EXHIBIT JC-10

BEFORE THE

NEW JERSEY BOARD OF PUBLIC UTILITIES

# IN THE MATTER OF THE PETITION OF JERSEY CENTRAL POWER & LIGHT COMPANY PURSUANT TO N.J.S.A. 40:55D-19 FOR A DETERMINATION THAT THE MONTVILLE - WHIPPANY 230 KV TRANSMISSION PROJECT IS REASONABLY NECESSARY FOR THE SERVICE, CONVENIENCE OR WELFARE OF THE PUBLIC

## Direct Testimony

of

**Kyle G. King**

**Re: Electrical Field Effects**

## I. INTRODUCTION AND BACKGROUND

**Q. Please state your name and business address.**

A. My name is Kyle G. King, with a business address of 64 Sherwood Drive, Lenox, MA 01240.

**Q. By whom are you employed and in what capacity?**

A. I am the President of K&R Consulting, an electric power engineering company I founded in 2004. Prior to starting the engineering firm, I was the Director of the Electric Power Research Institute ("EPRI") High Voltage Research and Test Center in Lenox, Massachusetts.

**Q. Please describe your professional experience and educational background.**

A. I have Bachelor and Masters Degrees in Electrical Engineering from Union College in Schenectady, NY. I have been a Licensed Professional Engineer in New York since 1993. Over the past 20 years, I have been the Project Manager for many EPRI programs including Transmission Line EMF Management. I have authored numerous EPRI handbooks and taught dozens of courses concerning transmission line design and magnetic field management. I also co-authored EPRI's EMF series of handbooks.

**Q. Have you previously testified in Board of Public Utilities ("Board" or "BPU") proceedings?**

A. Yes, I filed pre-filed testimony and testified as an expert witness during evidentiary hearings in front of the New Jersey BPU on five previous occasions: in November 2009 as part of PSE&G's Susquehanna-Roseland 500 kV Project; in December 2012 as part of PSE&G's North-Central Reliability 230 kV Project; in September 2013 as part of PSE&G's Ridgewood 69 kV Project; in September 2014 as part of PSE&G's McCarter 230/26/13 kV Switching Station Project; and in October 2014 as part of JCP&L's Oceanview 230 kV Project.

**Q. Have you testified in proceedings before other utility regulatory commissions?**

A. Yes, in January 2005 I testified as an expert witness in front of the Connecticut Siting Council as part of Northeast Utilities Middletown-Norwalk 345 kV Project.

**Q. Would you describe the purpose of your testimony?**

A. My testimony supports Jersey Central Power & Light Company's ("JCP&L") petition to the BPU regarding the Montville - Whippany 230 kV transmission project (the "Project"). I prepared an electrical engineering analysis of the existing Montville - Whippany 34.5 kV subtransmission lines, and the 115 kV and 230 kV transmission lines and how they will be affected by the Project upgrades. My analysis included the effects of electric fields, magnetic fields, audible noise, and radio noise associated with the Project. Each of these parameters is compared to the edge of rights-of-way levels along the thirteen unique line segments.

**Q. Are you sponsoring any exhibits attached to this testimony?**

A. Yes, attached as Exhibit KGK-1 is my curriculum vitae and attached as Exhibit KGK-2 is my report, "Electrical Effects from the Montville - Whippany 230 kV Project."

## II. ELECTRIC AND MAGNETIC FIELDS GENERALLY

**Q. Please describe the purpose of your testimony**.

A. The purpose of this testimony is to describe and quantify the electrical effects of the Project. These include the levels of 60-hertz EMF[1], corona effects and noise produced by the Project.

**Q. Briefly, what are electric and magnetic fields?**

A. Electric fields are a vector quantity with both a magnitude and a direction. The direction corresponds to the direction that a positive charge would move in the field. Sources of electric fields are electrical charges. Transmission lines, distribution lines, house wiring, and appliances generate electric fields in their vicinity because of electrical charge (voltage) on energized conductors. Electric fields are typically described in units of volts-per-meter (V/m) or kilovolts-per-meter (kV/m). On the power system in North America, the voltage and charge on the energized conductors are cyclic (plus to minus to plus) at a rate of 60 times per second. This changing voltage results in electric fields near sources that are also time-varying at a frequency of 60 hertz.

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[1] "EMF" is an acronym for "electric and magnetic fields."

The concentrated electric field at the surface of transmission line conductors may cause a phenomenon called corona. Corona results from the electrical breakdown or ionization of air in very strong electric fields at the surface of the conductor, and can be a source of audible noise, radio noise, and ultraviolet light. Several factors, including conductor voltage, shape, and diameter, and surface irregularities such as scratches, nicks, dust, or water drops, can affect a conductor’s electrical surface gradient and its corona performance. The conductor design selected for the proposed transmission lines are of sufficient diameter and spacing to limit the localized electrical stress on the air at the conductor surface and minimize corona related effects.

Similar to electric fields, magnetic fields are a vector quantity characterized by both magnitude and direction. Electrical charges in motion (electrical currents) generate magnetic fields. In the case of transmission lines, distribution lines, house wiring, and appliances, the 60-Hz electric current flowing in the conductors generates a time-varying, 60-Hz magnetic field in the vicinity of these conductors. The strength of a magnetic field is measured in terms of magnetic lines of force per unit area, or magnetic flux density. The term “magnetic field,” as used here, is synonymous with magnetic flux density and is expressed in units of milligauss (mG).

**Q.** **What are typical sources of electric and magnetic fields and what are the levels you might expect to find associated with those sources?**

A. Electric and magnetic fields are created by any device which produces, carries, or uses electrical energy. The National Institute of Environmental Health Sciences ("NIEHS") has estimated the average level of background magnetic fields range from 0.5 to 5.0 mG in most homes. The New Jersey Department of Environmental Protection also lists typical magnetic field levels measured six inches away from common appliances. The NJDEP list includes:

Hair dryer - 300 milligauss
Electric shaver - 100 milligauss
Blender - 70 milligauss
Can opener - 600 milligauss
Coffee maker - 7 milligauss
Microwave oven - 200 milligauss
Color TV (1 foot away) - 7 milligauss

Typical levels of magnetic field in New York City Metro-North Commuter Railroad cars range from 40 to 60 mG, and increase to 90 to 145 mG during acceleration. The earth has a static magnetic field of approximately 570 mG over its entire surface. The earth's field at any position is constant in both magnitude and direction as opposed to the constantly changing power frequency magnetic fields discussed in this testimony.

Electric field levels are not easy to predict within homes because buildings, trees, and common objects all substantially shield (or reduce) electric field levels. A study of electric field levels near a range of common appliances ranged from 3 to 70 V/m approximately one foot away from the appliance.

## III. EMF ASSOCIATED WITH THE PROJECT

**Q. Can you explain how JCP&L designed the Project to reduce the levels of magnetic fields?**

A. JCP&L has employed a policy of “prudent avoidance” on this Project. Prudent avoidance is a precautionary principle in risk management, stating that reasonable efforts to minimize potential risks should be taken when the actual magnitude of the risks is unknown. The principle was proposed by Prof. Granger Morgan of Carnegie Mellon University in 1989 in the context of electromagnetic radiation safety (in particular, fields produced by power lines) calling it a “common sense strategy for dealing with some difficult social and scientific dilemmas." While New Jersey has no specific magnetic field limit for power lines, certain states have either formally or informally adopted the prudent avoidance policy in considering power line applications.

The conclusions reached by national and international scientific and health agencies from their evaluation of EMF research, and the guidelines for exposure they have recommended, make clear that exposures to EMF that people encounter in their daily life, including those from transmission lines like the Project, do not pose any recognized long-term health risks.

While not adopted by any federal regulatory body, the prudent avoidance principle has been adopted in some form by a number of state regulatory bodies, including the public utility commissions in California, Colorado, Connecticut and Hawaii. Several international health agencies have also adopted the prudent avoidance policy including the National Institute of Environmental Health

Sciences ("NIEHS"), which states: "that power companies and utilities [should] continue siting power lines to reduce exposures and … explore ways to reduce the creation of magnetic fields around transmission and distribution lines without creating new hazards." Similarly, the World Health Organization ("WHO") recommends in a recent fact sheet, "When constructing new facilities … low-cost ways of reducing exposures may be explored. Appropriate exposure reduction measures will vary from one country to another. However, policies based on the adoption of arbitrary low exposure limits are not warranted."

**Q. Did you model the existing and proposed electric and magnetic fields for JCP&L in connection with the Project?**

A. Yes, I modeled the existing and proposed line configurations to compare the expected levels of electric and magnetic fields in 2018, the first full year in which the Project will be in service, against the existing levels. The results of my study are summarized in a separate report attached hereto as Exhibit KGK-2.

**Q. Can you explain exactly how you performed your study and the results of the study for the Project?**

A. To quantify electrical effects of the Project, I calculated the electric and magnetic fields, radio noise, and audible noise caused by corona from the transmission lines using the EPRI Transmission Line Workstation computer programs. The study results confirmed the Project will meet all New Jersey regulations for electric fields and audible noise. For a more detailed review, please see my report attached hereto as Exhibit KGK-2.

**Q. What estimates of the power flows (load) on the transmission lines did you use to model magnetic field levels?**

A. The electrical current carried on a power line or other conductor is the source of the magnetic field. JCP&L witness Larre Hozempa provided transmission and distribution line currents for each circuit in 2014 and 2018.

**Q. Did you take any measurements of magnetic fields produced by the existing transmission lines that are now operating along the proposed Project route?**

A. Yes, electric and magnetic field measurements were completed at five locations along the edges of the existing ROWs in August 2014. The results are provided in Exhibit KGK-2.

**Q. What will be the levels of the magnetic field associated with the operation of the existing and proposed 34.5 kV, 115 kV, and 230 kV lines for this Project?**

A. The calculated magnetic field from the pre-project conditions along the edges of the existing, in use, ROWs (shown in Table 2 of Exhibit KGK-2) from the Whippany Substation to the Montville Substation ranges from 1.6 mG to 62.4 mG for the existing lines in 2014. After the Project is completed, the calculated expected magnetic field from the typical summer current along the edges of the ROW from Whippany to Montville Substations will range from 0.7 to 58.4 mG in

2018. Additional magnetic field details are provided in my report attached hereto as Exhibit KGK-2.

**Q. What is the upper-limit for magnetic field on this Project?**

A. The typical summer loading levels described above and in the “EMF Report” may be occasionally exceeded. To describe the upper expected limit for magnetic field levels, I used the maximum summer conductor rating for each unique ROW segment. The calculated edge of ROW magnetic field levels corresponding to those maximum possible currents are between 37.9 mG and 270.2 mG for the lines between the Whippany and Montville Substations.

## IV. STATE STANDARDS FOR EMF AND AUDIBLE NOISE

**Q. Does the State of New Jersey have electric field requirements?**

A. Yes, the State of New Jersey has a guideline of 3 kV/m for electric fields at the edge of the ROW. This guideline was established by the New Jersey Department of Environmental Protection on June 4, 1981.

**Q. Upon completion, will the Project meet the State of New Jersey’s electric field requirements?**

A. Yes, as set forth in Exhibit KGK-2, the Project will meet the State of New Jersey’s electric field guideline of 3.0 kV/m at the edge of the ROW. The Project will produce a maximum electric field of 0.7 kV/m along the edges of the ROWs.

For comparison, the existing circuits produce a maximum of 0.3 kV/m along the edges of the ROWs.

**Q. Does the State of New Jersey have any magnetic field requirements?**

A. The State of New Jersey does not have a limit for magnetic fields from transmission lines.

**Q. Has JCP&L taken steps in the siting and design of the proposed Project that will minimize EMF levels in the vicinity of the Project?**

A. Yes. As set forth in more detail in Exhibit KGK-2, by using existing ROWs for the majority of the Project and selecting the transmission line phasing, JCP&L has applied Prudent Avoidance principles and limited magnetic field levels under summer loading conditions.

**Q. Does New Jersey have limits on audible noise that would apply to nearby residences?**

A. Yes, New Jersey has published limits for Audible Noise. The New Jersey Administrative Code Section 7:29-1.2 (a) (2) (i) establishes a limit of 50 dBA for "continuous airborne sound" between the hours of 10:00 P.M. and 7:00 A.M.

**Q. Are the audible noise levels expected by the Project below these levels?**

**A.** Yes. 34.5 kV, 115 kV, and 230 kV transmission lines do not typically produce much corona or associated audible noise. Existing noise levels along the edges of the Project ROW under wet conductor conditions are approximately 45.5 dBA. Under the same conditions, the calculated audible noise levels after the Project is completed in 2018 are approximately 45.8 dBA. The project noise levels are well below the New Jersey 50 dBA limit.

**Q. Does this conclude your direct testimony?**

A. Yes, it does.

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**K & R Consulting, LLC** 7/04 - Present

President Lenox, MA

- President of K & R Consulting, LLC – a power engineering services and consulting company focused on delivering comprehensive solutions for Electric Utility power line outage mitigation and improved power system reliability
- Author of EPRI's Handbook for Power Line Lightning Protection
- Consulting and training activities include power system lightning and surge protection, grounding (including mitigation of step and touch potentials), electric and magnetic fields, corona, noise, and high voltage power system phenomena

**EPRIsolutions** 3/02 – 7/04

Director – Power Delivery Center Lenox, MA

- Director of Operations of 35 acre high voltage research, development and engineering center with a dozen engineering and technical staff
- Responsible for entire center operation including 1500 kV 3-phase AC and ± 1500 kV DC Transmission Sources, 5.6 Million Volt Impulse Generator, Transmission and Distribution Substations, and Full Scale Insulator and Surge Arrester Contamination and Accelerated Aging Facilities
- Lead Consultant and Chief Instructor on all power system lightning, grounding, and surge protection activities.
- Authored numerous EPRI handbooks, guidebooks, and project reports in the areas of Lightning Protection, Surge Arresters , Grounding, and Magnetic Field Management

**Electric Power Research Institute** 10/98 – 2/02

Research Engineer / Program Manager Lenox, MA

- Program Manager for transmission line lightning, grounding, and surge arresters
- Lead Consultant and Chief Instructor on all power system lightning and grounding activities.
- Taught dozens of power system engineering courses in Lightning Protection, Grounding, Arrester Application, and Electric and Magnetic Field Management.
- Authored numerous EPRI handbooks, guidebooks, and project reports in the areas of Lightning Protection, Surge Arresters, Grounding, and Magnetic Field Management

**Enertech Consultants** 10/94 – 10/98
Research Engineer Lee, MA

- Co-authored EPRI's Magnetic Field Management Handbooks
- Lead consultant for magnetic field characterization, modeling, and shielding using finite element modeling electromagnetic calculation tools.
- Co-developed prototype data logging instrument with integrated position and timing references using the Global Positioning System (GPS) satellites.

**General Electric** 7/92 -10/94
High Voltage Transmission Research Center Lenox, MA
Research Engineer

- Instructor for Magnetic Field Management and Shielding sections of EPRI's High Voltage Transmission Line Design Seminar
- Designed and tested scale passive cancellation loops for magnetic field management of transmission and distribution lines and conducted magnetic field mitigation studies for 115 kV - 500 kV transmission corridors

**General Electric** 8/88 – 7/92
US Navy Nuclear - Machinery Apparatus Operation Schenectady, NY
Project Engineer

- Responsible for the design, development, and production of Instrumentation and Control equipment for US Navy Nuclear Power Plants
- Managed prototype developments of Universal Instrumentation Circuit Card Module Test Set and ultrasonic water level measurement equipment

## EDUCATION & REGISTRATION

MS Electrical Engineering, Union College - Schenectady, NY
BS Electrical Engineering, Union College - Schenectady, NY
New York State Licensed Professional Engineer

## HONORS & AWARDS

Young Engineer of the Year - GE Industrial and Power Systems
Tau Beta Pi - National Engineering Honor Society
Eta Kappa Nu - Electrical Engineering Honor Society

Exhibit KGK-2

# Electrical Effects from the Montville - Whippany 230 kV Project

January 26, 2015

Prepared for:
Jersey Central Power & Light Company

Prepared by:
Kyle G. King
K & R Consulting, LLC

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## Executive Summary

PJM Interconnection, L.L.C. ("PJM"), the regional entity responsible for planning the transmission system within its footprint, has identified the need to add a third 230 kV transmission circuit into the Montville substation. The proposed transmission line will run from the Jersey Central Power & Light Company ("JCP&L") Whippany substation in East Hanover Township to the JCP&L Montville substation in Montville Township (the "Project"). The entire project is located in Morris County, New Jersey.

