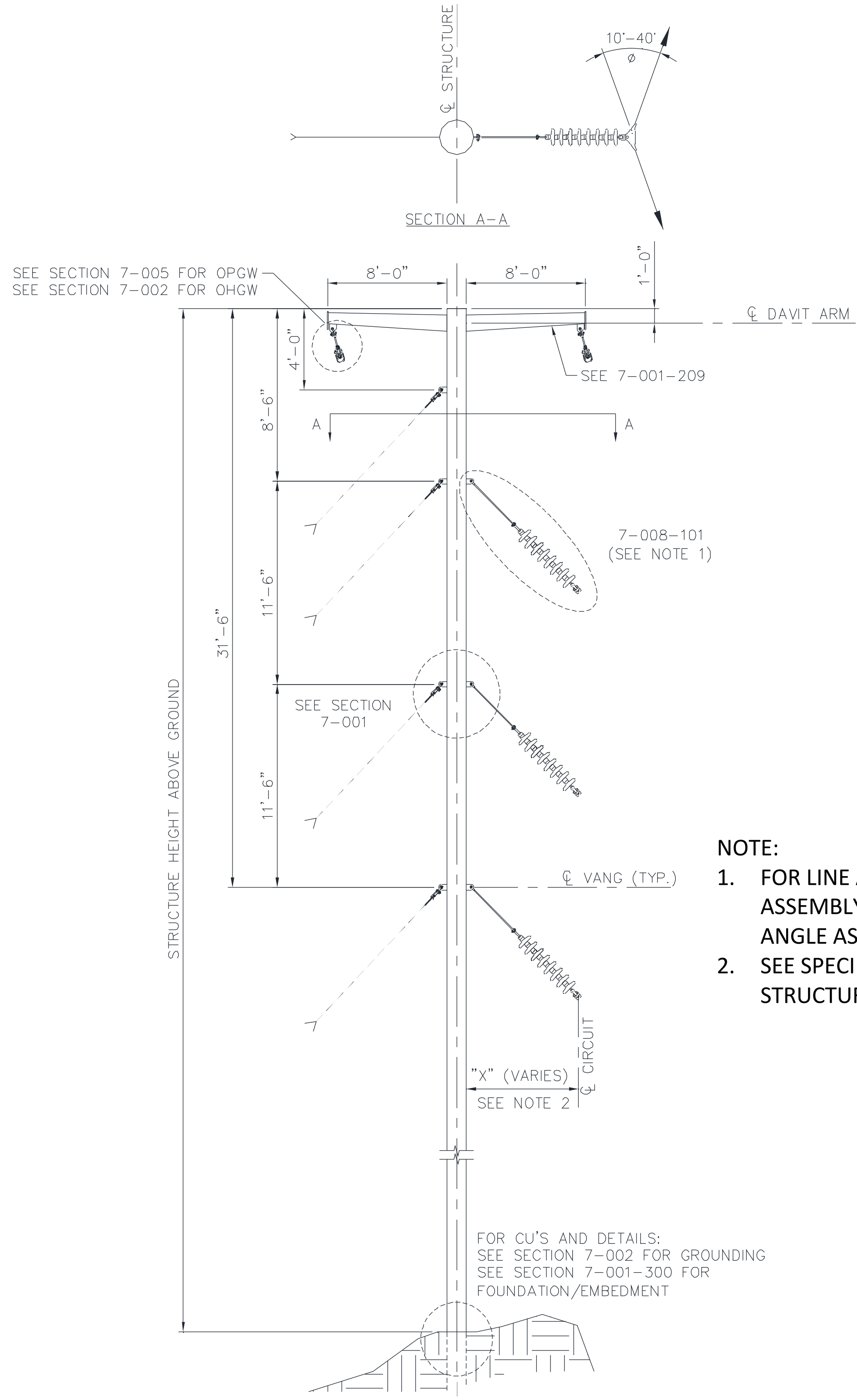
Rev	Date	ECN	Sponsor	Reviewer
00	03/18/2016	ECN-6316	MSD	SDS
01	02/14/2022	ECN-15222	JAK	KEL
02	05/21/2023	ECN-16828	JMB	JFK

Transmission Construction Standards
PPL Corporate

Approved: Kyle Supinski

Manager T&S Standards

Approved: E171459 Pepper, Maxwell Huntington

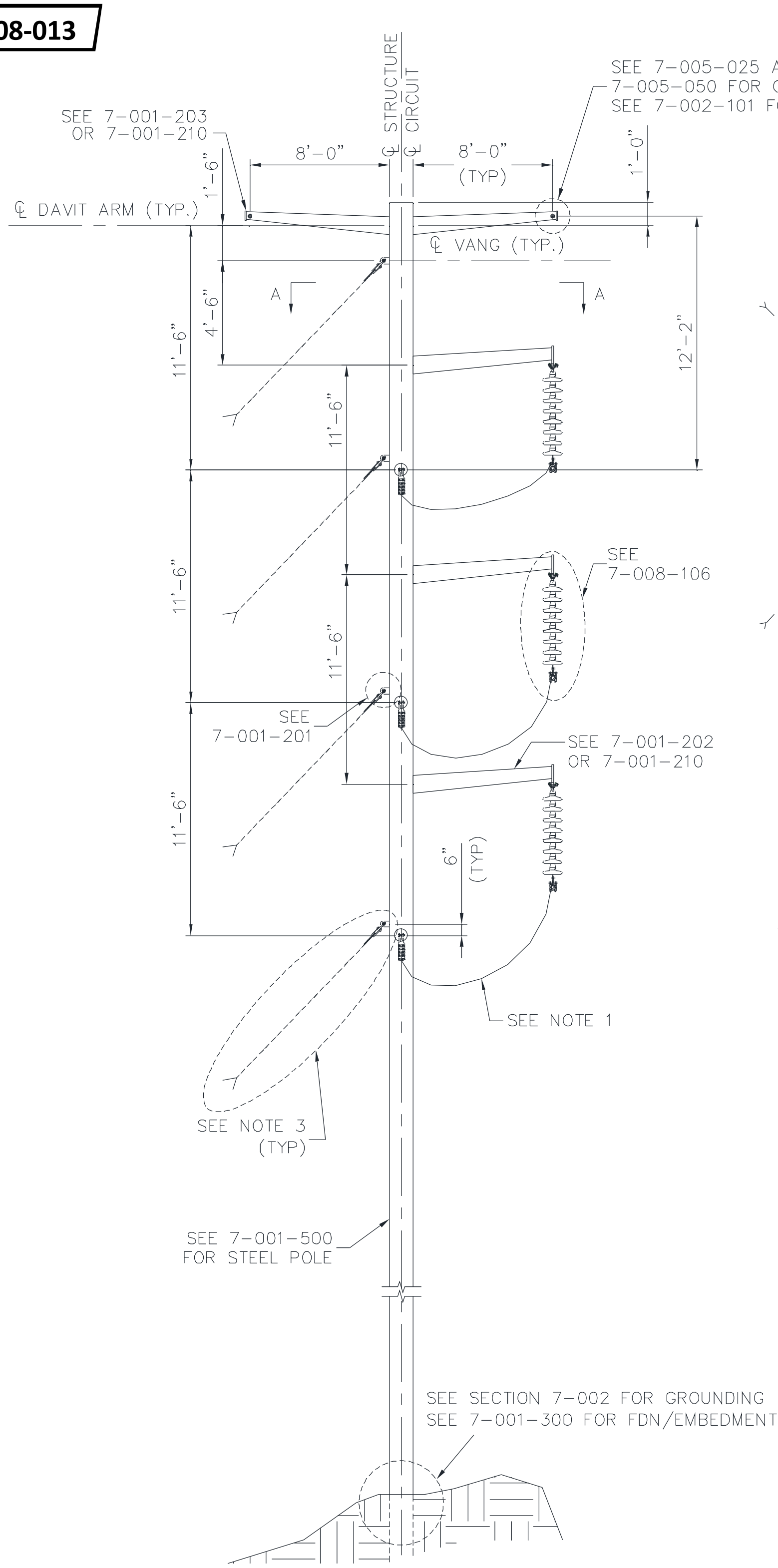


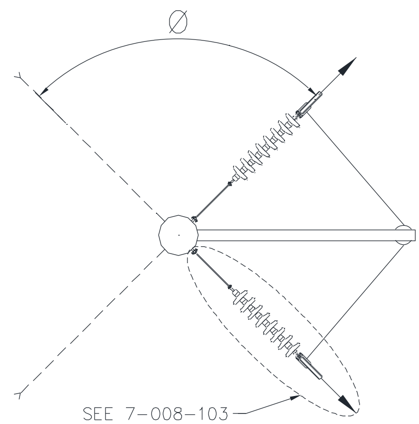
NOTE:
1. FOR LINE ANGLES 10°-30° USE LOW ANGLE ASSEMBLY, FOR ANGLES 31°-40° USE HIGH ANGLE ASSEMBLY.
2. SEE SPECIFIC JOB INSTRUCTIONS FOR STRUCTURE LAYOUT DIMENSIONS.

Rev	Date	ECN	Sponsor	Reviewer
00	03/18/2016	ECN-XXXX	MSD	SDS
01	05/21/2023	ECN-16828	JMB	JFK

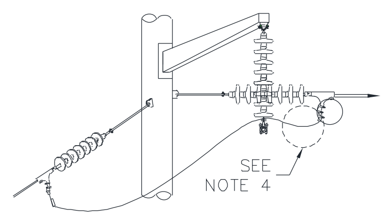
Transmission Construction Standards
PPL Corporate
Approved: Kyle Supinski
Manager T&S Standards

T-7-008-013





SECTION A-A



JUMPER LOOP DETAILS

Notes:

1. A minimum 46 inch clearance shall be maintained from any point on the jumper to all grounded structural components and hardware.
2. Line angle may exceed 90° with approval from PPL Engineering/Standards.
3. See 7-001 for guy wire and anchor assemblies. Guy wire and anchor assemblies may vary per Job Specific Drawings.
4. See 7-003-005 for conductor jumper loops, as necessary.

Rev	Date	ECN	Sponsor	Reviewer	Transmission Construction Standards PPL Corporate
00	03/18/2016	ECN-6316	MSD	SDS	
01	03/11/2022	ECN-15806	JAK	KEL	Approved: Kyle Supinski
02	5/21/2023	ECN-16828	JMB	JFK	Manager T&S Standards

Approved: E171459 Pepper, Maxwell Huntington

T-7-008-043

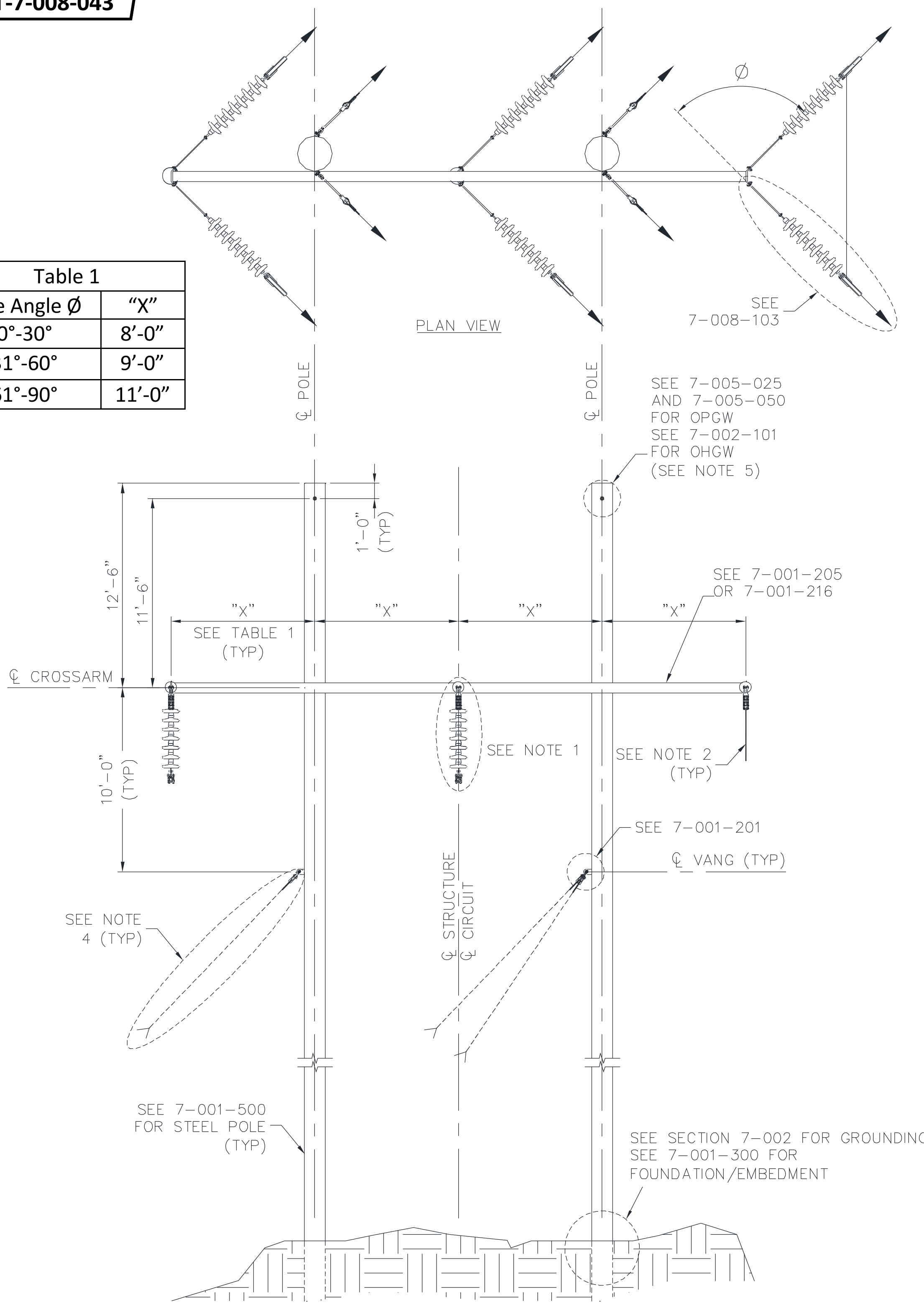


Table 1	
Line Angle Ø	"X"
0°-30°	8'-0"
31°-60°	9'-0"
61°-90°	11'-0"

Notes:

1. For line angles over 10°, install jumper suspension assembly (7-008-106) on outside and middle phases only.
2. A minimum 46-inch clearance shall be maintained from any point on the jumper to all grounded structural components and hardware.
3. Line angle may exceed 90° with approval from PPL Engineering/ Standards.
4. See 7-001 for guy wire and anchor assemblies. Guy and anchor arrangement may vary per Job Specific Drawings.
5. Shield wire assembly may be installed on the pole top plate for standard class poles.
6. For areas with side slopes or uneven terrain, see Job Specific Drawings for potential differences in attachment points as measured from the pole top.

Rev	Date	ECN	Sponsor	Reviewer	Transmission Construction Standards PPL Corporate
00	03/18/2016	ECN-6316	MSD	SDS	
01	02/14/2022	ECN-15222	JAK	KEL	Approved: Kyle Supinski
02	05/21/2023	ECN-16828	JMB	JFK	Manager T&S Standards

Approved: E171459 Pepper, Maxwell Huntington

APPENDIX E AGENCY CORRESPONDENCE

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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

In Reply Refer To: 06/04/2024 14:02:19 UTC
Project Code: 2024-0099044
Project Name: The Tiverton Tap Rebuild 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:

Updated 4/12/2023 - *Please review this letter each time you request an Official Species List, we will continue to update it with additional information and links to websites may change.*

About Official Species Lists

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. Federal and non-Federal project proponents have responsibilities under the Act to consider effects on listed species.

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 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. The Service recommends that verification be completed by visiting the IPaC website at regular intervals during project planning and implementation for updates to species lists and information. An updated list may be requested by returning to an existing project's page in IPaC.

Endangered Species Act Project Review

Please visit the "**New England Field Office Endangered Species Project Review and Consultation**" website for step-by-step instructions on how to consider effects on listed species and prepare and submit a project review package if necessary:

https://www.fws.gov/office/new-england-ecological-services/endangered-species-project-review

NOTE Please do not use the **Consultation Package Builder** tool in IPaC except in specific situations following coordination with our office. Please follow the project review guidance on our website instead and reference your **Project Code** in all correspondence.

Northern Long-eared Bat - (**Updated 4/12/2023**) The Service published a final rule to reclassify the northern long-eared bat (NLEB) as endangered on November 30, 2022. The final rule went into effect on March 31, 2023. You may utilize the **Northern Long-eared Bat Rangewide Determination Key** available in IPaC. More information about this Determination Key and the Interim Consultation Framework are available on the northern long-eared bat species page:

https://www.fws.gov/species/northern-long-eared-bat-myotis-septentrionalis

For projects that previously utilized the 4(d) Determination Key, the change in the species' status may trigger the need to re-initiate consultation for any actions that are not completed and for which the Federal action agency retains discretion once the new listing determination becomes effective. If your project was not completed by March 31, 2023, and may result in incidental take of NLEB, please reach out to our office at newengland@fws.gov to see if reinitiation is necessary.

Additional Info About Section 7 of the Act
Under section 7(a)(2) of the Act and its implementing regulations (50 CFR 402 et seq.), Federal agencies are required to determine whether projects may affect threatened and endangered species and/or designated critical habitat. If a Federal agency, or its non-Federal representative, determines 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 Federal agency also may need to consider proposed species and proposed critical habitat in the consultation. 50 CFR 402.14(c)(1) specifies the information required for consultation under the Act regardless of the format of the evaluation. 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:

https://www.fws.gov/service/section-7-consultations

In addition to consultation requirements under Section 7(a)(2) of the ESA, please note that under sections 7(a)(1) 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. Please contact NEFO if you would like more information.

Candidate species that appear on the enclosed species list have no current protections under the ESA. The species' occurrence on an official species list does not convey a requirement to consider impacts to this species as you would a proposed, threatened, or endangered species. The ESA does not provide for interagency consultations on candidate species under section 7, however, the Service recommends that all project proponents incorporate measures into projects to benefit candidate species and their habitats wherever possible.