This report describes and quantifies the electrical effects of the Project. These effects include the levels of 60-hertz (Hz) electric and magnetic fields ("EMF"), high frequency radio noise, and the levels of audible noise produced by the lines. Electrical effects occur near all transmission lines, therefore, the levels of these quantities for the proposed lines were calculated and compared with those from the existing lines on the Rights-of-Way ("ROW").

The voltage on the conductors of transmission line generates an electric field in the space between the conductors and the ground. The electric field is calculated or measured in units of volts-per-meter (V/m) or kilovolts-per-meter (kV/m) at a height of one meter above the ground. The current flowing in the conductors of the transmission line generates a magnetic field in the air and earth near the transmission line. Current is expressed in units of amperes (A). The magnetic field is expressed in milligauss (mG), and is also usually measured or calculated at a height of one meter above the ground. The electric field at the surface of the conductors causes a phenomenon called corona. Corona is the electrical breakdown or ionization of air in very strong electric fields, and is the source of audible noise, electromagnetic radiation, and visible light.

To quantify electrical effects along the route, the electric and magnetic fields, radio noise, and audible noise caused by corona from the transmission lines were calculated using the Electric Power Research Institute ("EPRI") Transmission Line Workstation computer program. In this program, the calculation of 60-Hz fields uses standard superposition techniques for vector fields from individual conductors. Vector fields have both magnitude and direction which must be taken into account when combining fields from different sources. Important input parameters to the computer program are voltage, current, and geometric configuration of the line. The validity of these computer models has been verified against field measurements and reported in many technical papers and reports over the past thirty years.

Electric fields are calculated using an imaging method. Fields from the conductors and their images in the ground plane are superimposed with the proper magnitude and phase to produce the total electric field at a selected location. The total magnetic field is calculated from the vector summation of the fields from currents in all the transmission-line conductors. Balanced (equal) currents are assumed for each three-phase circuit. Electric and magnetic fields for the Project were calculated at the standard height one meter above the ground as recommended in the Institute of Electrical and Electronics

Engineers ("IEEE") Standard Procedures for Measurement of Power Frequency Electric and Magnetic Fields from AC Power Lines (ANSI/IEEE Std. 644-1994). Calculations were performed past the edge of ROW in both directions from the centerline of the existing corridors.

The corona performance of the Project was also predicted using the EPRI Transmission Line Workstation computer program. Corona performance is calculated using equations that were developed over several years of research and field measurements on numerous high-voltage transmission lines. The validity of this approach for corona-generated audible and radio noise has been demonstrated through comparisons with measurements on other lines all over the United States. Important input parameters to the computer program are voltage, current, conductor size, and geometric configuration of the line.

Corona is a highly variable phenomenon that depends on conditions along a length of line. Predictions of the levels of corona effects are reported in statistical terms to account for this variability. Calculations of audible noise and electromagnetic interference levels were made under the maximum possible operating voltage for each line with the same three dimensional model used for electric and magnetic fields. Levels of audible noise are presented for foul weather conditions (wet conductors). This provides the worst case corona effects because water drops on a conductor distort the electric field near the conductor surface and substantially increase the corona levels. Wet conductors can occur during periods of rain, fog, snow, or icing.

## Line Description

The transmission line upgrade Project is divided into thirteen segments. Each segment has a unique ROW cross section configuration and ROW width. The calculated parameters in this report are presented for each of the thirteen segments. The ROW segments and configurations are shown in Figures 1 through 13. For most of the project length, the new 230 kV circuit will follow the path of the existing 34.5 kV circuits (K-115 and O-93) between the Whippany and Montville substations.

The new single circuit poles will have three phases arranged vertically on one side of the structure. Voltage and current waves are displaced by 120° in time (one-third of a cycle) on each electrical phase. The maximum phase-to-phase voltage on the new 230 kV circuit is 242 kV. Each phase of the new 230 kV circuit will have a single 1.5-inch diameter conductor (1590 kcmil 45/7 Aluminum Conductor Steel Reinforced (ACSR) "Lapwing”). There are also two grounded lightning shield wires placed above the top phase conductor attachment points. Minimum midspan conductor-to-ground clearance for the new 230 kV circuit will be greater than 26 feet at maximum conductor temperature.