Migratory Birds

In addition to responsibilities to protect threatened and endangered species under the Endangered Species Act (ESA), there are additional responsibilities under the Migratory Bird Treaty Act (MBTA) and the Bald and Golden Eagle Protection Act (BGEPA) to protect native birds from project-related impacts. Any activity, intentional or unintentional, resulting in take of migratory birds, including eagles, is prohibited unless otherwise permitted by the U.S. Fish and Wildlife Service (50 C.F.R. Sec. 10.12 and 16 U.S.C. Sec. 668(a)). For more information regarding these Acts see:

https://www.fws.gov/program/migratory-bird-permit

https://www.fws.gov/library/collections/bald-and-golden-eagle-management

Please feel free to contact us at **newengland@fws.gov** with your **Project Code** in the subject line if you need more information or assistance regarding the potential impacts to federally proposed, listed, and candidate species and federally designated and proposed critical habitat.

Attachment(s): Official Species List

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:

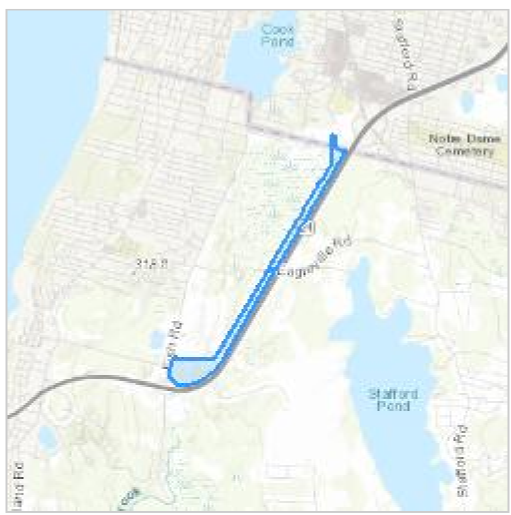
New England Ecological Services Field Office
70 Commercial Street, Suite 300
Concord, NH 03301-5094
(603) 223-2541

PROJECT SUMMARY

Project Code: 2024-0099044
Project Name: The Tiverton Tap Rebuild Project
Project Type: Transmission Line - Maintenance/Modification - Above Ground
Project Description: The Narragansett Electric Company d/b/a Rhode Island Energy (RIE or the Company) is
proposing the Tiverton Tap Rebuild Project (Project) which is located in Tiverton, Rhode
Island. The Project includes rebuilding the existing L14 and M13 115-kV Tiverton Tap Lines
(Tiverton Tap and Taps), a distance of approximately 2.1 miles in Tiverton. The Tiverton Tap
ROW begins approximately 0.1 mile west of Route 24 at the Tiverton/Fall River,
Massachusetts border and continues south to the Tiverton Substation at 940 Fish Road in
Tiverton

Project Location:

The approximate location of the project can be viewed in Google Maps: https://www.google.com/maps/@41.66043155,-71.16730107473825,14z



Counties: Massachusetts and Rhode Island

ENDANGERED SPECIES ACT SPECIES

There is a total of 3 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. Note that 1 of these species should be considered only under certain conditions.

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

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

---

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

MAMMALS

NAME	STATUS
Northern Long-eared Bat *Myotis septentrionalis* No critical habitat has been designated for this species. This species only needs to be considered under the following conditions: ▪ This species only needs to be considered if the project includes wind turbine operations. Species profile: https://ecos.fws.gov/ecp/species/9045	Endangered
Tricolored Bat *Perimyotis subflavus* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/10515	Proposed Endangered

INSECTS

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

CRITICAL HABITATS

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

YOU ARE STILL REQUIRED TO DETERMINE IF YOUR PROJECT(S) MAY HAVE EFFECTS ON ALL ABOVE LISTED SPECIES.

IPAC USER CONTACT INFORMATION

Agency: Private Entity
Name: Mike Banaitis
Address: 303 U.S. Route One
City: Freeport
State: ME
Zip: 04032
Email mike.banaitis@powereng.com
Phone: 2073300085

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

In Reply Refer To: 06/04/2024 14:16:25 UTC
Project code: 2024-0099044
Project Name: The Tiverton Tap Rebuild Project

Federal Action Agency (if applicable): Army Corps of Engineers

Subject: Record of project representative's no effect determination for 'The Tiverton Tap Rebuild Project'

Dear Mike Banaitis:

This letter records your determination using the Information for Planning and Consultation (IPaC) system provided to the U.S. Fish and Wildlife Service (Service) on June 04, 2024, for 'The Tiverton Tap Rebuild Project' (here forward, Project). This project has been assigned Project Code 2024-0099044 and all future correspondence should clearly reference this number. **Please carefully review this letter.**

Ensuring Accurate Determinations When Using IPaC

The Service developed the IPaC system and associated species' determination keys in accordance with the Endangered Species Act of 1973 (ESA; 87 Stat. 884, as amended; 16 U.S.C. 1531 et seq.) and based on a standing analysis. All information submitted by the Project proponent into IPaC must accurately represent the full scope and details of the Project.

Failure to accurately represent or implement the Project as detailed in IPaC or the Northern Long-eared Bat Rangewide Determination Key (Dkey), invalidates this letter. ***Answers to certain questions in the DKey commit the project proponent to implementation of conservation measures that must be followed for the ESA determination to remain valid.***

Determination for the Northern Long-Eared Bat

Based upon your IPaC submission and a standing analysis, your project has reached the determination of "No Effect" on the northern long-eared bat. To make a no effect determination, the full scope of the proposed project implementation (action) should not have any effects (either positive or negative), to a federally listed species or designated critical habitat. Effects of the action are all consequences to listed species or critical habitat that are caused by the proposed action, including the consequences of other activities that are caused by the proposed action. A consequence is caused by the proposed action if it would not occur but for the proposed action and it is reasonably certain to occur. Effects of the action may occur later in time and may include consequences occurring outside the immediate area involved in the action. (See § 402.17).

Under Section 7 of the ESA, if a federal action agency makes a no effect determination, no consultation with the Service is required (ESA §7). If a proposed Federal action may affect a listed species or designated critical habitat, formal consultation is required except when the Service concurs, in writing, that a proposed action "is not likely to adversely affect" listed species or designated critical habitat [50 CFR §402.02, 50 CFR§402.13].

Other Species and Critical Habitat that May be Present in the Action Area

The IPaC-assisted determination for the northern long-eared bat does not apply to the following ESA-protected species and/or critical habitat that also may occur in your Action area:

- Monarch Butterfly *Danaus plexippus* Candidate
- Tricolored Bat *Perimyotis subflavus* Proposed Endangered

You may coordinate with our Office to determine whether the Action may affect the animal species listed above and, if so, how they may be affected.

Next Steps

Based upon your IPaC submission, your project has reached the determination of “No Effect” on the northern long-eared bat. If there are no updates on listed species, no further consultation/ coordination for this project is required with respect to the northern long-eared bat. However, the Service recommends that project proponents re-evaluate the Project in IPaC if: 1) the scope, timing, duration, or location of the Project changes (includes any project changes or amendments); 2) new information reveals the Project may impact (positively or negatively) federally listed species or designated critical habitat; or 3) a new species is listed, or critical habitat designated. If any of the above conditions occurs, additional coordination with the Service should take place to ensure compliance with the Act.

If you have any questions regarding this letter or need further assistance, please contact the New England Ecological Services Field Office and reference Project Code 2024-0099044 associated with this Project.

Action Description

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

1. Name

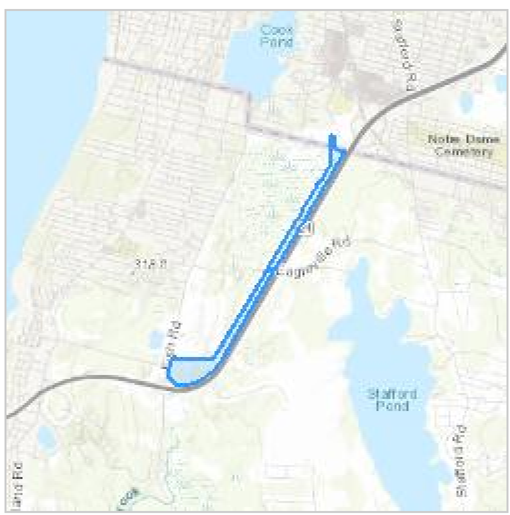
The Tiverton Tap Rebuild Project

2. Description

The following description was provided for the project 'The Tiverton Tap Rebuild Project':

> The Narragansett Electric Company d/b/a Rhode Island Energy (RIE or the Company) is
> proposing the Tiverton Tap Rebuild Project (Project) which is located in Tiverton, Rhode
> Island. The Project includes rebuilding the existing L14 and M13 115-kV Tiverton Tap Lines
> (Tiverton Tap and Taps), a distance of approximately 2.1 miles in Tiverton. The Tiverton Tap
> ROW begins approximately 0.1 mile west of Route 24 at the Tiverton/Fall River,
> Massachusetts border and continues south to the Tiverton Substation at 940 Fish Road in
> Tiverton

The approximate location of the project can be viewed in Google Maps: https://www.google.com/maps/@41.66043155,-71.16730107473825,14z



DETERMINATION KEY RESULT

Based on the information you provided, you have determined that the Proposed Action will have no effect on the Endangered northern long-eared bat (Myotis septentrionalis). Therefore, no consultation with the U.S. Fish and Wildlife 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 for those species.

QUALIFICATION INTERVIEW

1. Does the proposed project include, or is it reasonably certain to cause, intentional take of the northern long-eared bat or any other listed species?

   Note: Intentional take is defined as take that is the intended result of a project. Intentional take could refer to research, direct species management, surveys, and/or studies that include intentional handling/encountering, harassment, collection, or capturing of any individual of a federally listed threatened, endangered or proposed species?

   No

2. The proposed action does not intersect an area where the northern long-eared bat is likely to occur, based on the information available to U.S. Fish and Wildlife Service as of the most recent update of this key. If you have data that indicates that northern long-eared bats are likely to be present in the action area, answer "NO" and continue through the key.

   Do you want to make a no effect determination?

   Yes

PROJECT QUESTIONNAIRE

IPAC USER CONTACT INFORMATION

Agency: Private Entity
Name: Mike Banaitis
Address: 303 U.S. Route One
City: Freeport
State: ME
Zip: 04032
Email mike.banaitis@powereng.com
Phone: 2073300085

LEAD AGENCY CONTACT INFORMATION

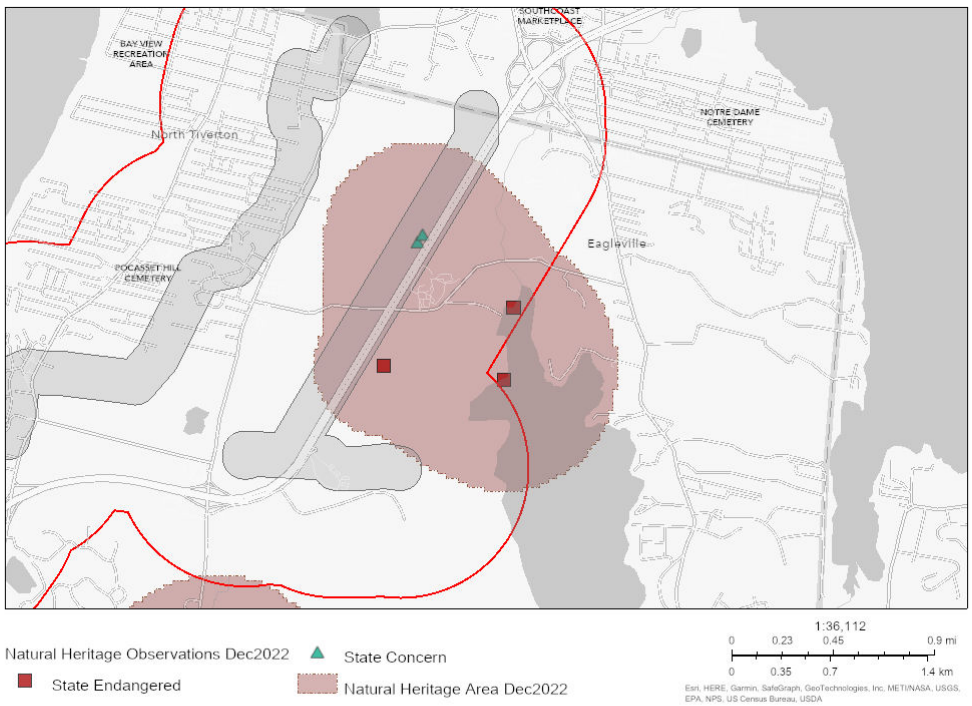
Lead Agency: Army Corps of Engineers
Name: Keith Goulet
Email: Keith.A.Goulet@usace.army.mil
Phone: 9783188296

Natural Heritage Screening PowerEng

Area of Interest (AOI) Information

Area : 332,936,609.21 ft²

Jul 11 2023 14:37:59 Eastern Daylight Time



Observations within 2500 feet of project study area.

Summary

Name	Count	Area(ft²)	Length(ft)
Natural Heritage Observations Dec2022	4	N/A	N/A

Natural Heritage Observations Dec2022

#	Family	Genus	Species	COMNAME	SurvDate	LAST_OBS	RI_ STAT	Count
1	Equisetaceae	Equisetum	hyemale ssp. affine	Tall Scouring-rush	8/5/2020	2020	State Concern	1
2	Equisetaceae	Equisetum	hyemale ssp. affine	Tall Scouring-rush	11/7/2009	2020	State Concern	1
3	Gentianaceae	Sabatia	kennedyana	Plymouth Gentian, Marsh-pink	07/23/2008	2008	State Endangered	1
4	Insect	Williamsonia	lintneri	Ringed Boghaunter	05/21/1999	1999	State Endangered	1

STATE OF RHODE ISLAND

HISTORICAL PRESERVATION & HERITAGE COMMISSION

Old State House 150 Benefit Street Providence, RI 02903

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

November 10, 2023

Via email: jaime.donta@powereng.com

Jaime Donta, M.A.
Cultural Resources Specialist -Northeast Area Lead
POWER Engineers, Inc.
2 Hampshire St., Suite 301
Foxborough, MA 02035

Re: RIHPHC Project No. 15254
L14 and M13 Transmission Line Improvements
Tiverton and Portsmouth, Rhode Island

Dear Ms. Donta:

The Rhode Island Historical Preservation and Heritage Commission (RIHPHC) staff has reviewed the information that you provided for the above-referenced project. The Narragansett Electric Company (TNEC) is proposing to refurbish the L14 and M13 electric transmission line infrastructure in Portsmouth and Tiverton, Rhode Island. The project will require permits from the US Army Corps of Engineers, the RI Coastal Resources Management Council, and the RI Department of Transportation. Power Engineers, Inc. initiated consultation for the project in December 2020. At the time, the project was conceptual and limited to two poles in the crossing area of the Sakonnet River.

In your letter on October 10, 2023, Powers asked the RIHPHC to (1) concur that no archaeology survey be conducted within the project area, (2) provide guidance on any above-ground historic resources, and (3) assist with the delineation of the area of potential effect. You also stated the initial project "has been subsumed within a larger assets condition refurbishment project." It is our opinion that the undertaking is the larger refurbishment project and that the Sakonnet River crossing should not be reviewed independently from the larger project.

Initially in December 2020, Power asked the RIHPHC to identify known historic properties at the Sakonnet River crossing. We informed Power on February 9, 2021 that the Sakonnet River Railroad Swing Bridge was determined eligible for listing in the National Register prior to its demolition. In addition to this bridge, there was a small railroad bridge that crossed over Riverside Drive in Tiverton; the cut granite abutments are still intact. We determined that the Riverside Drive bridge contributes to the Sakonnet River Railroad Swing Bridge and hence the abutments and extant tracks are considered historic.

The Riverside Drive Historic District is directly adjacent if not within the potential direct APE for this undertaking. This district was determined eligible through a consensus determination of eligibility between the Federal Highway Administration, RIDOT, and the RIHPHC in 2002. While the Riverside Drive railroad bridge appears to just outside the boundary of the district, it is our opinion that the bridge remnants should be considered eligible within this district because the district derives significance from the railroad, which was the impetus for the development of the area, and the period of significance begins with the construction of this railroad line.

Other known historic properties (including those determined eligible or listed) within the vicinity in Tiverton include the Main Road Historic District - determined eligible through a consensus determination of eligibility, the Osborn-Bennett Historic District, the Benjamin Barker House at 1229 Main Road, the Joseph Hicks House at 494 Main Road, and Bourne Mill. In Portsmouth, the Battle of Rhode Island Historic District – National Historic Landmark and Borden Farm may be within the APE. Power should consult our survey books to further identify historic properties.

Power has asked the RIHPHC to assist with the delineation of an APE. The RIHPHC is unable to do so with the information provided. We need to understand the difference in height, location, and material proposed for each pole that will be replaced in order to determine an appropriate direct and indirect APE. Please also inform our office of the status of the Army Corp permit and reviewer for this project.

These comments are provided in accordance with Section 106 of the National Historic Preservation Act. If you have any questions, please contact RIHPHC Project Review Coordinator Elizabeth Totten at 401-222-2671 or elizabeth.totten@preservation.ri.gov.

Sincerely,

Elizabeth Totten
FOR

Jeffrey Emidy
Executive Director
Interim State Historic Preservation Officer

Copy via email: Jacob Begin, Jacob.begin@ridot.ri.gov, RIDOT Cultural Resources Unit

STATE OF RHODE ISLAND

HISTORICAL PRESERVATION & HERITAGE COMMISSION

Old State House 150 Benefit Street Providence, RI 02903

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

February 26, 2024

Via email: jaime.donta@powereng.com

Jaime M. Donta
Cultural Resources Specialist
Power Engineers, Inc.
2 Hampshire Street, Suite 301
Foxborough, MA 02035

Re: RIHPHC Project No. 15254
L14/M13 Main Line and Tiverton Tap Rebuild Project
Tiverton & Portsmouth, Rhode Island

Dear Ms. Donta:

The Rhode Island Historical Preservation and Heritage Commission (RIHPHC) staff has reviewed the information that you provided for the above-referenced project. The RI Energy is proposing to replace the structures and lines L14/M13 in Tiverton and Portsmouth, Rhode Island. The undertaking will require permits from the U.S. Army Corps of Engineers.

Power Engineers, Inc. has requested that the RIHPHC suggest an area of potential effect for the proposed undertaking. Power has supplied the RIHPHC with initial changes in structure height based upon 30% and 50% engineering design. Based upon this design, some structures may be lowered in height while others will be raised 15-45 feet. There is one instance where a structure will be ~95 feet higher. The APE for projects of this type is typically one-quarter mile (0.25) from either side of the transmission line. We feel that this is an appropriate APE based upon the information provided.

These comments are provided in accordance with Section 106 of the National Historic Preservation Act. If you have any questions, please contact RIHPHC Project Review Coordinator Elizabeth Totten at 401-222-2671 or elizabeth.totten@preservation.ri.gov.