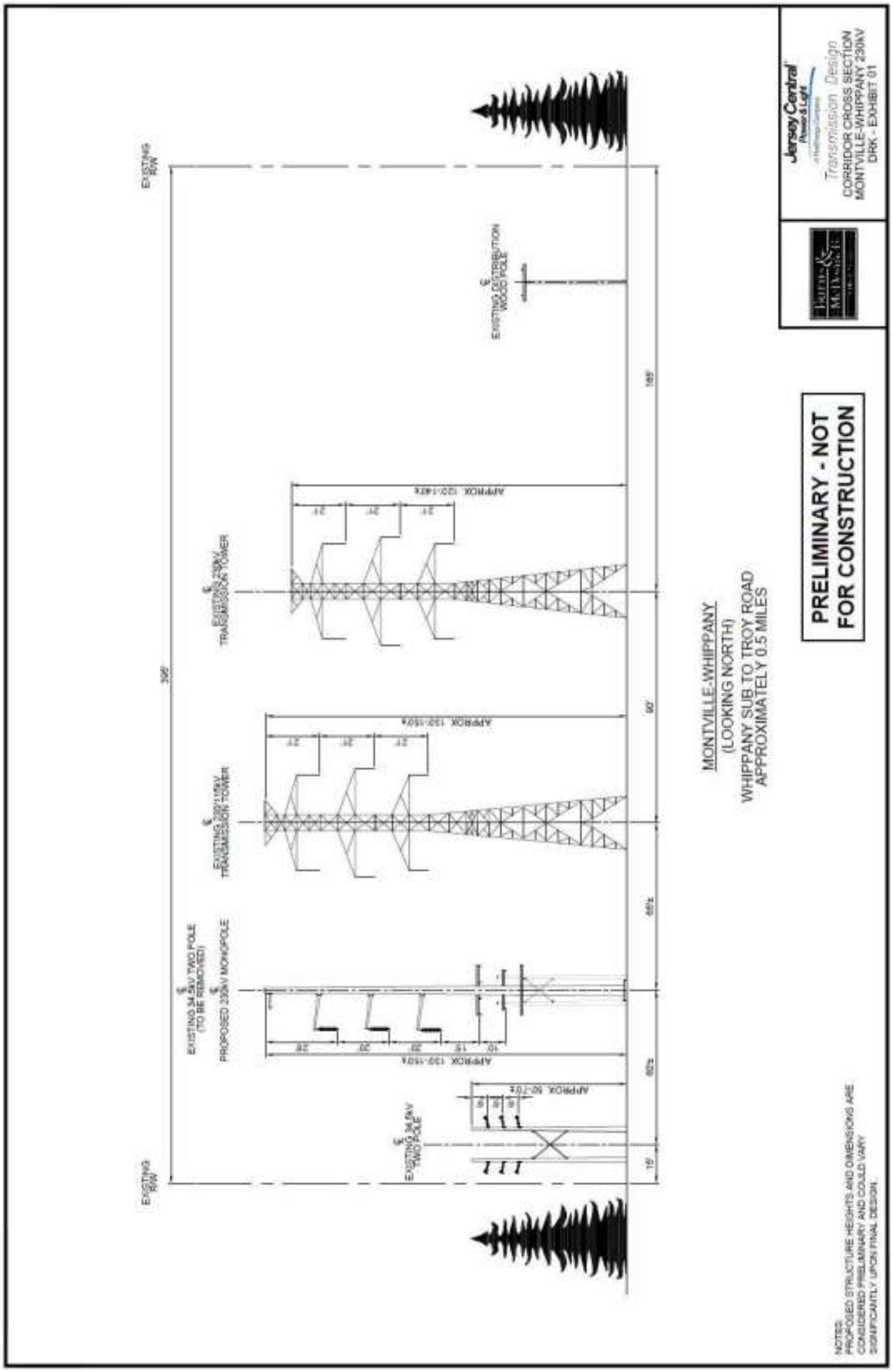


**Figure 1** – Proposed Montville-Whippany configuration for Segment 1 - looking north.

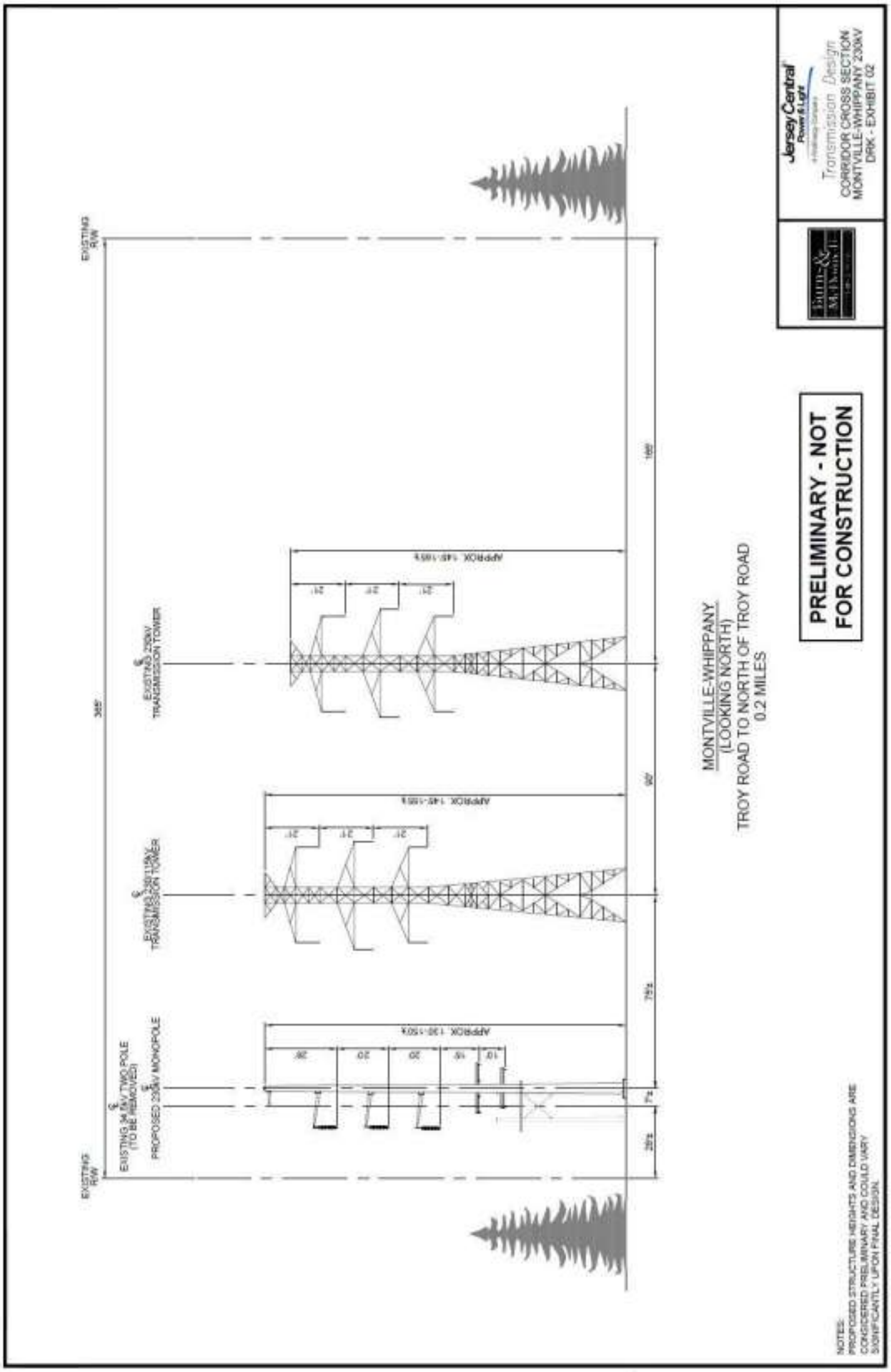


**Figure 2** – Proposed Montville-Whippany configuration for Segment 2 - looking north.

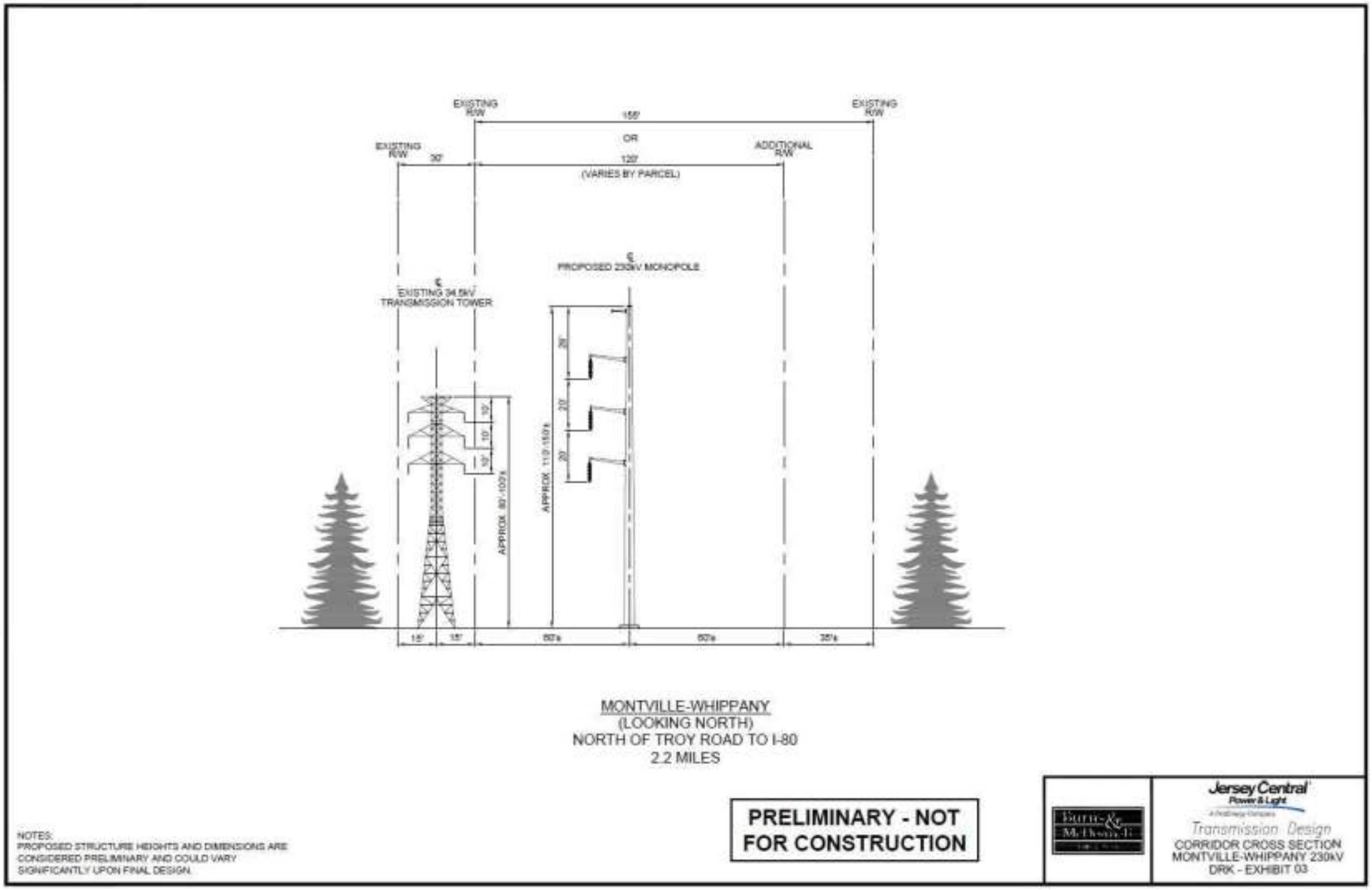
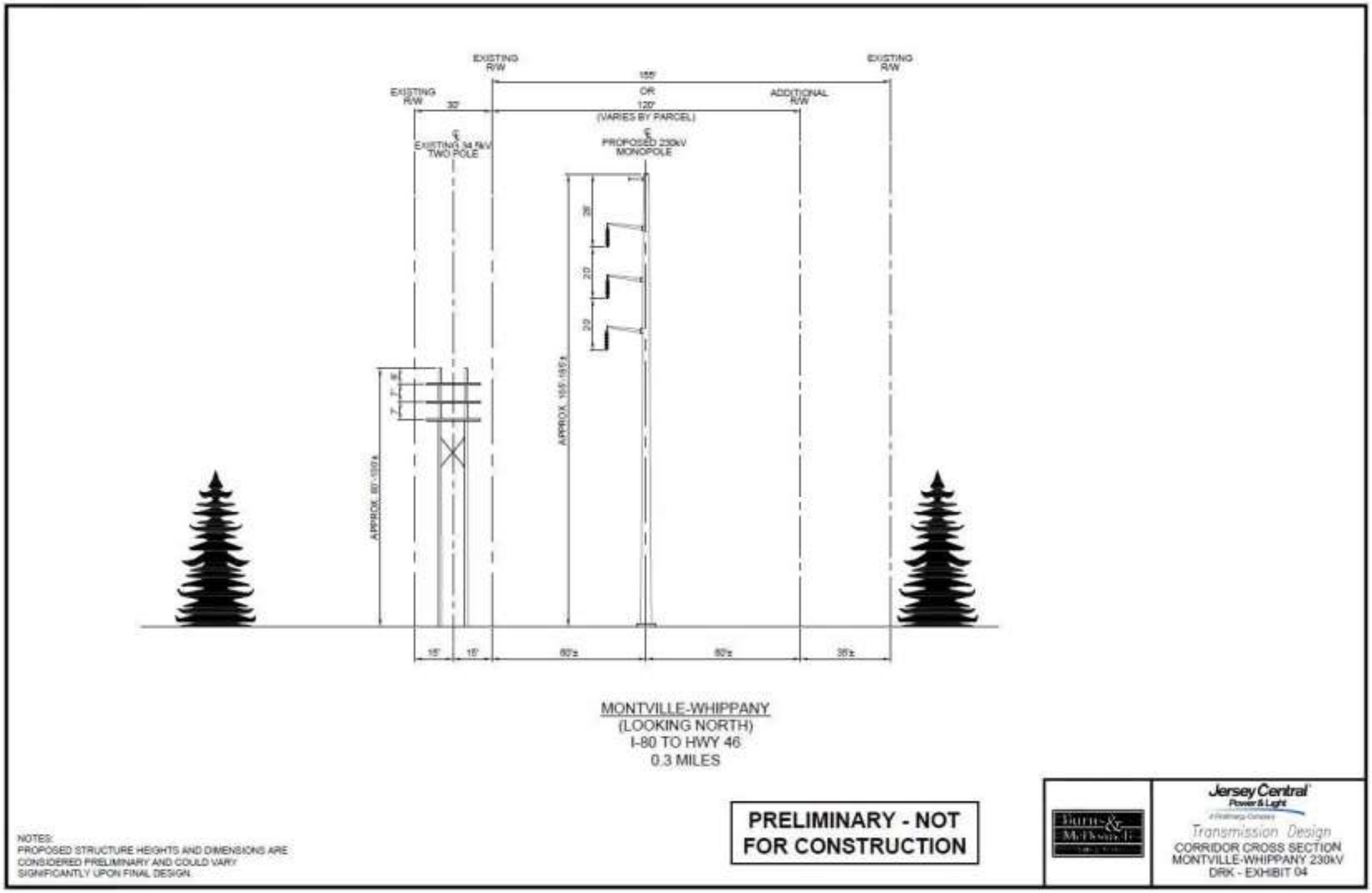


**Figure 3** – Proposed Montville-Whippany configuration for Segment 3 - looking north.



NOTES:
PROPOSED STRUCTURE HEIGHTS AND DIMENSIONS ARE CONSIDERED PRELIMINARY AND COULD VARY SIGNIFICANTLY UPON FINAL DESIGN.