Sincerely,

Elizabeth Totten
FOR

Jeffrey Emidy
Executive Director
State Historic Preservation Officer

240226.02est

State of Rhode Island
Coastal Resources Management Council
Oliver H. Stedman Government Center
4808 Tower Hill Road, Suite 3
Wakefield, RI 02879-1900

(401) 783-3370
Fax (401) 783-2069

FINDING OF NO SIGNIFICANT IMPACT

February 28, 2024

Rhode Island Energy
c/o Elisabeth Peterman
280 Melrose Street
Providence, RI 02907

RE: CRMC Assent No. F2024-02-072: ***Perform a subsurface investigation program on the existing Rhode Island Energy transmission line right-of-way by advancing geotechnical exploratory borings to support the planning and design of the rebuild and reconfiguration of the existing L14 and M13 115kV transmission line structures and overhead conductors. Work shall be performed in accordance with Rhode Island Energy Environmental Guidance dated 2/8/2022, pages 1-46 and submitted Geotech Boring Access Plan dated 2/6/2024, pages 1-7.*** Project Location: Line L14 & M13 Existing ROW, Portsmouth

Dear Applicant:
The Coastal Resources Management Council has reviewed your project proposal and has determined the findings of no significant impact on coastal resources. This project must be completed within three (3) years of the date of this notification, unless written application requesting an extension is received by CRMC sixty (60) days prior to the expiration date. If this project involves excess excavated materials, excess soils, excess construction materials, and debris (including any destructed materials) these materials shall be removed from the site and disposed of at an inland landfill or a suitable and legal upland location. **If the project involves earthwork, appropriate erosion controls shall be utilized**. All applicable policies, prohibitions, and standards of the RICRMP shall be upheld.

CAUTION: The limits of authorized work shall be only for that which was approved by the CRMC. Any activities or alterations in which deviate from this assent or what was detailed on the CRMC approved plans will require a separate application and review. Additionally, if the information provided to the CRMC for this review is inaccurate or did not reveal all necessary information or data, then this permit may be found to be null and void. Plans for any future alteration of the shoreline or construction or alteration within the 200' zone of CRMC jurisdiction or in coastal waters must be submitted for review to the CRMC prior to commencing such activity.

Permits, licenses or easements issued by the Council are valid only with the conditions and stipulation under which they are granted and imply no guarantee of renewal. The initial application or an application for renewal may be subject to denial or modification. If an application is granted, said permit, license and easement may be subject to revocation and/or modification for failure to comply with the conditions and stipulations under which the same was issued or for other good cause.

Applicant agrees that as a condition to the granting of this assent, members of the Coastal Resources Management Council or its staff shall have access to applicant's property to make on-site inspections to insure compliance with the assent.

A copy of this authorization to perform construction related activities shall be kept on site and available for inspection. NOTE: Failure to have this letter on site or work in excess of your proposal constitutes a violation under this program.

Sincerely,

Brittany Spurlock, Asst. Administrative Officer
Coastal Resources Management Council

/bms

APPENDIX F VISUAL SIMULATION

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EXISTING CONDITIONS

PROPOSED CONDITIONS

EAGLEVILLE ROAD, TOWN OF TIVERTON

Photo simulations are for discussion purposes only. Final design is subject to change pending public, engineering, and regulatory review.

L14 & M13 MAINLINE AND TIVERTON TAP
REBUILD PROJECT

Viewpoint 5

Date: 04/08/2024 **Time:** 3:13 pm **Viewing Direction:** Northeast

5 Photo Location — Existing Transmission Line

Rhode Island Energy™
a PPL company

APPENDIX G CURRENT STATUS OF RESEARCH ON EXTREMELY LOW FREQUENCY ELECTRIC AND MAGNETIC FIELDS AND HEALTH: RHODE ISLAND ENERGY TRANSMISSION LINE PROJECTS – THE NARRAGANSETT ELECTRIC COMPANY (JUNE 3, 2022)

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APPENDIX G CURRENT STATUS OF RESEARCH ON EXTREMELY LOW FREQUENCY ELECTRIC AND MAGNETIC FIELDS AND HEALTH (June 3, 2022)

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Health Sciences Practice

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

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

Prepared for:

The Narragansett Electric Company

Prepared by:

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

June 3, 2022

Table of Contents

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Acronyms and Abbreviations

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

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

Limitations

At the request of the Narragansett Electric Company, Exponent, Inc., prepared this summary report on the status of research related to extremely low frequency electric- and magnetic-field exposure and health. The findings presented herein are made to a reasonable degree of scientific certainty. Exponent reserves the right to supplement this report and to expand or modify opinions based on review of additional material as it becomes available, through any additional work, or review of additional work performed by others.

The scope of services performed during this investigation may not adequately address the needs of other users of this report, and any re-use of this report or its findings, conclusions, or recommendations presented herein are at the sole risk of the user. The opinions and comments formulated during this assessment are based on observations and information available at the time of the investigation. No guarantee or warranty as to future life or performance of any reviewed condition is expressed or implied.

Executive Summary

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

Section 1 of this report discusses the nature, sources, and typical environmental exposure levels of ELF EMF. ELF EMF are invisible fields surrounding all objects that generate, use, or transmit electricity. There are also natural sources of ELF EMF, including the electric fields associated with the normal functioning of our circulatory and nervous systems. People living in developed countries are constantly exposed to ELF EMF in their environments since electricity is a fundamental part of technologically-advanced societies. Sources of man-made ELF EMF include appliances, wiring, and motors, as well as distribution and transmission lines.

Research on ELF EMF and health began with the goal of finding therapeutic applications and understanding biological electricity (i.e., the role of electrical potentials across cell membranes and current flows between cells in our bodies). Over the past 50 years, researchers have examined whether ELF EMF from man-made sources can cause short- or long-term health effects in humans using a variety of study designs and techniques. This research considered many aspects of physiology and diseases, including cancers in children and adults, neurodegenerative diseases, reproductive effects, and cardiovascular disease.

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

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

The World Health Organization (WHO) published a health risk assessment of ELF EMF in 2007 that critically reviewed the cumulative epidemiologic and laboratory research to date, which accounted for the strength and quality of the individual research studies they evaluated. Section 3 provides a summary of the WHO's conclusions with regard to the major outcomes they evaluated. The WHO report provided the following overall conclusions:

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

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

A number of national and international scientific organizations have published reports or scientific statements with regard to the possible health effects of ELF EMF since January 2006, which are listed in Section 5. The conclusions of these documents are generally consistent with the WHO review published in 2007 and with the scientific consensus articulated in Section 4.

There are no national recommendations, guidelines, or standards in the United States to regulate ELF EMF or to reduce public exposures, although the WHO recommends adherence to the exposure limits established by the International Commission on Non-Ionizing Radiation Protection or the International Committee for Electromagnetic Safety for the prevention of acute health effects at high exposure levels, which are summarized in Section 6. In light of their assessments of the scientific research, some scientific organizations recommend low-cost interventions to reduce ELF EMF exposure. While the large body of existing research does not confirm any likely harm associated with ELF EMF exposure at low levels, research on this topic will continue to reduce remaining uncertainty.

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

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

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

1 Introduction

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

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

Nature of extremely low frequency electric and magnetic fields

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

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

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

- **Magnetic fields** are produced by the flow of electric currents; however, unlike electric fields, most materials do not readily block magnetic fields. The strength of a magnetic field is expressed as magnetic flux density in units of gauss (G) or milligauss (mG), where 1 G=1,000 mG.[2] The strength of the magnetic field at any point depends on characteristics of the source. In the case of power lines, magnetic-field strength is dependent on the arrangement of conductors, the amount of current flow, and distance from the conductors.

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

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

Sources and exposure

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

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

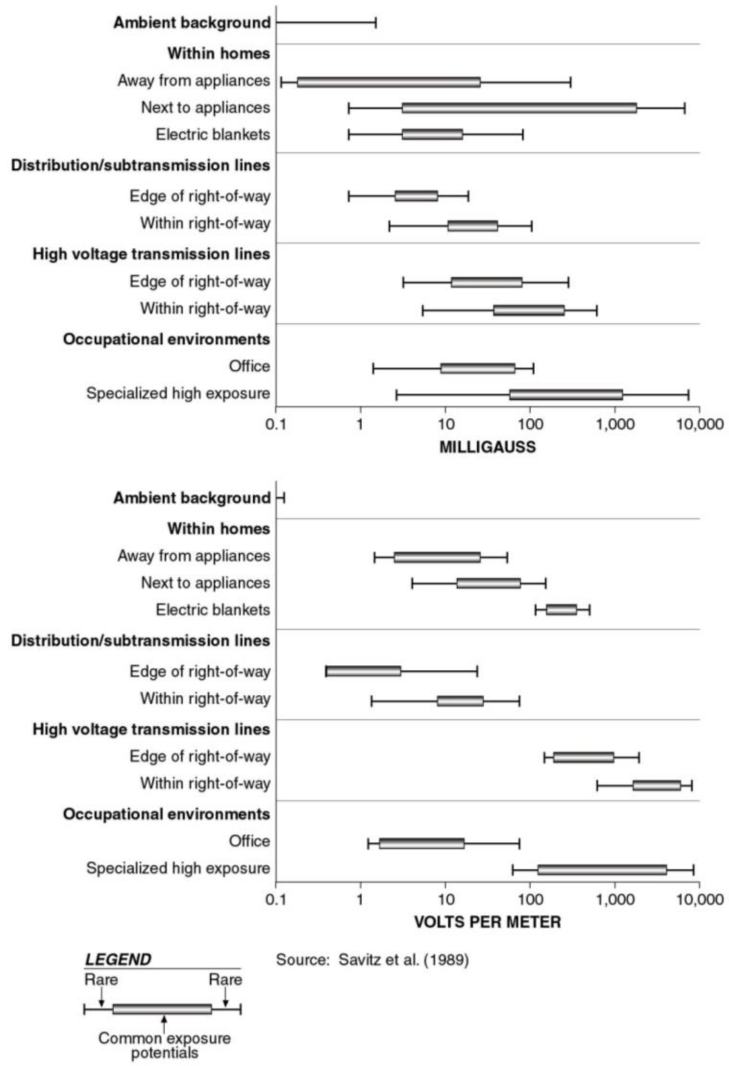

Figure 2. Electric- and magnetic-field strengths in the environment.

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

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

- *Personal magnetic-field exposure:*
    - The vast majority of persons in the United States have a time-weighted average (TWA) exposure to magnetic fields less than 2 mG (Zaffanella and Kalton, 1998).[3]
    - In general, personal magnetic-field exposure is greatest at work and during travel (Zaffanella and Kalton, 1998).
- *Residential magnetic-field exposure:*
    - The highest magnetic-field levels are typically found directly next to appliances (Zaffanella, 1993). For example, Gauger (1985) reported the maximum AC magnetic field at 3 centimeters from a sampling of appliances as 3,000 mG (can opener); 2,000 mG (hair dryer); 5 mG (electric oven); and 0.7 mG (refrigerator).
    - Several parameters affect the distribution of personal magnetic-field exposures at home: residence type, residence size, type of water line, and proximity to overhead power lines. Persons living in small homes, apartments, homes with metal piping, and homes close to three-phase electric power distribution and transmission lines tend to have higher at-home magnetic-field levels (Zaffanella and Kalton, 1998).
    - Residential magnetic-field levels are caused by currents from nearby transmission and distribution systems, pipes or other conductive paths, and electrical appliances (Zaffanella, 1993).
- *Workplace magnetic-field exposure*
    - Some occupations (e.g., electric utility workers, sewing machine operators, telecommunications workers) have higher exposures due to work near equipment with high magnetic-field levels (NIEHS, 2002).

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

- *Power line magnetic-field exposure*
    - The magnetic-field levels associated with transmission and distribution lines vary substantially depending on their configuration, amount of current flow (load), and distance from conductors, among other parameters. At distances of approximately 300 feet from overhead transmission lines and during average electricity demand, the magnetic-field levels from many transmission lines are often similar to the background levels found in most homes, as illustrated in Figure 2 above, and as discussed in a National Institute of Environmental Health Sciences booklet on EMF (NIEHS, 2002).

Known effects

Similar to virtually any exposure, adverse effects can be expected from exposure to very high levels of ELF EMF. If the current density or electric field induced by an extremely strong magnetic field exceeds a certain threshold, excitation of muscles and nerves is possible (ICNIRP, 2010). Also, strong electric fields can induce charges on the surface of the body that can lead to small shocks (i.e., micro shocks). These acute, shock-like effects cause no long-term damage or health consequences. Limits for the general public and workplace have been set to prevent these effects, but there are no real-life situations where these levels are exceeded on a regular basis. Standards and guidelines are discussed in more detail in Section 6.

2 Methods for Evaluating Scientific Research

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

Weight-of-evidence reviews

The scientific process entails looking at *all* the evidence on a particular issue in a systematic and thorough manner to evaluate if the overall data present a logically coherent and consistent picture. This is often referred to as a weight-of-evidence review in which all studies are considered together, giving more weight to studies of higher quality, and using an established analytic framework to arrive at a conclusion about a possible causal relationship. Weight-of-evidence reviews typically are conducted within the larger framework of health risk assessments or evaluations of particular exposures or exposure circumstances that qualitatively and quantitatively define health risks. Several agencies have described weight-of-evidence and health risk assessment methods, including the International Agency for Research on Cancer (IARC), which routinely evaluates substances such as drugs, chemicals, and physical agents for their ability to cause cancer; the WHO International Programme for Chemical Safety; the U.S. Environmental Protection Agency (US EPA), which sets guidance for public exposures; the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) for the European Union; and the U.S. National Toxicology Program (NTP) (USEPA, 1993, 1996; WHO, 1994; SCENIHR, 2012; NTP, 2015). Two steps precede a weight-of-evidence evaluation: 1) a systematic review to identify the relevant literature, and 2) an evaluation of each relevant study to determine its strengths and weaknesses.

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

Exposure considerations

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

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

Each of these methods has strengths and limitations (Kheifets and Oksuzyan, 2008). Magnetic-field exposure is ubiquitous, but it varies for each individual over a lifetime because the locations one frequents change and the ELF EMF sources in those locations also change. This lack of consistency makes valid estimates of personal magnetic-field exposure challenging. Furthermore, without a biological basis to define a relevant exposure metric (average exposure or peak exposure) and a defined critical period for exposure (e.g., *in utero*, shortly before diagnosis), relevant and valid assessments of exposure are problematic. Exposure misclassification is one of the most significant concerns in studies of ELF EMF.

In general, long-term, personal measurements are the metrics selected by epidemiologists. Other methods are generally weaker because they may not be strong predictors of long-term exposure and do not account for all magnetic-field sources. ELF EMF can be estimated indirectly by assigning an estimated amount of exposure to an individual based on calculations considering nearby power installations or a person's job title (e.g., using a JEM). For instance, a relative estimate of exposure could be assigned to all machine operators based on historical information on the magnitude of the magnetic field produced by the machine. Indirect measurements are not as accurate as direct measurements because they do not contain information specific to that person or the exposure situation. In the example of machine operators, the indirect measurement may not account for how much time any one individual spends working at that machine, any differences in the job tasks performed by each machine operator, or any potential variability in magnetic fields produced by the machines over time (Kheifets et al., 2009;[4] Gobba et al., 2011). In addition, such occupational measurements do not account for the worker's residential magnetic-field exposures.

Types of health research studies

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

The most common types of epidemiologic studies in the ELF EMF literature are case-control and cohort studies. In case-control studies, people with and without the disease of interest are identified and the exposures of interest are evaluated. Often, people are interviewed or their personal records (e.g., medical records or employment records) are reviewed in order to establish the exposure history for each individual. The exposure histories are then compared between the diseased and non-diseased populations to determine whether any statistically significant

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

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

Experimental studies are designed to test specific hypotheses under controlled conditions and are vital to assess cause-and-effect relationships. An example of a human experimental studies relevant to this area of research would be ones that measure the impact of magnetic-field exposure on acute biological responses in humans, such as hormone levels. These studies are conducted in laboratories under controlled conditions. *In vivo* studies of animals and *in vitro* experimental studies also are conducted under controlled conditions in laboratories. *In vivo* studies expose laboratory animals to very high levels of a chemical or physical agent to determine whether exposed animals develop cancer or other effects at higher rates than unexposed animals, while attempting to control other factors that could possibly affect disease rates (e.g., diet, genetics). *In vitro* studies of isolated cells and tissues are important because they can help scientists understand biological mechanisms that relate to the same exposure in whole body humans and animals. The responses of cells and tissues outside the body, however, may not reflect the response of those same cells if maintained in a living system, so their relevance cannot be assumed. Therefore, it is both necessary and desirable to assess whether a particular agent could cause adverse health effects using both epidemiologic and experimental studies, and both approaches have been used to evaluate whether exposure to ELF EMF has any adverse effects on human health. Epidemiologic studies are valuable because they are conducted in human populations, but they are limited by their non-experimental design and typical retrospective nature. In epidemiologic studies of magnetic fields, for example, researchers cannot control the amount of individual exposure, how exposure occurs over time, the contribution of different sources, or individual behavior other than exposure that may affect disease risk, such as diet. In valid risk assessments of ELF EMF, epidemiologic studies are considered alongside experimental studies of laboratory animals, while studies of isolated cells and tissues are generally considered supplementary.

Estimating risk

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

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

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

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

Statistical significance

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

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

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

Meta-analysis and pooled analysis

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

The disadvantage of meta- and pooled analyses is that they can convey a false sense of consistency across studies if *only* the combined estimate of effect is considered (Rothman and Greenland, 1998). These analyses typically combine data from studies with different study populations, methods for measuring and defining exposure, and disease definitions. This is particularly true for analyses that combine data from case-control studies, which often use very different methods for the selection of cases and controls and exposure assessment (Linet, 2003). Therefore, meta- and pooled analyses are used not only to synthesize or combine data, but also to understand which factors cause the results of the studies to vary (i.e., publication date, study design, possibility of selection bias), and how these factors affect the associations calculated from the data of all the studies combined (Rothman and Greenland, 1998).

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

Bias in epidemiologic studies

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

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

Cause versus association and evaluating evidence regarding causal associations

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

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

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

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

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

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

Biological response versus disease in human health

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

3 The WHO 2007 Report: Methods and Conclusions

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

In 2007, the WHO published their Environmental Health Criteria (EHC) 238 on EMF summarizing health research in the ELF range. The EHC conducted their review using standard scientific procedures, as outlined in its Preamble and described above in Section 2. The Task Group responsible for the report's overall conclusions consisted of 21 scientists from around the world with expertise in a wide range of scientific disciplines. They relied on the conclusions of previous weight-of-evidence reviews,[5] where possible, and mainly focused on evaluating studies published after an IARC review of ELF EMF and cancer in 2002.