**Figure 4** – Proposed Montville-Whippany configuration for Segment 4 - looking north.

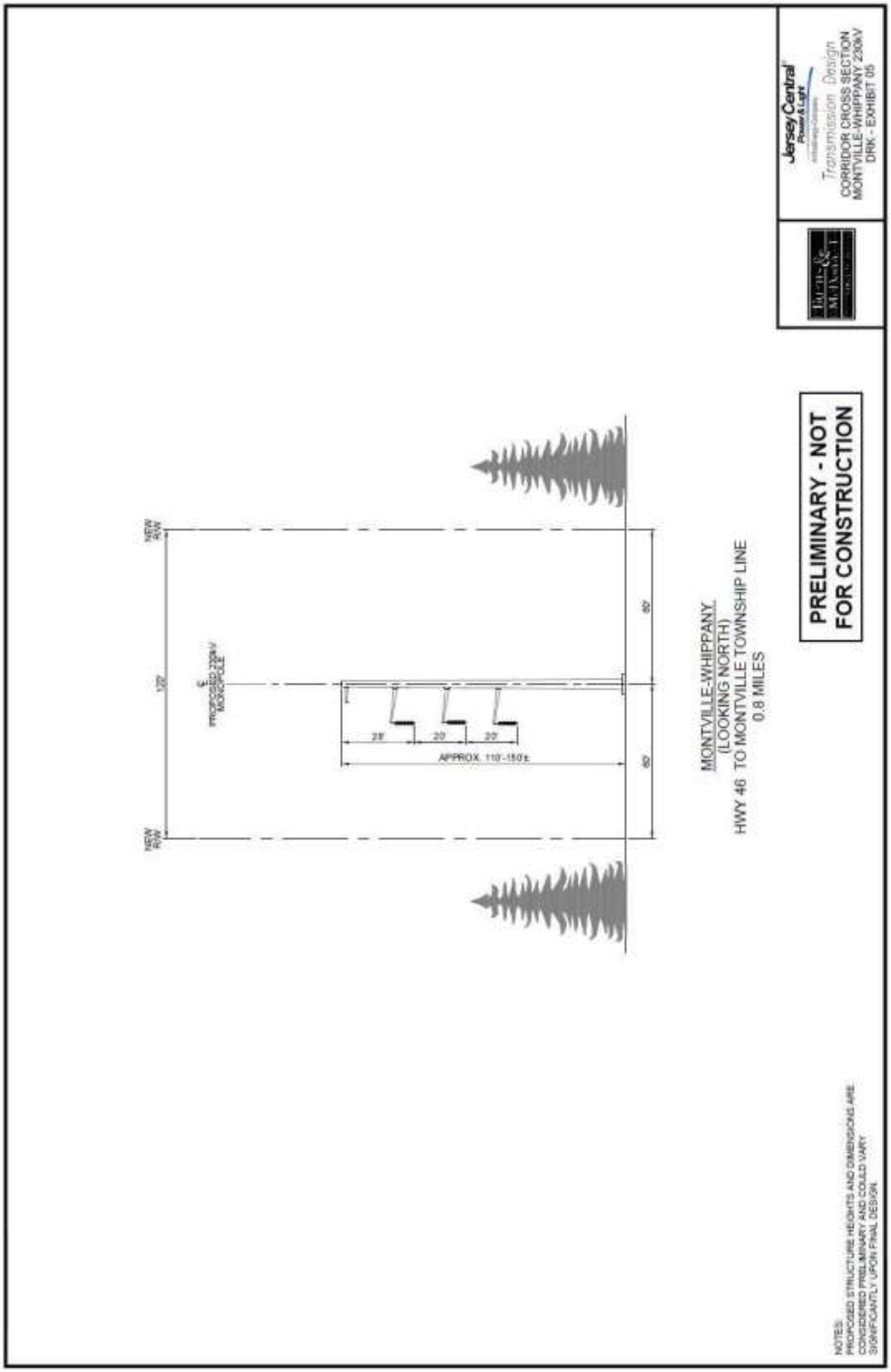


**Figure 5** – Proposed Montville-Whippany configuration for Segment 5 - looking north.

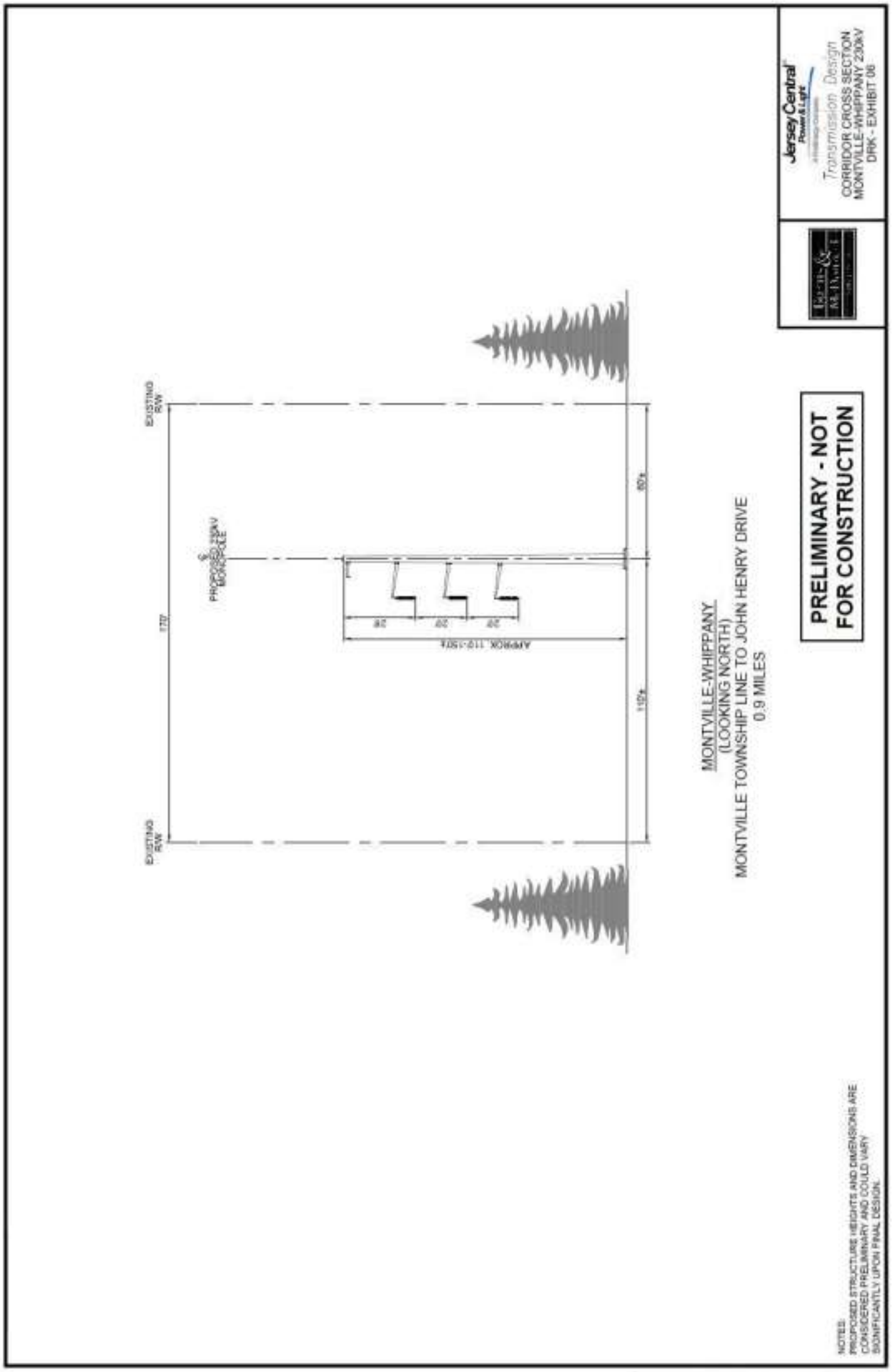


**Figure 6** – Proposed Montville-Whippany configuration for Segment 6 - looking north.

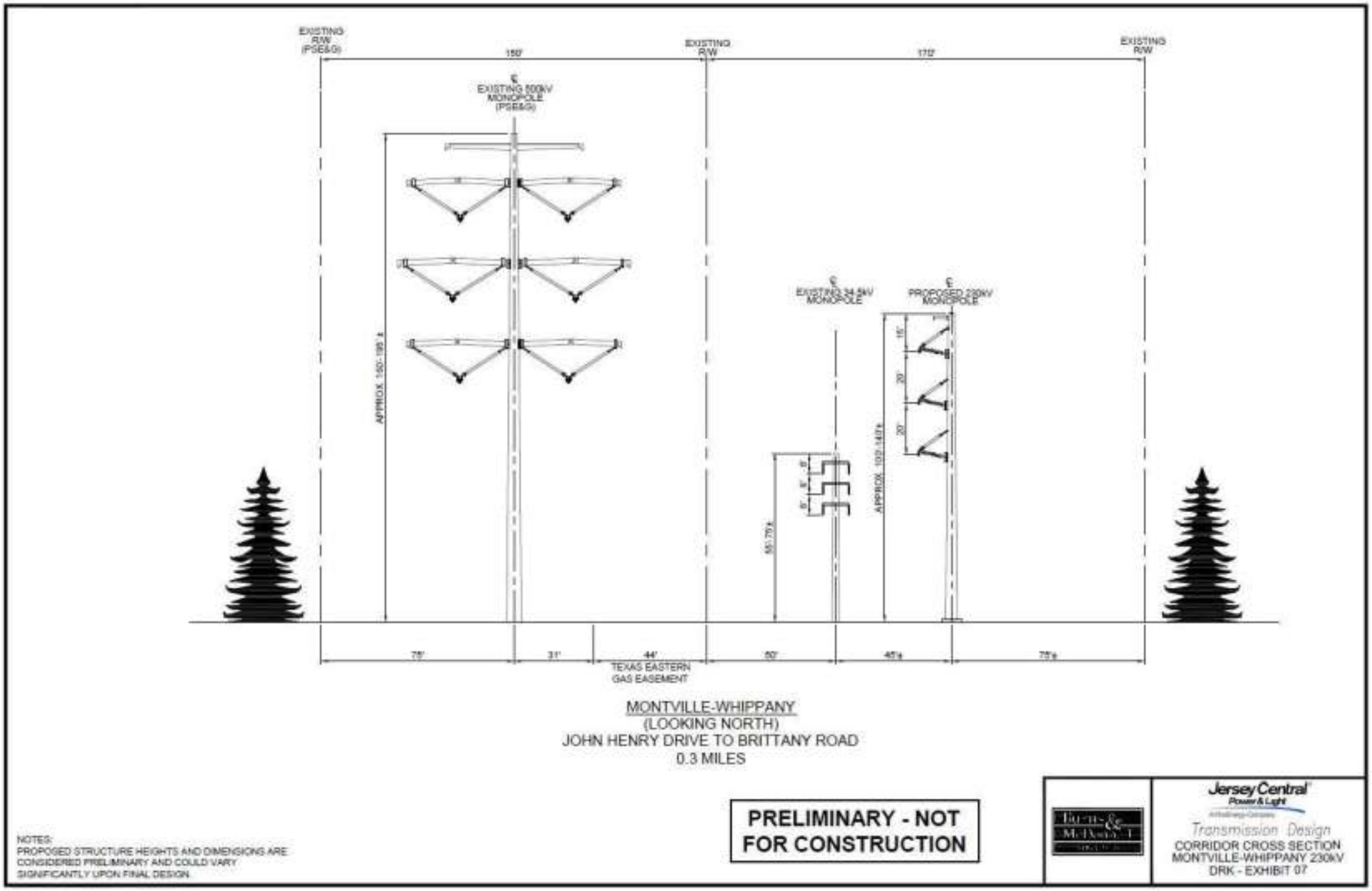


**Figure 7** – Proposed Montville-Whippany configuration for Segment 7 - looking north.

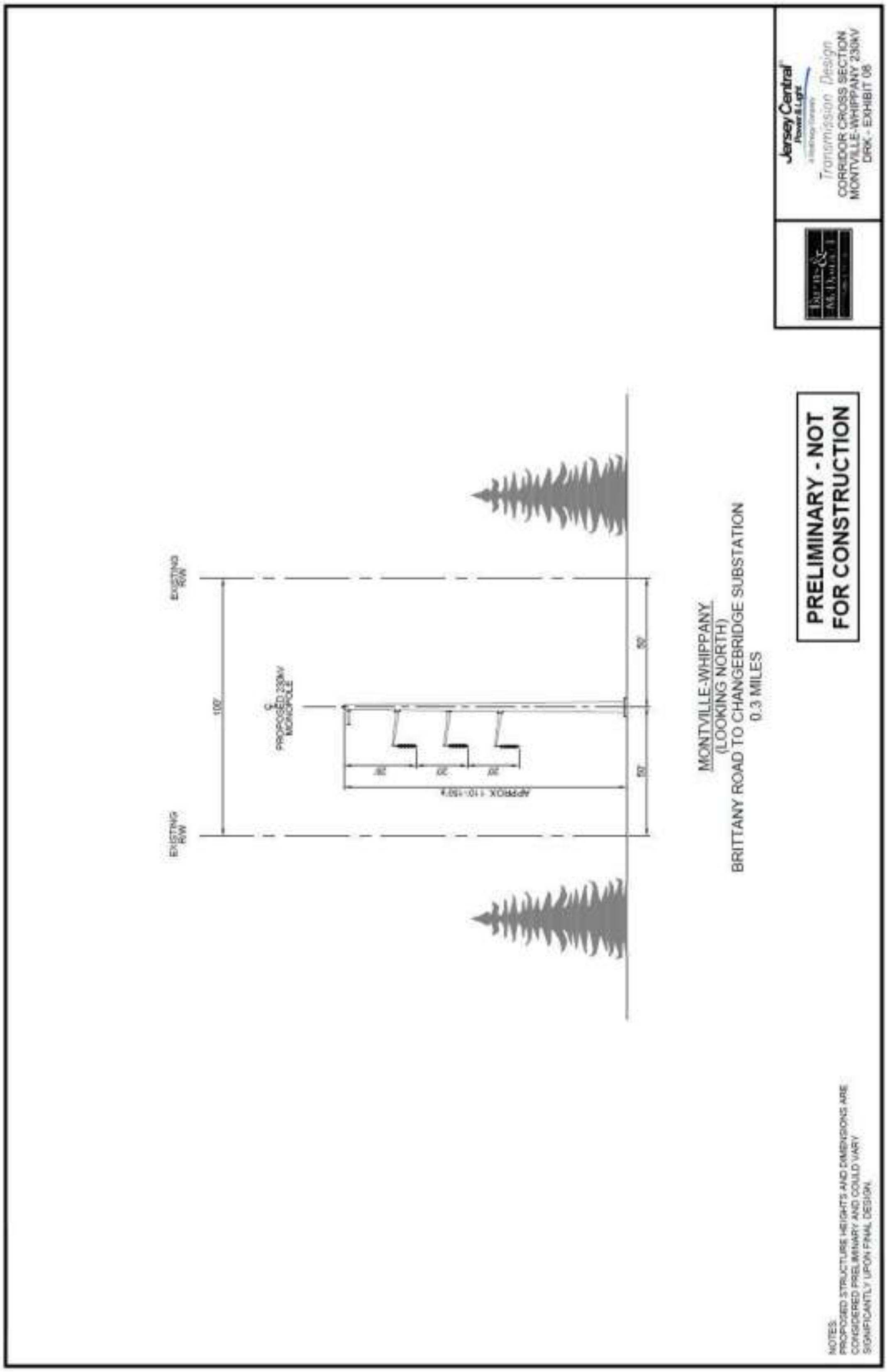


**Figure 8** – Proposed Montville-Whippany configuration for Segment 8 - looking north.

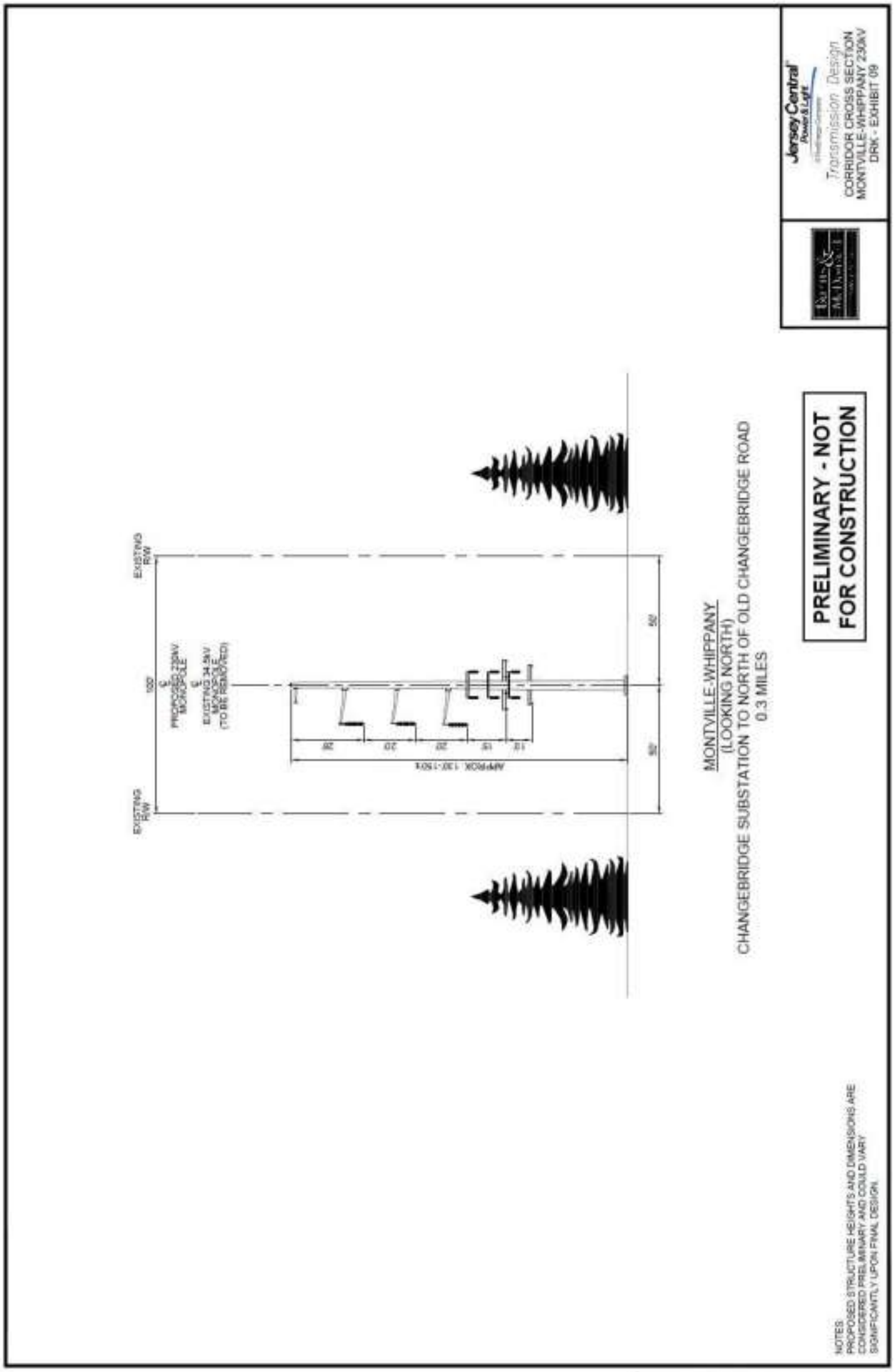


**Figure 9** – Proposed Montville-Whippany configuration for Segment 9 - looking north.

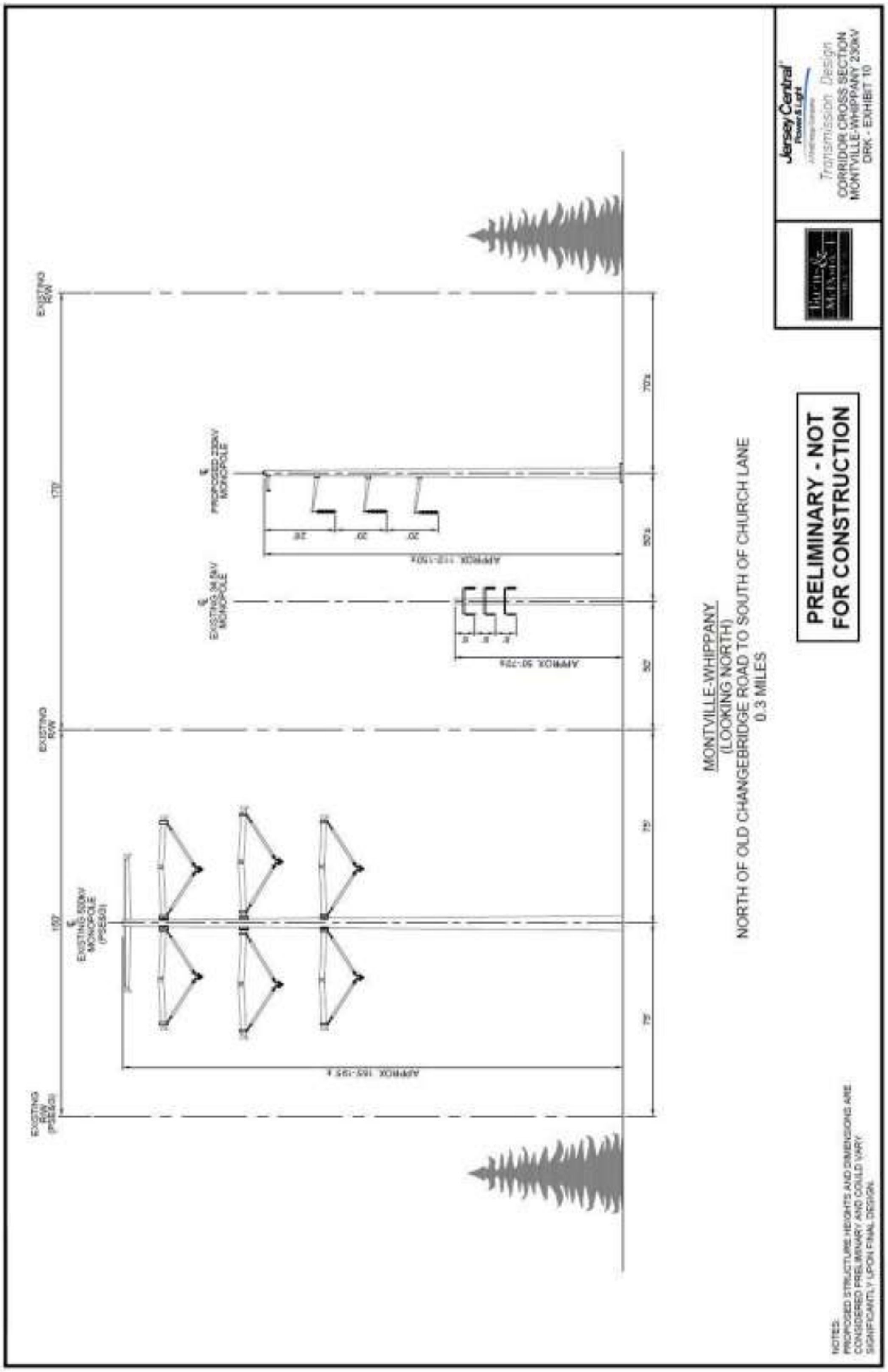


**Figure 10** – Proposed Montville-Whippany configuration for Segment 10 - looking north.

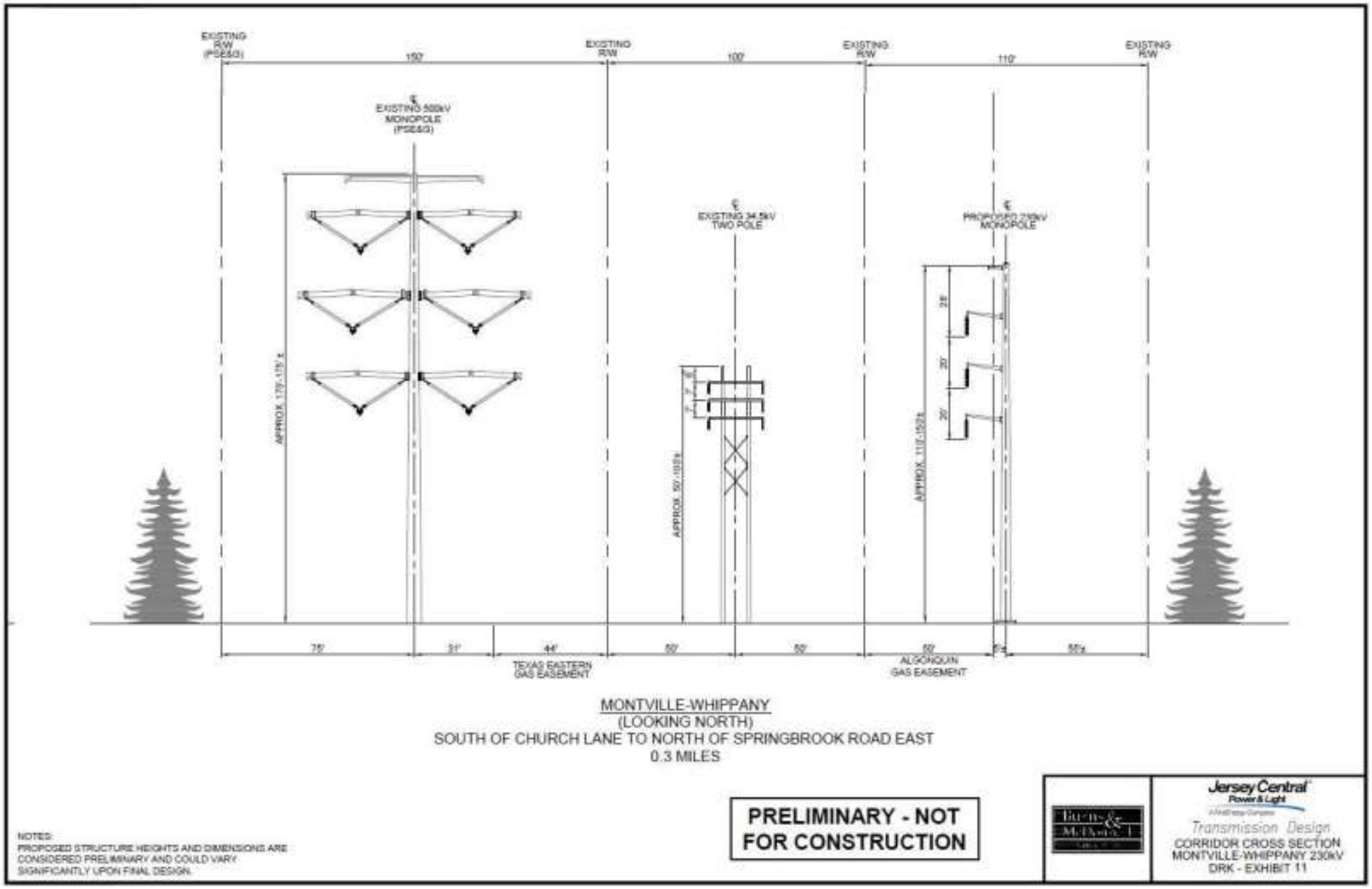


**Figure 11** – Proposed Montville-Whippany configuration for Segment 11 - looking north.

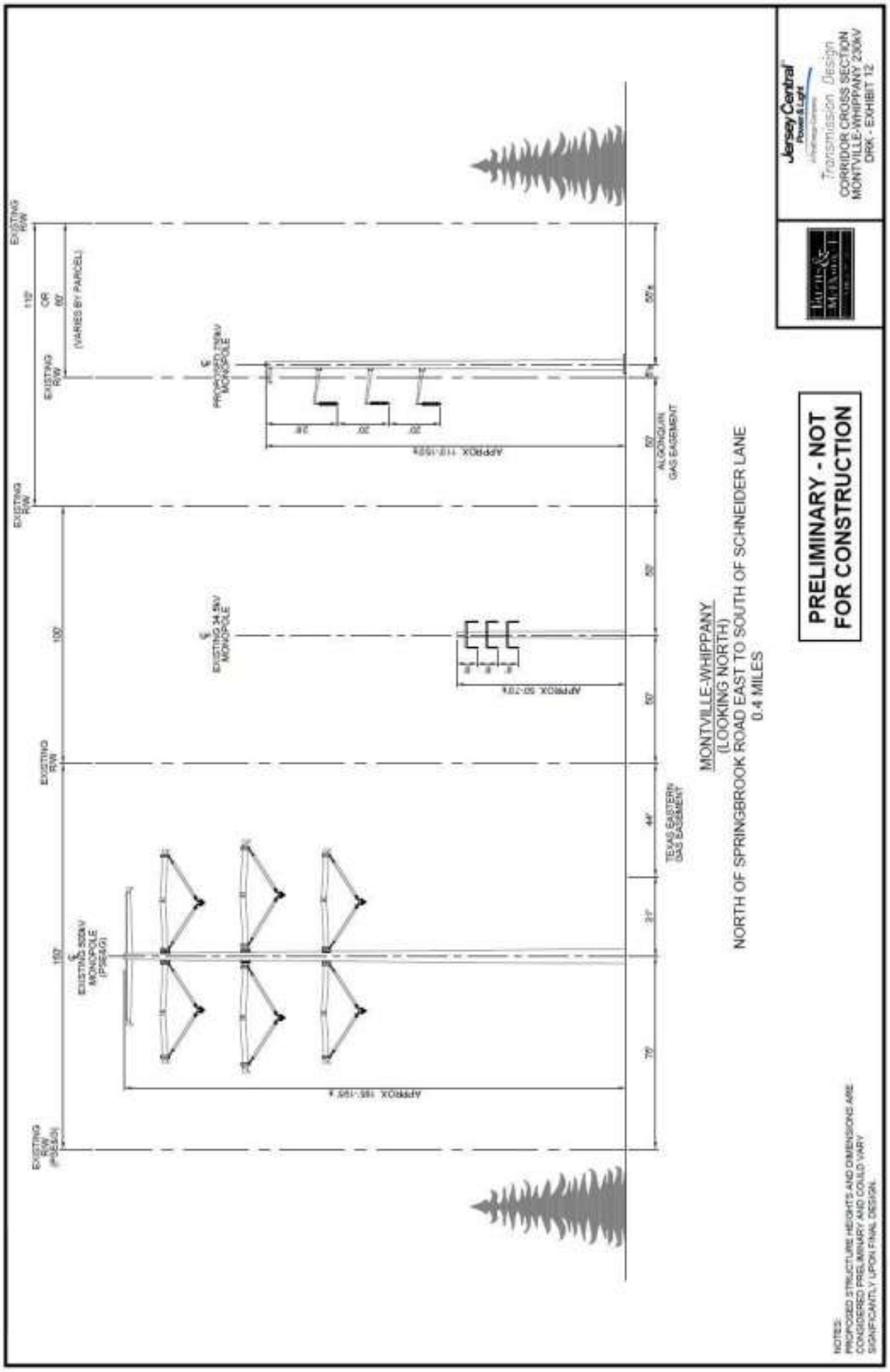


**Figure 12** – Proposed Montville-Whippany configuration for Segment 12 - looking north.

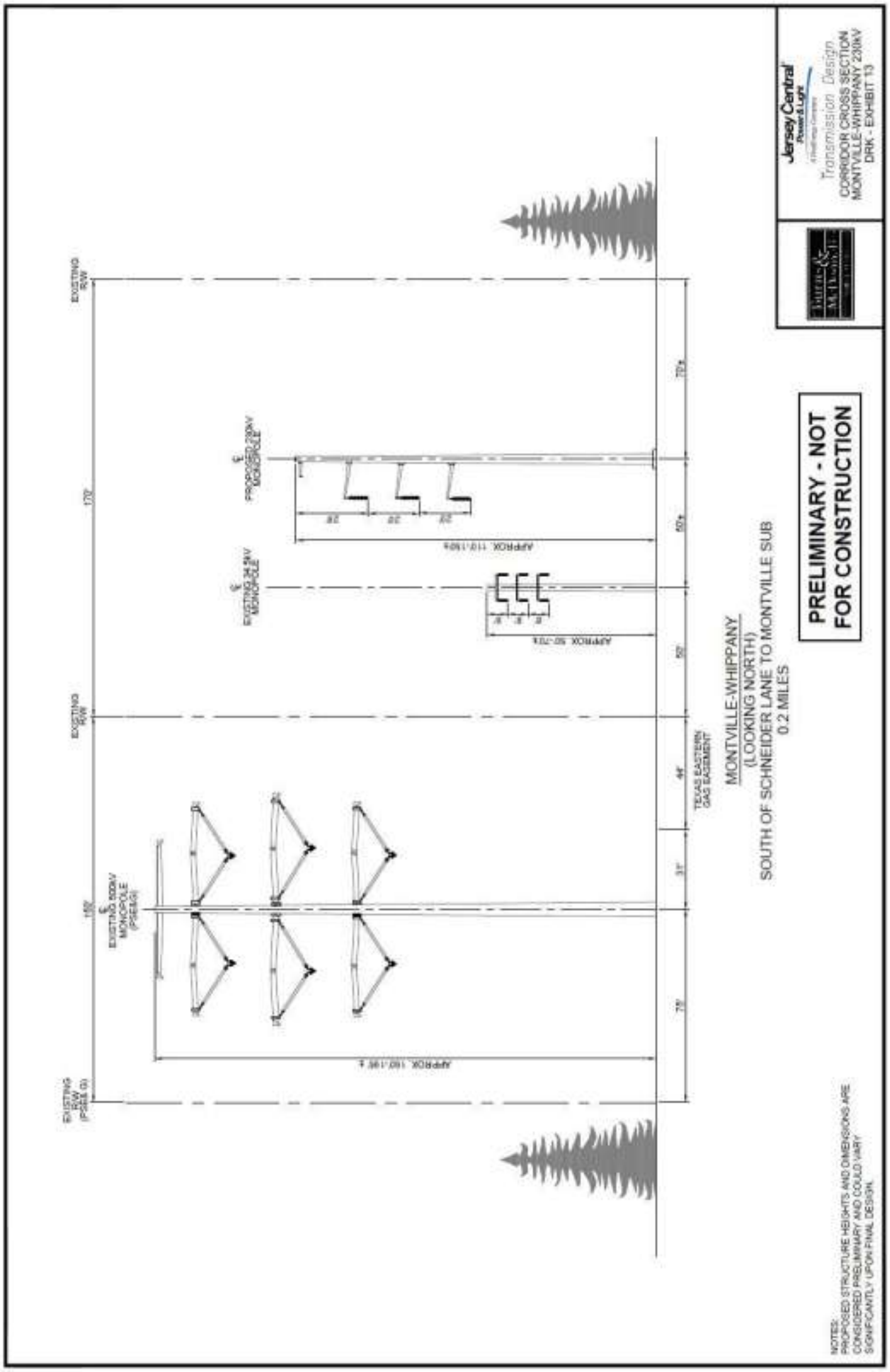


**Figure 13** – Proposed Montville-Whippany configuration for Segment 13 - looking north.

## Electric Field

Electric field is a vector quantity with both a magnitude and a direction. The direction corresponds to the direction that a positive charge would move in the field. The source of electric field is the electrical charge on the conductors. Transmission lines, distribution lines, house wiring, and appliances all generate electric fields in their vicinity because of unbalanced electrical charge (voltage) on energized conductors. On the power system in North America, the voltage and charge on the energized conductors are cyclic (plus to minus to plus) at a rate of 60 times per second. This changing voltage results in electric fields near sources that are also time-varying at a frequency of 60 Hz.

As described earlier, electric fields are expressed in units of volts per meter (V/m) or kilovolts (thousands of volts) per meter (kV/m). Electric and magnetic-field magnitudes in this report are expressed in root-mean-square (rms) units. The spatial distribution of a transmission line electric field depends on the charge on the conductors, the position of the conductors, and the measurement or calculation distance away from the conductors. On the ground, under a transmission line, the electric field is nearly constant in magnitude and direction over distances of several feet. When a conducting object, such as a vehicle or person, is located in a time-varying electric field, currents and voltages are induced on the object. If the object is connected to the ground, then the total current induced in the body (the "short-circuit current") flows to earth.

The electric field created by a high-voltage transmission line extends from the energized conductors to other conducting objects such as the ground, towers, vegetation, buildings, vehicles, and people. The calculated strength of the electric field at a height of one meter above flat clear earth is frequently used to describe the electric field under transmission lines. The most important transmission-line parameters that determine the electric field at a one meter height are conductor configuration, the height above ground, and the line voltage.

Calculations of electric fields from transmission lines are performed with computer programs based on well-known physical principles. The calculated values under these conditions represent an ideal situation. When practical conditions approach this ideal model, measurements and calculations agree. Often, however, conditions are far from ideal because of variable terrain and vegetation. The fields from many different sources may be added vectorially and it is possible to compute the fields from several different lines if the electrical and geometrical properties of the lines are known.

The techniques for measuring transmission-line electric fields are described in ANSI/IEEE Standard No. 644-1994. Provided that the conditions at a measurement site closely approximate those of the ideal situation assumed for calculations, measurements of electric fields agree well with the calculated values. Measured electric fields are easily shielded by common objects and the resulting measurements are typically lower than calculated values.

Maximum or peak field values occur over a small area at midspan, where conductors are closest to the ground. As the location of an electric-field profile approaches a transmission structure, the conductor clearance increases, and the peak field decreases. Transmission line electric fields at the edge of the ROW are not as sensitive as the peak field to conductor height. Computed values at the edge of the ROW for any line height are fairly representative of what can be expected all along the transmission-line corridor. Buildings, vegetation and other grounded objects all shield (reduce) the electric field.

Table 1 shows the existing and proposed edge of ROW electric field levels for each of the thirteen unique ROW cross section configurations in the Project. These maximum values were calculated from a model of the conductors at maximum circuit voltage and minimum conductor clearance to ground. Actual field measurements of the proposed transmission line would provide lower levels of electric field because the lines are not typically operated at their maximum voltage level. These levels shown in Table 1 are all well below the New Jersey State guideline of 3 kV/m at the ROW edge.