The WHO Task Group and IARC use specific terms to describe the strength of the evidence in support of causality between specific agents and cancer. These categories are described here because, while they are meaningful to scientists who are familiar with the IARC process, they can create an undue level of concern with the general public. *Sufficient evidence of carcinogenicity* is assigned to a body of epidemiologic research if a positive association has been observed in studies in which chance, bias, and confounding can be ruled out with reasonable confidence. *Limited evidence of carcinogenicity* describes a body of epidemiologic research

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

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

Summary categories are assigned by considering the conclusions of each body of evidence (epidemiologic, *in vivo*, and *in vitro*) together. As identified in Figure 3, categories include (from highest to lowest risk): *carcinogenic to humans*; *probably carcinogenic to humans*; *possibly carcinogenic to humans*; *not classifiable as to its carcinogenicity to humans*; and *probably not carcinogenic to humans*. These categories are intentionally meant to err on the side of caution, giving more weight to the possibility that the exposure is truly carcinogenic and less weight to the possibility that the exposure is not carcinogenic. The category *possibly carcinogenic to humans* denotes exposures for which there is limited evidence of carcinogenicity in epidemiologic studies and less than sufficient evidence of carcinogenicity in studies of experimental animals. *In vitro* research is not described in Figure 3 because it provides ancillary information; it is used to a lesser degree in evaluating carcinogenicity and is classified simply as strong, moderate, or weak.

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

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

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

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

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

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

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

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

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

Figure 3. Basic IARC method for classifying exposures based on potential carcinogenicity. Note that in 2019, IARC removed the category *Probably not a Carcinogen* (Group 4), as only one chemical had ever been assigned to that category. https://monographs.iarc.who.int/wp-content/uploads/2019/07/2019-SR-001-Revised_Preamble.pdf. Accessed March 18, 2022

The IARC has reviewed over 1,000 substances and exposure circumstances to evaluate their potential carcinogenicity. Eighty percent of exposures fall in the categories *possibly carcinogenic* (31 percent) or *not classifiable* (48 percent).[6] This occurs because it is nearly impossible to prove that something is completely safe, and few exposures show a clear-cut or probable risk, so most agents will end up in either of these two categories. Throughout the history of the IARC, only one agent has been classified as *probably not carcinogenic*, which illustrates the conservatism of the evaluations and the difficulty in proving the absence of an effect beyond all doubt.

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

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

The WHO concluded the following regarding specific diseases:

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

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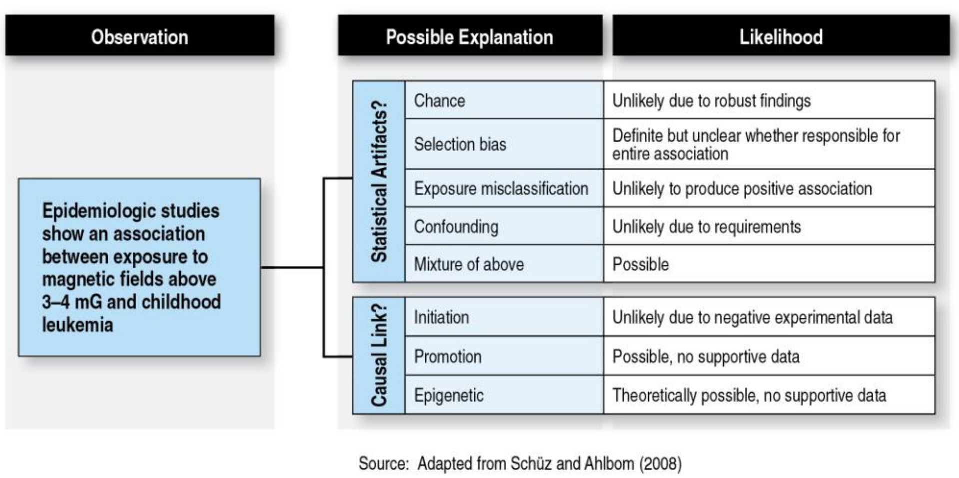
[6] https://monographs.iarc.fr/agents-classified-by-the-iarc/. Accessed March 18, 2022.

The WHO report systematically evaluated several factors that might be partially, or fully, responsible for the consistent association, including: chance, misclassification of magnetic-field exposure, confounding from hypothesized or unknown risk factors, and selection bias (*see* Figure 4). The authors concluded the following:

- Chance is an unlikely explanation since the pooled analyses had a large sample size and decreased variability.
- Control selection bias probably occurs to some extent in these studies and would result in an overestimate of the true association, but would not explain the entire observed association.
- It is less likely that confounding occurs, although the possibility that some yet-to-be identified confounder is responsible for the association cannot be fully excluded.
- Exposure misclassification would likely result in an underestimate of the true association, although it is not entirely clear.

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



Source: Adapted from Schüz and Ahlbom (2008)

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

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

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

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

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

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

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

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

4 Current Scientific Consensus

The following sections identify and describe epidemiologic and *in vivo* studies related to ELF EMF and health published between December 2018 and December 2021. The purpose of this section is to evaluate whether the findings of these recent studies alter the conclusions published by the WHO in their 2007 report, as described in Section 3. A previous Exponent report summarized the literature through December 2018 (Exponent, 2019) and concluded that those results did not provide sufficient evidence to alter the basic conclusion of the WHO EHC published in 2007.

A structured literature search was conducted using PubMed, a search engine provided by the National Library of Medicine and the National Institutes of Health that includes over 33 million up-to-date citations from MEDLINE and other life science journals for biomedical articles (http://www.pubmed.gov). A well-defined search strategy was used to identify English language literature indexed between December 2018 and December 2021.[7] All fields (e.g., title, abstract, keywords) were searched with various search strings that referenced the exposure and disease of interest.[8] A researcher with experience in this area reviewed the titles and abstracts of these publications for inclusion in this evaluation. The following specific inclusion criteria were applied:

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

[7] Since the literature search was performed at the end of December 2021, and there is sometimes a delay between the publication date of a study and the date it is indexed in PubMed, it is possible that some studies published prior to December 2021 are not included in this update.

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

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

4. **Study design**. Study design included epidemiologic studies, meta-analyses, pooled analyses, human experimental studies, and *in vivo* studies of carcinogenicity. The review relies on the conclusions of the WHO with regard to *in vivo* studies in the areas of reproduction, development, neurology, and cardiology. Further, this report relies on the conclusions of the WHO report (as described in Section 3) regarding mechanistic data from *in vitro* studies since this field of study is less informative to the risk assessment process (IARC, 2002).
5. **Peer-review**. The study must have been peer-reviewed and published. Therefore, no conference proceedings, abstracts, or non-peer reviewed on-line materials were included.

Epidemiologic studies are evaluated below first by outcome (childhood cancer; adult cancer; reproductive or developmental effects; neurodegenerative disease; and cardiovascular effects), followed by an evaluation of *in vivo* research on carcinogenesis. Tables 2 through 9 list the relevant studies that were published from December 2018 through December 2021 in these areas.

Childhood health outcomes

Childhood leukemia

In 2002, the IARC assembled and reviewed research related to ELF EMF to evaluate the strength of the evidence in support of carcinogenicity. The IARC expert panel noted that when studies with the relevant information were combined in a pooled analysis (Ahlbom et al., 2000; Greenland et al., 2000), a statistically significant two-fold association was observed between childhood leukemia and estimated average exposure to high levels of magnetic fields (i.e., greater than 3 to 4 mG of average 24- and 48-hour exposure). This evidence was classified as limited evidence in support of carcinogenicity, falling short of sufficient evidence because chance, bias, and confounding could not be ruled out with reasonable confidence. Largely as a result of the findings related to childhood leukemia, the IARC classified magnetic fields as *possibly carcinogenic*, which, as noted previously, is a category that describes exposures with limited epidemiologic evidence and inadequate evidence from *in vivo* studies. The classification of *possibly carcinogenic* was confirmed by the WHO in their 2007 review.

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

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

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

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

Recent studies (December 2018 through December 2021)

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

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

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

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

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

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

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

Assessment

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

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

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

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

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

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

Childhood brain cancer

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

> As with childhood leukaemia, a pooled analysis of childhood brain cancer studies should be very informative and is therefore recommended. A pooled analysis of this kind can inexpensively provide a greater and improved insight into the existing data, including the possibility of selection bias and, if the

> studies are sufficiently homogeneous, can offer the best estimate of risk (WHO 2007, p. 18).

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

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

Recent studies (December 2018 through December 2021)

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

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

Assessment

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

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

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

Adult health outcomes

Breast cancer

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

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

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

Recent studies (December 2018 through December 2021)

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

Assessment

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

Adult brain cancer

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

The WHO stated the following:

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

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

Recent studies (December 2018 through December 2021)

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

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

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

Assessment

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

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

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

Adult leukemia and lymphoma

There is a vast literature on adult leukemia and ELF EMF, most of which is related to occupational exposure. Overall, the findings of these studies are inconsistent—some studies report a positive association between measures of ELF EMF and leukemia and other studies show no association. No pattern has been identified whereby studies of higher quality or design are more likely to produce positive or negative associations. The WHO subsequently classified the epidemiologic evidence for adult leukemia as inadequate. They recommended updating the existing European occupational cohorts and updating a meta-analysis on occupational magnetic-field exposure. Subsequently, Kheifets et al. (2008) provided an update to two meta-analyses they published in the 1990s. Their updated meta-analysis indicated that pooled risk estimates from more recent studies were lower than in past meta-analyses and that no consistent pattern was observed by leukemia subtypes. Thus, the combined results were not in support of a causal association between occupational EMF exposure and adult leukemia.

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

Recent studies (December 2018 through December 2021)

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

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

Assessment

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

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

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

Reproductive and developmental effects

In 2002, two studies received considerable attention because of a reported association between peak magnetic-field exposure greater than approximately 16 mG and miscarriage: a prospective cohort study of women in early pregnancy (Li et al., 2002) and a nested case-control study of women who miscarried compared to their late-pregnancy counterparts (Lee et al., 2002). These two studies improved on the existing body of literature because average exposure was assessed using 24-hour personal magnetic-field measurements (earlier studies on miscarriage were limited because they used surrogate measures of exposure, including visual display terminal use, electric blanket use, or wire code data). The Li et al. (2002) study, however, was criticized by the National Radiological Protection Board *inter alia* because of the potential for selection bias, a low compliance rate, measurement of exposure after miscarriages, and apparent selection of exposure categories after inspection of the data (NRPB, 2002). The scientific panels that considered these two studies concluded that the possibility of this bias precludes making any conclusions about the effect of magnetic fields on miscarriage (NRPB, 2004; FPTRPC, 2005; WHO, 2007). The WHO concluded, "[t]here is some evidence for increased risk of miscarriage associated with measured maternal magnetic-field exposure, but this evidence is inadequate" and recommended further epidemiologic research (WHO, 2007, p. 254).

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

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

Recent studies (December 2018 through December 2021)

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

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

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

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

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

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

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

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

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

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

Assessment

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

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

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

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

Neurodegenerative diseases

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

The majority of the studies reviewed by the WHO reported statistically significant associations between occupational magnetic-field exposure and mortality from Alzheimer's disease and ALS, although the design and methods of these studies were relatively weak (e.g., disease status was based on death certificate data, exposure was based on incomplete occupational information from census data, and there was no control for confounding factors). Furthermore, there were no biological data to support an association between magnetic fields and neurodegenerative diseases. The WHO panel concluded that there are inadequate data in support of an association between magnetic fields and Alzheimer's disease or ALS. The panel recommended more research in this area using improved methods; in particular they recommended studies that enrolled incident Alzheimer's disease cases (rather than ascertaining cases from death certificates), as well as studies that estimated electrical shock history in ALS cases.

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

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

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

Recent studies (December 2018 through December 2021)

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

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

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

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

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

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

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

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

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

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

Assessment

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

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

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

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

Cardiovascular disease

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

The WHO concluded:

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

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

Recent studies (December 2018 through December 2021)

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

Assessment

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

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

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

In vivo studies related to carcinogenesis

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

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

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

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

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

Chronic bioassays

The WHO review (2007) described four large-scale, long-term studies of rodents exposed to magnetic fields over the course of their lifetime that did not report increases in any type of cancer (Mandeville et al., 1997; Yasui et al., 1997; Boorman et al., 1999a, 1999b; McCormick et al., 1999). No directly relevant animal model for childhood ALL existed at the time of the WHO review. Some animals, however, develop a type of lymphoma similar to childhood ALL and studies exposing these predisposed transgenic mice to ELF magnetic fields did not report an increased incidence of this lymphoma type (Harris et al., 1998; McCormick et al., 1998; Sommer and Lerchl, 2004). Following the release of the WHO review, Bernard et al. (2008) reported that magnetic-field exposure did not affect development of the most common form of childhood leukemia induced in a rat model by a chemical carcinogen.

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

Carcinogenic agents plus magnetic fields (combined)

Studies investigated whether exposure to magnetic fields can promote cancer or act as a co-carcinogen in treated animals in combination with known cancer-causing agents, such as ionizing radiation, ultraviolet radiation, or other chemicals. While no effects were observed in these studies on chemically-induced, pre-neoplastic liver lesions, leukemia or lymphoma, skin tumors, or brain tumors (WHO, 2007, Tables 78-79), the WHO noted that incidence of 7,12-dimethylbenz[a]anthracene (DMBA)-induced mammary tumors was increased with magnetic-field exposure in a series of experiments in Germany (Löscher et al., 1993, 1994, 1997; Mevissen et al., 1993a, 1993b, 1996a, 1996b, 1998; Baum et al., 1995; Löscher and Mevissen, 1995), suggesting that magnetic-field exposure increased the proliferation of mammary tumors initiated by this chemical carcinogen. These results were not replicated in a subsequent series of experiments in a laboratory in the United States (Anderson et al., 1999; Boorman et al., 1999a, 1999b), possibly due to differences in experimental protocols and the species strain. In Fedrowitz et al. (2004) and Fedrowitz and Löscher (2008), exposure enhanced mammary tumor development in one sub-strain (Fischer 344 rats), but not in another sub-strain that was obtained from the same breeder, which argues against a promotional effect of magnetic fields.[9]

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

Magnetic-field effects on cellular processes potentially relevant to cancer

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

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

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

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

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

In summary, the WHO concluded the following with respect to *in vivo* research related to cancer: "[t]here is no evidence that ELF [EMF] exposure alone causes tumours. The evidence that ELF field exposure can enhance tumour development in combination with carcinogens is inadequate" (WHO, 2007, p. 322). Subsequent research, as reviewed in Exponent (2019) and below, has not provided any clear support for the idea that magnetic fields promote the development of tumors initiated by carcinogenic chemicals or that magnetic fields have any confirmed effect on oxidative processes that might damage DNA or other cellular components linked to cancer.

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

Cancer bioassays

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

Carcinogenic treatments plus magnetic fields (combined)

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

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

EMF effects on cellular processes potentially relevant to cancer

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

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

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

Magnetic- and electric-field treatments on tumor growth

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

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

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

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

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

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

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

Occupational biomarker studies

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

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

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

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

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

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

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

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

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

Oxidative indicator studies

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

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

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

Assessmen

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

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

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

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

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

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

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

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

5 Reviews Published by Scientific Organizations

A number of national and international scientific organizations have published reports or scientific statements with regard to the possible health effects of ELF EMF since January 2006. Although none of these documents represents a cumulative weight-of-evidence review of the caliber of the WHO review published in June 2007, their conclusions are of relevance. In general, the conclusions of these reviews are consistent with the scientific consensus articulated in Section 4.

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

- **The European Health Risk Assessment Network on Electromagnetic Fields Exposure**
    - http://efhran.polimi.it/docs/IMS-EFHRAN_09072010.pdf (EFHRAN, 2010 [*in vitro* and *in vivo* studies])
    - http://efhran.polimi.it/docs/D2_Finalversion_oct2012.pdf (EFHRAN, 2012 [human exposure])
- **The Health Council of Netherlands**
    - http://www.gezondheidsraad.nl/en/publications/bioinitiative-report-0 (HCN, 2008a)
    - http://www.gezondheidsraad.nl/en/publications/high-voltage-power-lines-0 (HCN, 2008b)
    - http://www.gezondheidsraad.nl/sites/default/files/200902.pdf (HCN, 2009a)
    - http://www.gezondheidsraad.nl/en/publications/advisory-letter-power-lines-and-alzheimer-s-disease (HCN, 2009b)

- **The Health Protection Agency (United Kingdom)**
    - http://www.hpa.org.uk/Publications/Radiation/DocumentsOfTheHPA/RCE01PowerFrequencyElectromagneticFieldsRCE1/ (HPA, 2006)
- **The International Commission on Non-Ionizing Radiation Protection**
    - http://www.icnirp.de/documents/LFgdl.pdf (ICNIRP, 2010)
    - https://www.icnirp.org/cms/upload/publications/ICNIRPlfgaps2020.pdf (ICNIRP, 2020)
- **The Scientific Committee on Emerging and Newly Identified Health Risks (European Union)**
    - http://ec.europa.eu/health/ph_risk/committees/04_scenihr/docs/scenihr_o_007.pdf (SCENIHR, 2007)
    - http://ec.europa.eu/health/ph_risk/committees/04_scenihr/docs/scenihr_o_022.pdf (SCENIHR, 2009)
    - http://ec.europa.eu/health/scientific_committees/emerging/docs/scenihr_o_041.pdf (SCENIHR, 2015)

The Swedish Radiation Protection Authority (SSI)

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

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

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

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

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

6 Standards and Guidelines

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

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

The International Committee on Electromagnetic Safety (ICES) also recommends limiting magnetic-field exposures at high levels because of the risk of acute effects, although their guidelines are higher than ICNIRP's guidelines; the ICES recommends a residential exposure limit (Exposure Reference Level) of 9,040 mG and an occupational exposure limit of 27,100 mG for 60-Hz magnetic fields (ICES, 2019, 2020). Both guidelines incorporate large safety factors.

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

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

In a 1985 decision, the Massachusetts Energy Facilities Siting Board (EFSB) approved an edge-of-ROW level of 85 mG as a benchmark for comparing different design alternatives. Since then, this benchmark has not served as a generally applicable standard or guideline. Instead, the EFSB has encouraged the use of practical and cost-effective designs to minimize magnetic-field levels along the edges of transmission line rights-of-way. This approach is consistent with recommendations of the WHO (2007) for addressing ELF EMF.

Table 10. Screening guidelines for EMF exposure

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

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

7 Summary

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

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

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