**Table 1** - Calculated maximum edge of ROW electric field levels for each unique Project ROW cross section configuration. All segments meet New Jersey State Guideline of 3.0 kV per meter.

| **Line Segment** | **2014 Existing (kV/m)** | | **2018 Post-Project (kV/m)** | |
|---|---|---|---|---|
| | **Western** | **Eastern** | **Western** | **Eastern** |
| #1 - (shown in Figure 1) | 0.2 | 0.2 | 0.2 | 0.2 |
| #2 - (shown in Figure 2) | 0.2 | 0.2 | 0.3 | 0.2 |
| #3 - (shown in Figure 3) | 0.3 | < 0.1 | 0.3 | 0.1 |
| #4 - (shown in Figure 4) | 0.2 | < 0.1 | 0.3 | 0.1 |
| #5 - (shown in Figure 5) | < 0.1 | < 0.1 | 0.3 | 0.2 |
| #6 - (shown in Figure 6) | < 0.1 | < 0.1 | 0.2 | 0.2 |
| #7 - (shown in Figure 7) | 0.3 | 0.1 | 0.2 | 0.1 |
| #8 - (shown in Figure 8) | < 0.1 | < 0.1 | 0.7 | 0.1 |
| #9 - (shown in Figure 9) | < 0.1 | < 0.1 | 0.4 | 0.1 |
| #10 - (shown in Figure 10) | 0.3 | < 0.1 | 0.2 | 0.1 |
| #11 - (shown in Figure 11) | 0.3 | < 0.1 | 0.3 | 0.1 |
| #12 - (shown in Figure 12) | 0.3 | < 0.1 | 0.2 | 0.1 |
| #13 - (shown in Figure 13) | 0.3 | < 0.1 | 0.2 | 0.1 |

## Magnetic Field

Similar to electric field, the magnetic field is a vector quantity characterized by both magnitude and direction. Electrical currents generate magnetic field. In the case of transmission lines, distribution lines, house wiring, and appliances, the 60-Hz electric current flowing in the conductors generates a time-varying, 60-Hz magnetic field in the vicinity of these conductors. The strength of a magnetic field is measured in terms of magnetic lines of force per unit area or magnetic flux density. The term “magnetic field,” as used here, is synonymous with magnetic flux density and is expressed in units of milligauss (mG).

Transmission line generated magnetic fields are quite uniform over horizontal and vertical distances of several feet near the ground. However, for small sources such as appliances, the magnetic field decreases rapidly over distances comparable with the size of the device.

The magnetic field generated by currents on transmission-line conductors extends from the conductors through the air and into the ground. The magnitude of the field at a height of one meter is frequently used to describe the magnetic field under transmission lines. The magnetic field is not influenced by humans or vegetation on the ground under the line. The direction of the maximum field varies with location. (The electric field is essentially vertical near the ground.) The most important transmission line parameters that determine the magnetic field at one meter height are conductor height above ground and magnitude of the currents flowing in the conductors. As distance from the transmission-line conductors increases, the magnetic field decreases.

As with electric field, the maximum or peak magnetic field occurs in areas near the centerline and at midspan where the conductors are the lowest. The magnetic field at the edge of the ROW is not very dependent on line height. For a double-circuit line or if more than one line is present, the peak field will depend on the relative electrical phasing of the conductors and the direction of power flow.

Prudent Avoidance is a precautionary principle in risk management, stating that reasonable efforts to minimize potential risks should be taken when the actual magnitude of the risks is unknown. The principle was proposed by Prof. Granger Morgan of Carnegie Mellon University in 1989 in the context of electromagnetic radiation safety (in particular, fields produced by power lines) calling it a “common sense strategy for dealing with some difficult social and scientific dilemmas". While New Jersey has no specific magnetic field limit for power lines, many states have either formally or informally adopted the Prudent Avoidance policy in considering power line applications.

The conclusions reached by national and international scientific and health agencies from their evaluation of EMF research, and the guidelines for exposure they have recommended make clear that exposures to EMF that people encounter in their daily life, including those from transmission lines like the one considered here, do not pose any recognized long-term health risks.

While not adopted by any regulatory body at the national level in the USA, the Prudent Avoidance principle has been adopted in some form by a number of local regulatory bodies, including the public utility commissions in California, Colorado, Connecticut and Hawaii. Several international health agencies have also adopted the Prudent Avoidance policy including the National Institute of Environmental Health Sciences ("NIEHS"), which states: "that power companies and utilities [should] continue siting power lines to reduce exposures and … explore ways to reduce the creation of magnetic fields around transmission and distribution lines without creating new hazards." Similarly, the World Health Organization ("WHO") recommends in a recent fact sheet, "When constructing new facilities … low-cost ways of reducing exposures may be explored. Appropriate exposure reduction measures will vary from one country to another. However, policies based on the adoption of arbitrary low exposure limits are not warranted."

For comparison with predicted future line current levels, JCP&L provided Summer Peak loading for 2014 and 2018 for all circuits on the common ROW segments between the Whippany and Montville substations. Figures 14 through 26 show the calculated magnetic field profiles along a ROW cross sections at one meter above ground for the existing and new circuits for the thirteen major line sections of the Project in New Jersey. These values were calculated using the 2014 and 2018 summer peak line currents provided by the JCP&L Planning department. The profiles were calculated at midspan, which represents the lowest conductor height above ground, and the highest level of magnetic field.

Table 2 lists the edge of ROW magnetic field levels associated with the pre and post Project summer line currents. The data in Table 2 corresponds to the edge of ROW values shown in Figures 14 through 26.

Table 3 lists the magnetic field levels for the maximum circuit currents. The maximum circuit currents were provided by JCP&L for all circuits on the common ROW segments between the Whippany and Montville substations. The peak current magnetic fields listed in Table 3 are provided calculation exercise of an upper limit only, the magnetic field levels from the actual lines will always be well below these levels now and in the future. It would not be physically possible for all circuits on these ROWs to carry their maximum current at the same time.

By using existing ROWs for the majority of the Project and selecting the phasing of the new transmission circuit, JCP&L has applied Prudent Avoidance principles and limited magnetic field levels under summer loading conditions for the Project.

**Table 2** - Calculated edge of ROW magnetic field levels for each of the thirteen unique Project ROW cross section configuration under 2014 (pre-project) and 2018 (post-project) summer loading conditions.

| Line Segment | 2014 Existing (mG) | | 2018 Post-Project (mG) | |
|---|---|---|---|---|
| | **Western** | **Eastern** | **Western** | **Eastern** |
| #1 - (shown in Figure 1) | 23.4 | 14.5 | 19.0 | 8.2 |
| #2 - (shown in Figure 2) | 21.8 | 14.5 | 15.9 | 8.2 |
| #3 - (shown in Figure 3) | 13.0 | 1.7 | 14.1 | 1.3 |
| #4 - (shown in Figure 4) | 9.3 | 1.6 | 10.0 | 1.5 |
| #5 - (shown in Figure 5) | < 0.1 | < 0.1 | 1.9 | 0.9 |
| #6 - (shown in Figure 6) | < 0.1 | < 0.1 | 0.7 | 0.9 |
| #7 - (shown in Figure 7) | 59.4 | 5.2 | 60.5 | 3.6 |
| #8 - (shown in Figure 8) | < 0.1 | < 0.1 | 2.4 | 1.1 |
| #9 - (shown in Figure 9) | 17.6 | 18.1 | 17.7 | 20.2 |
| #10 - (shown in Figure 10) | 54.8 | 5.1 | 55.9 | 4.1 |
| #11 - (shown in Figure 11) | 62.4 | 3.9 | 58.4 | 2.8 |
| #12 - (shown in Figure 12) | 59.4 | 4.3 | 55.4 | 3.1 |
| #13 - (shown in Figure 13) | 54.8 | 5.1 | 55.9 | 4.1 |

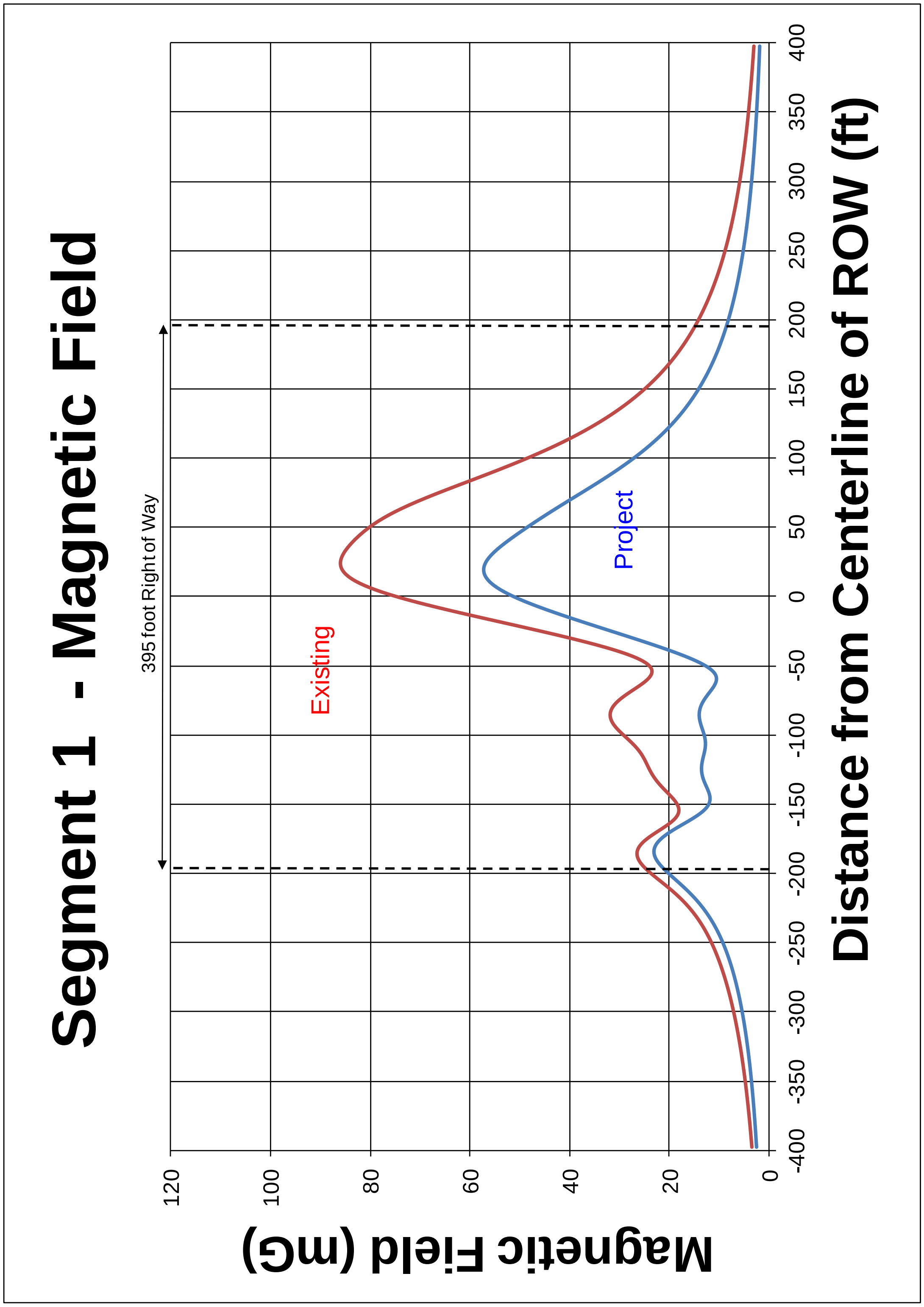


**Figure 14** – Calculated magnetic field profiles for the existing and proposed transmission lines for the Montville-Whippany Project in Segment 1 (corresponding to the configuration shown in Figure 1 and calculated with the 2014 and 2018 line currents from Table 4).

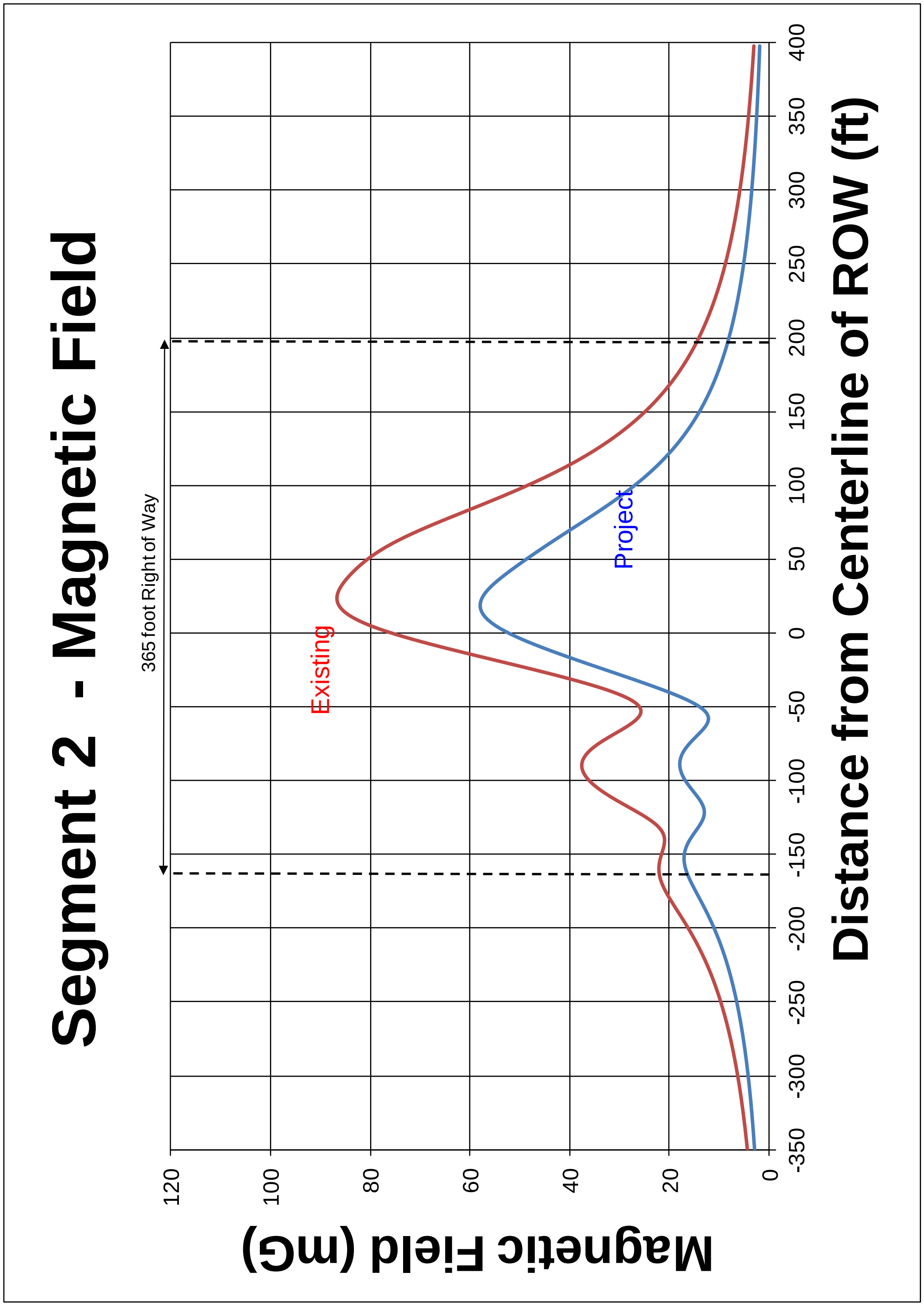


**Figure 15** – Calculated magnetic field profiles for the existing and proposed transmission lines for the Montville-Whippany Project in Segment 2 (corresponding to the configuration shown in Figure 2 and calculated with the 2014 and 2018 line currents from Table 4).

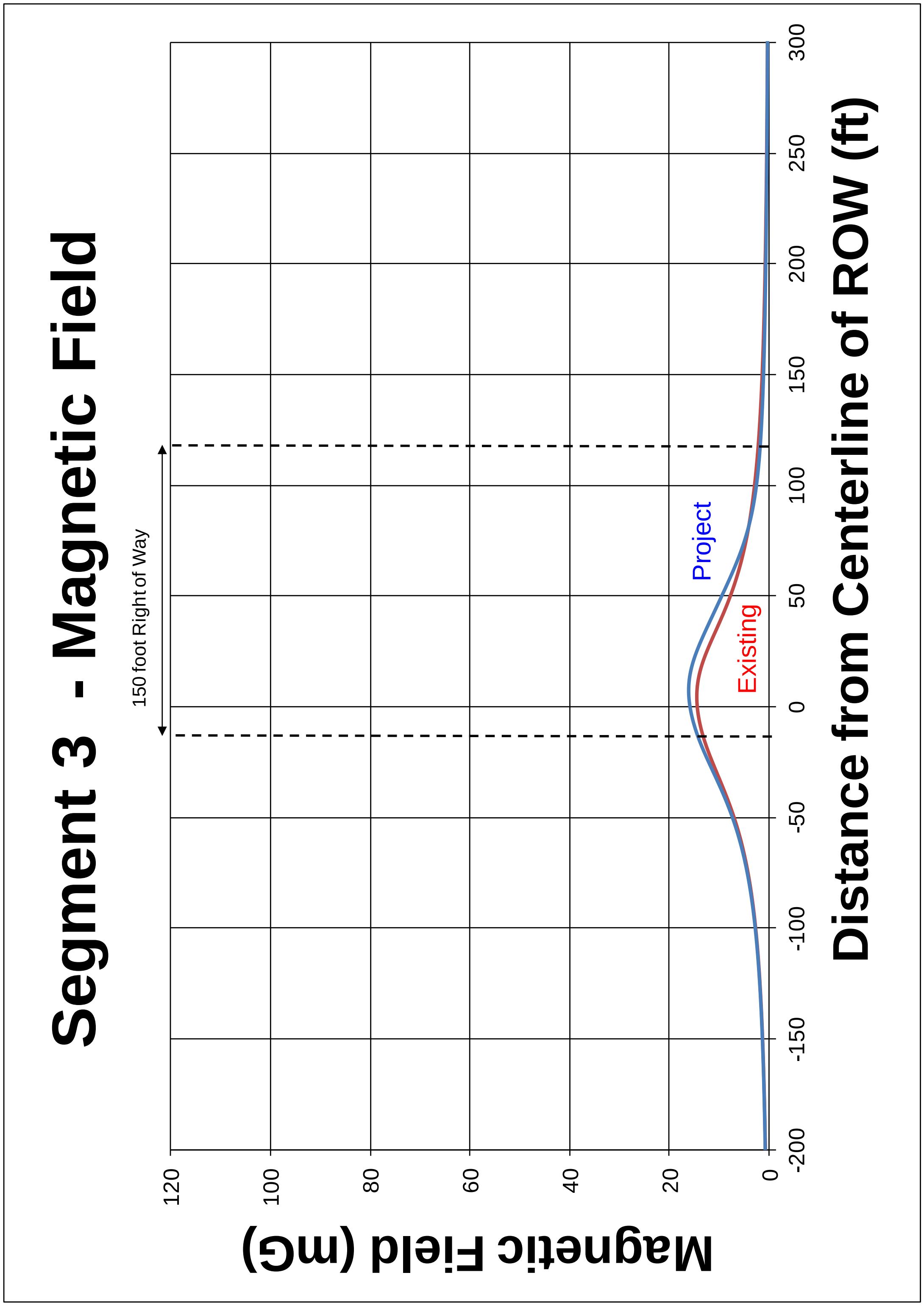


**Figure 16** – Calculated magnetic field profiles for the existing and proposed transmission lines for the Montville-Whippany Project in Segment 3 (corresponding to the configuration shown in Figure 3 and calculated with the 2014 and 2018 line currents from Table 4).

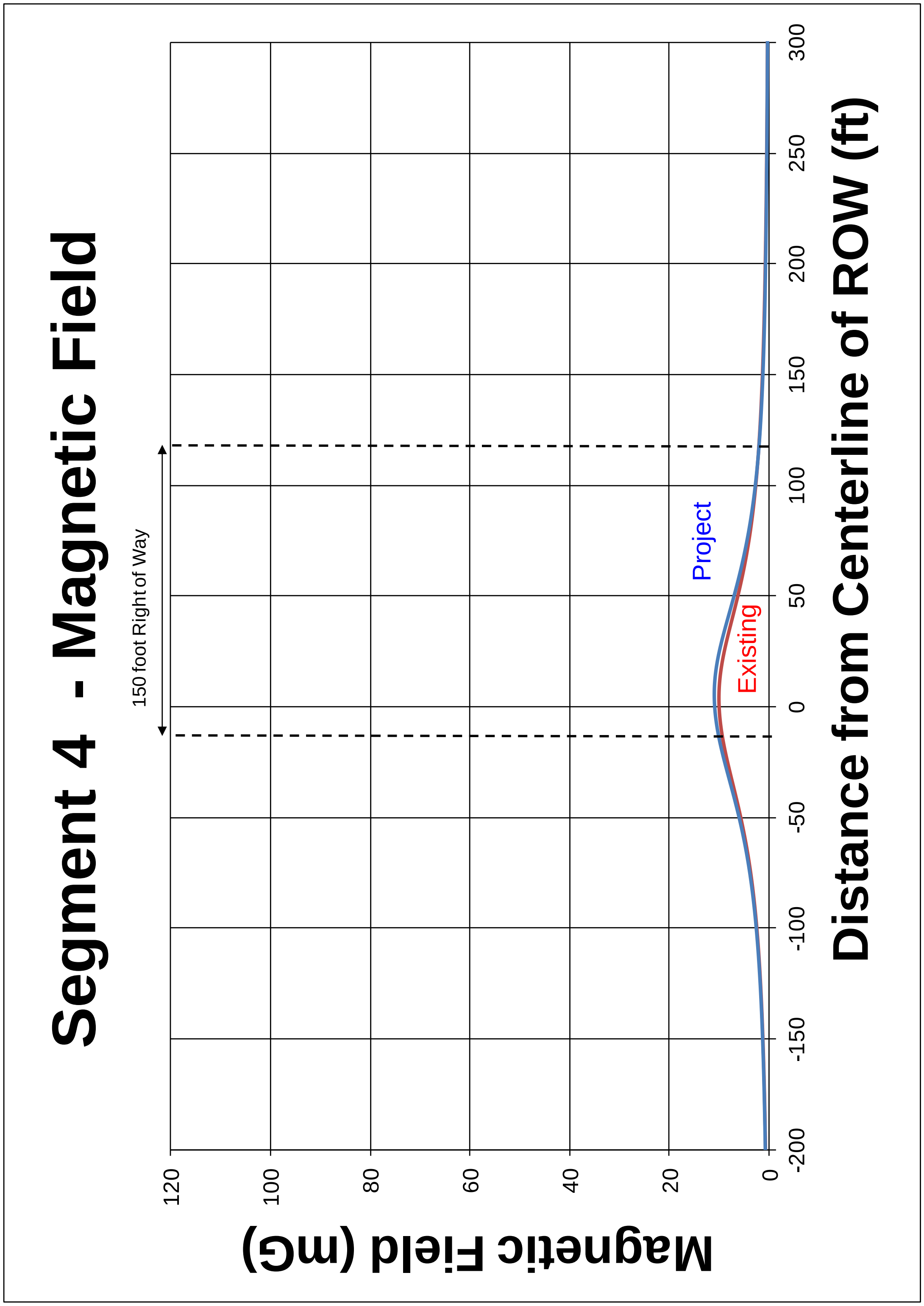


**Figure 17** – Calculated magnetic field profiles for the existing and proposed transmission lines for the Montville-Whippany Project in Segment 4 (corresponding to the configuration shown in Figure 4 and calculated with the 2014 and 2018 line currents from Table 4).

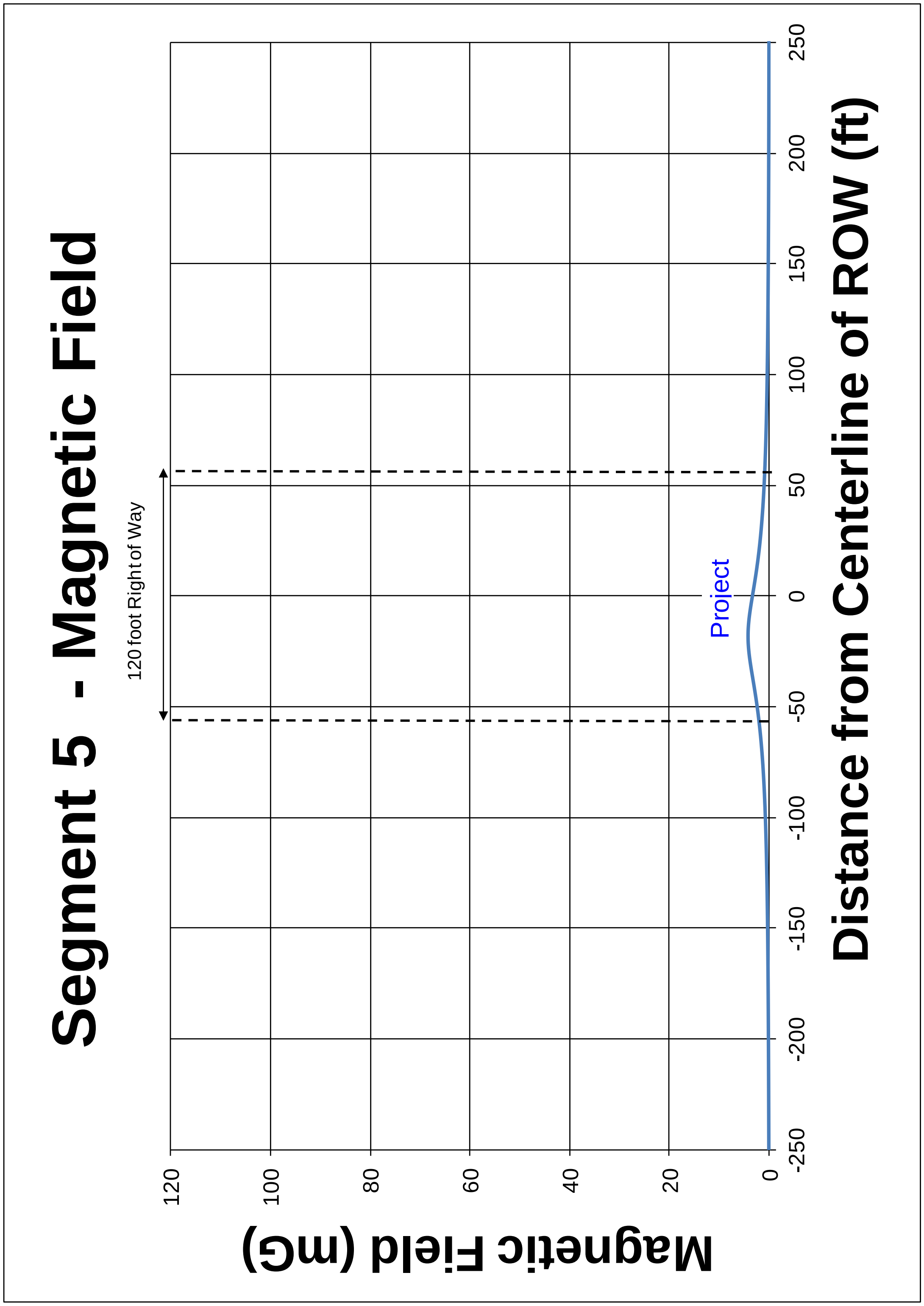


**Figure 18** – Calculated magnetic field profiles for the existing and proposed transmission lines for the Montville-Whippany Project in Segment 5 (corresponding to the configuration shown in Figure 5 and calculated with the 2014 and 2018 line currents from Table 4).

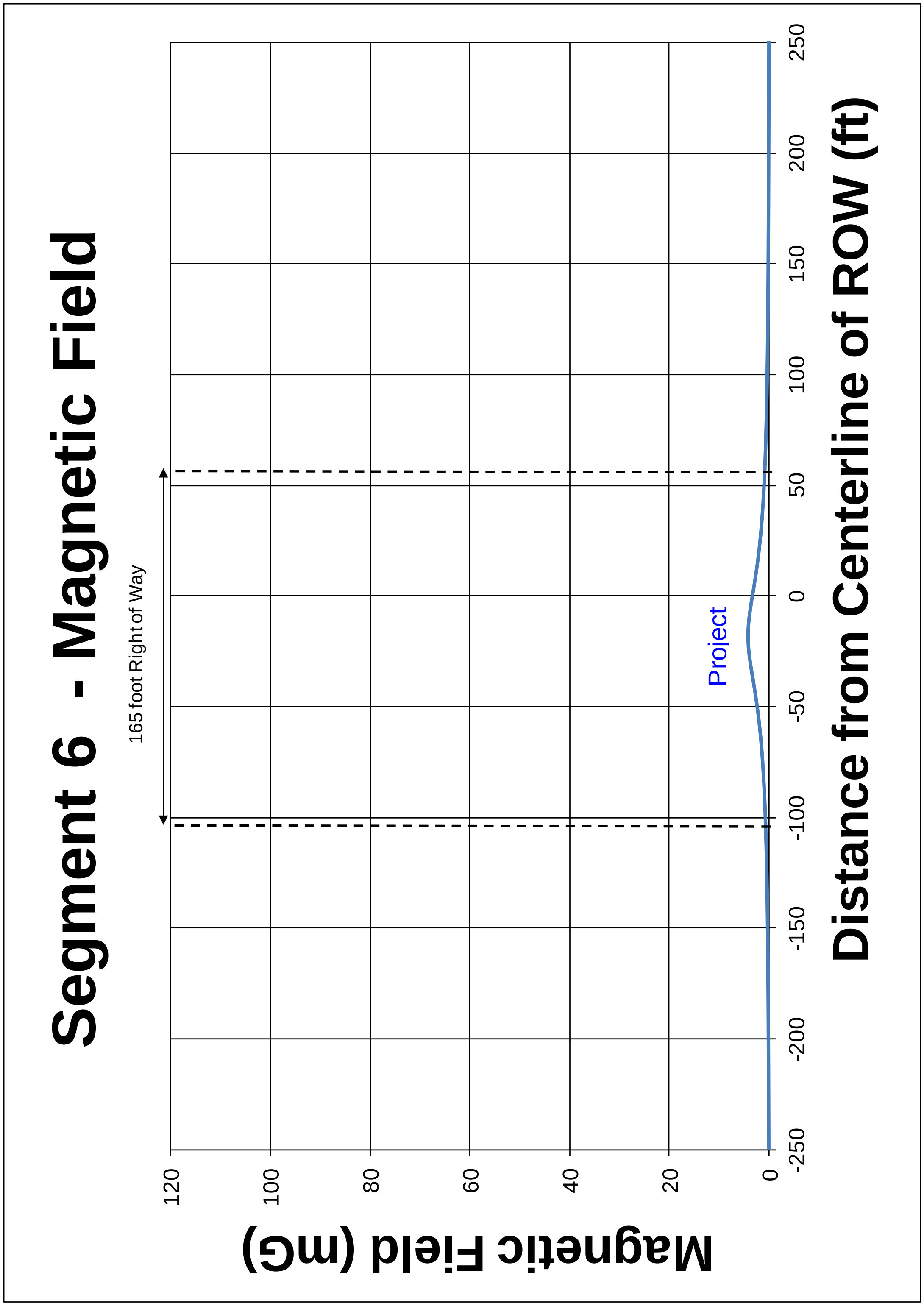


**Figure 19** – Calculated magnetic field profiles for the existing and proposed transmission lines for the Montville-Whippany Project in Segment 6 (corresponding to the configuration shown in Figure 6 and calculated with the 2014 and 2018 line currents from Table 4).

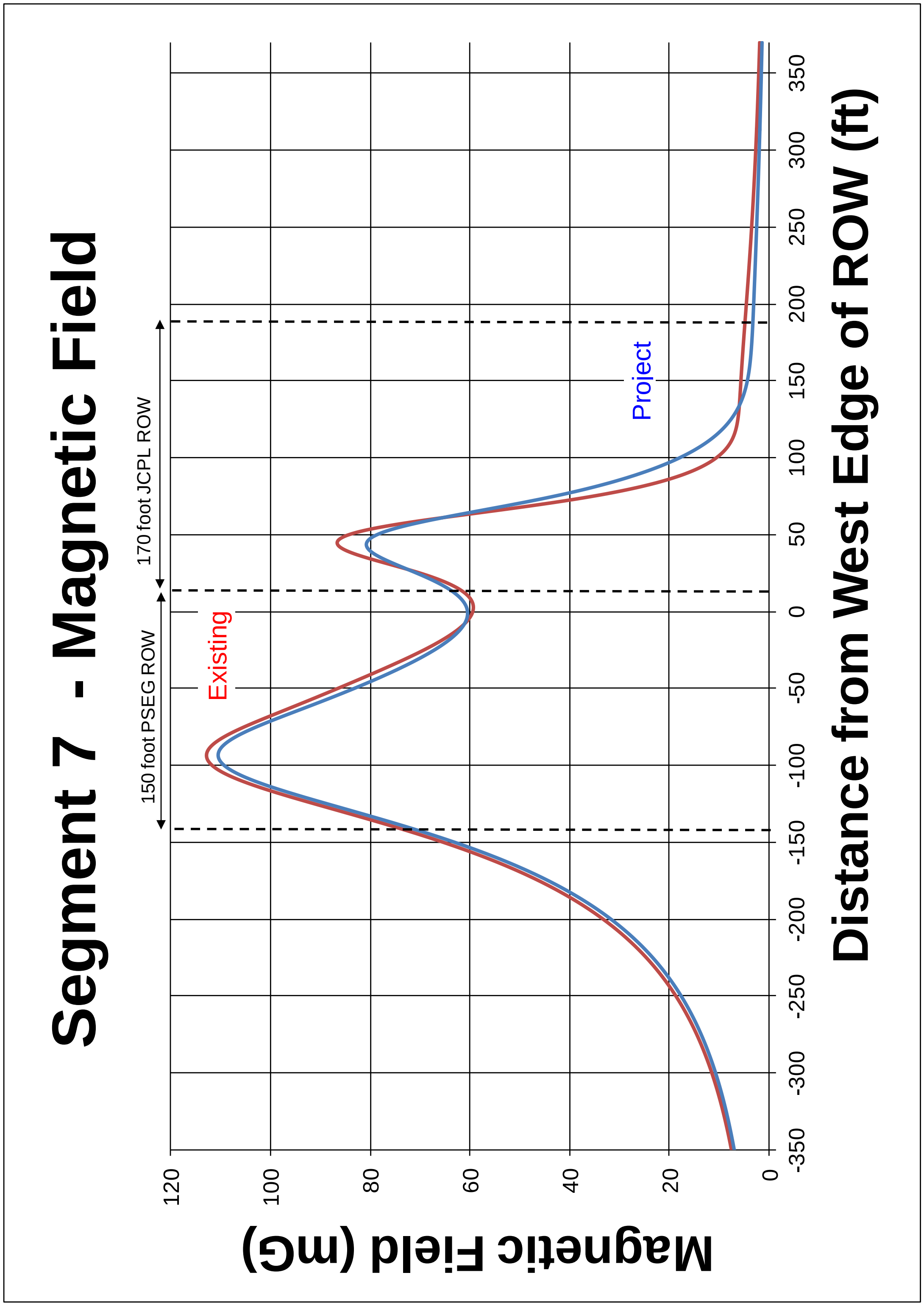


**Figure 20** – Calculated magnetic field profiles for the existing and proposed transmission lines for the Montville-Whippany Project in Segment 7 (corresponding to the configuration shown in Figure 7 and calculated with the 2014 and 2018 line currents from Table 4).

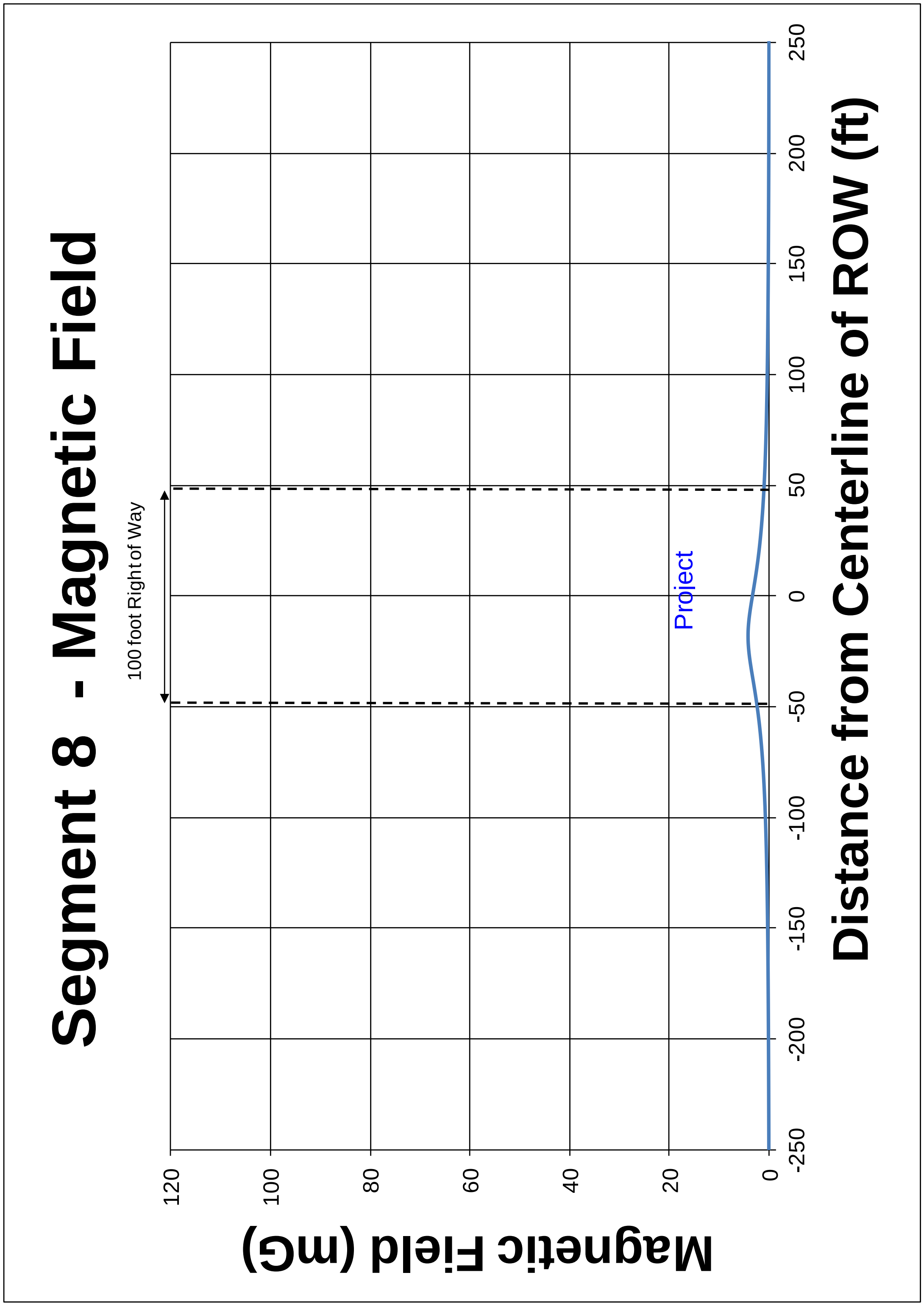


**Figure 21** – Calculated magnetic field profiles for the existing and proposed transmission lines for the Montville-Whippany Project in Segment 8 (corresponding to the configuration shown in Figure 8 and calculated with the 2014 and 2018 line currents from Table 4).

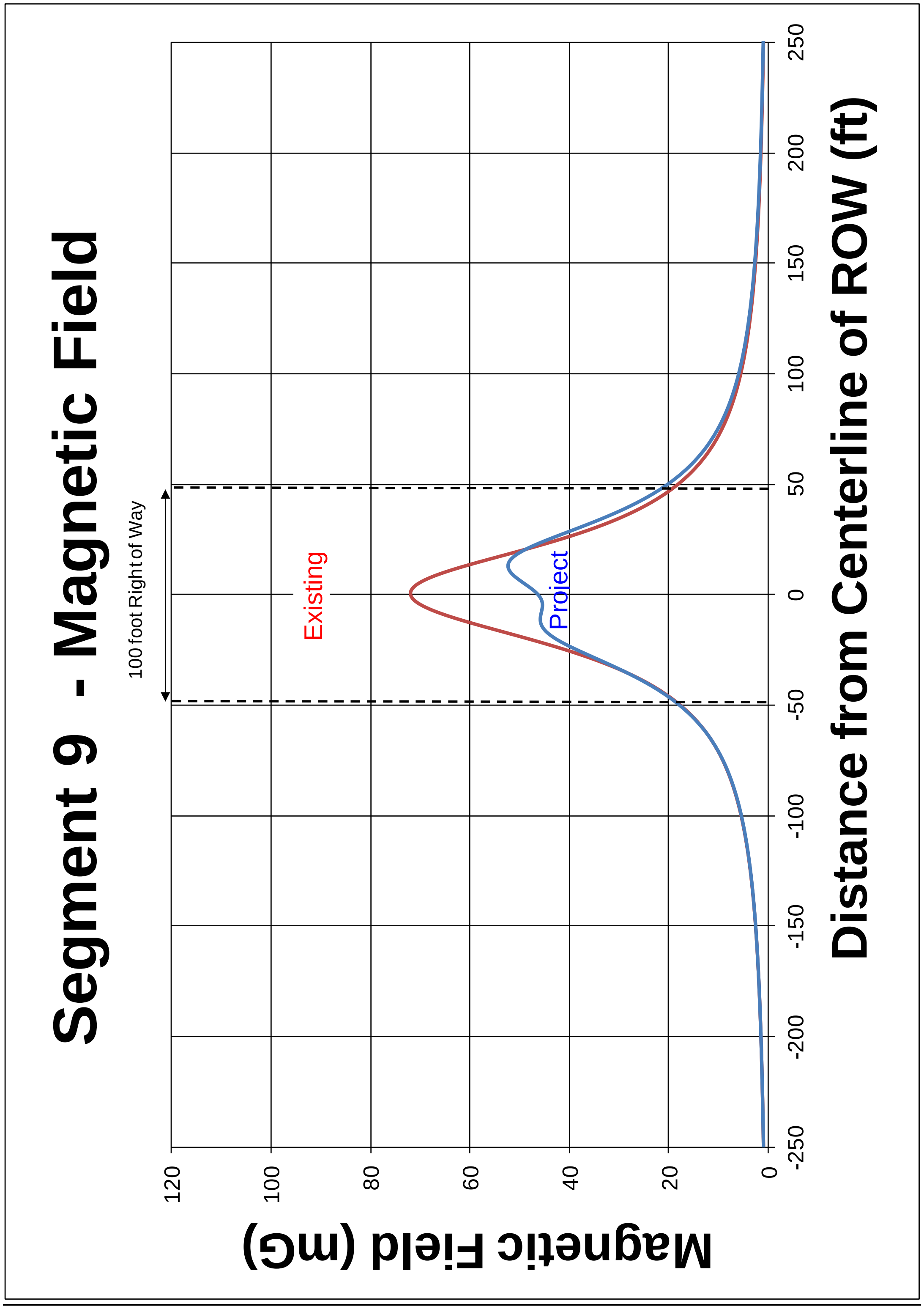


**Figure 22** – Calculated magnetic field profiles for the existing and proposed transmission lines for the Montville-Whippany Project in Segment 9 (corresponding to the configuration shown in Figure 9 and calculated with the 2014 and 2018 line currents from Table 4).

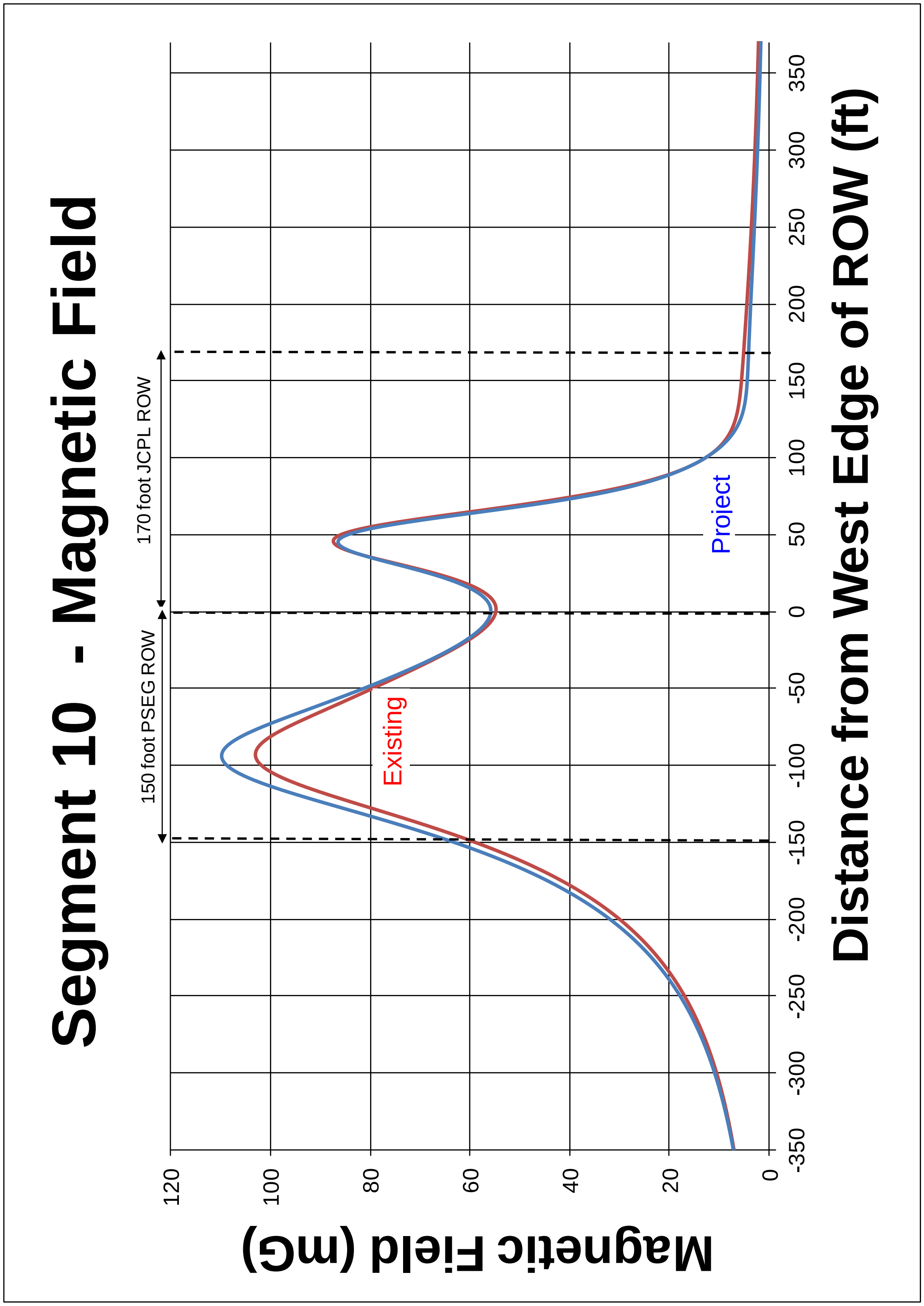


**Figure 23** – Calculated magnetic field profiles for the existing and proposed transmission lines for the Montville-Whippany Project in Segment 10 (corresponding to the configuration shown in Figure 10 and calculated with the 2014 and 2018 line currents from Table 4).

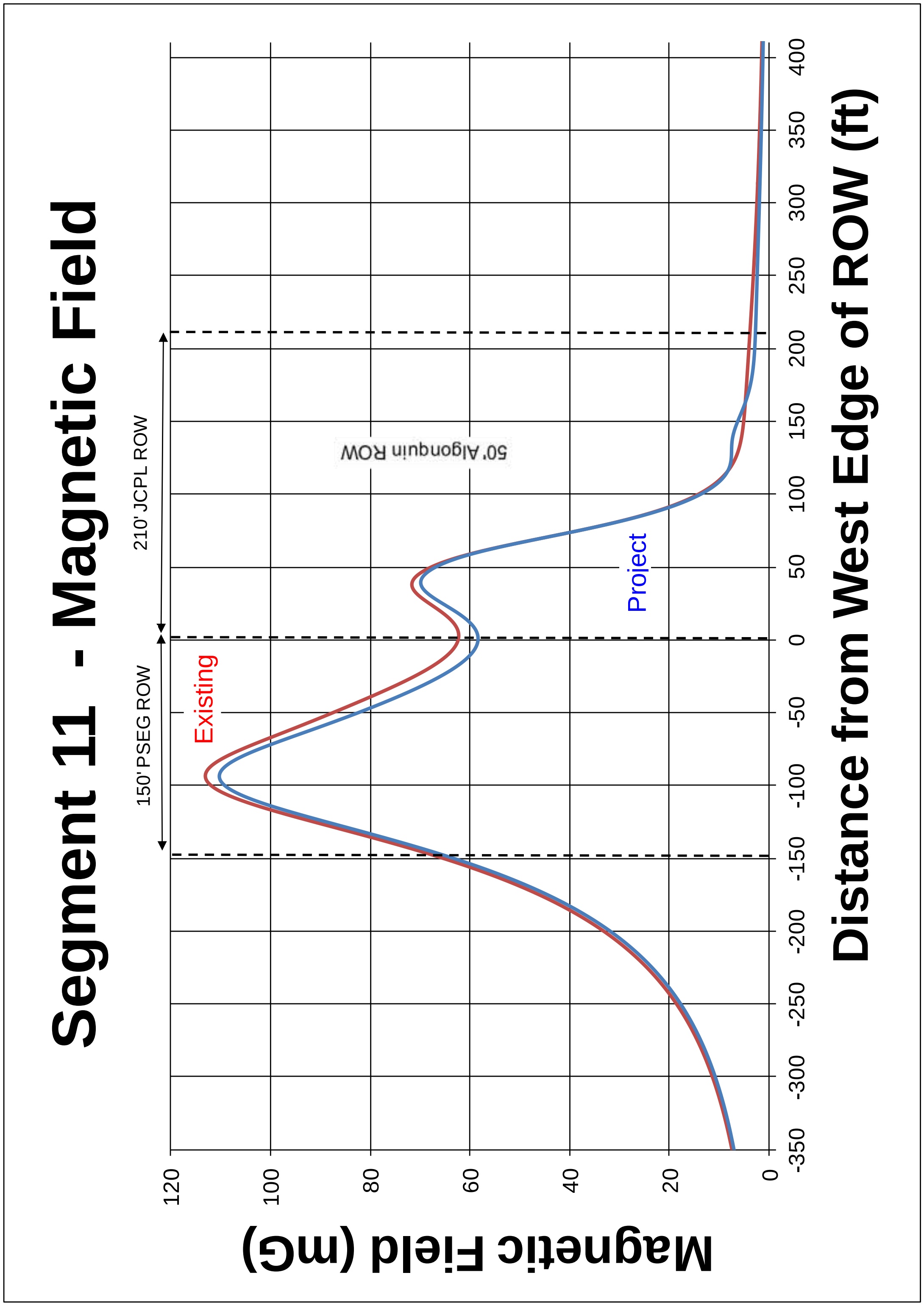


**Figure 24** – Calculated magnetic field profiles for the existing and proposed transmission lines for the Montville-Whippany Project in Segment 11 (corresponding to the configuration shown in Figure 11 and calculated with the 2014 and 2018 line currents from Table 4).

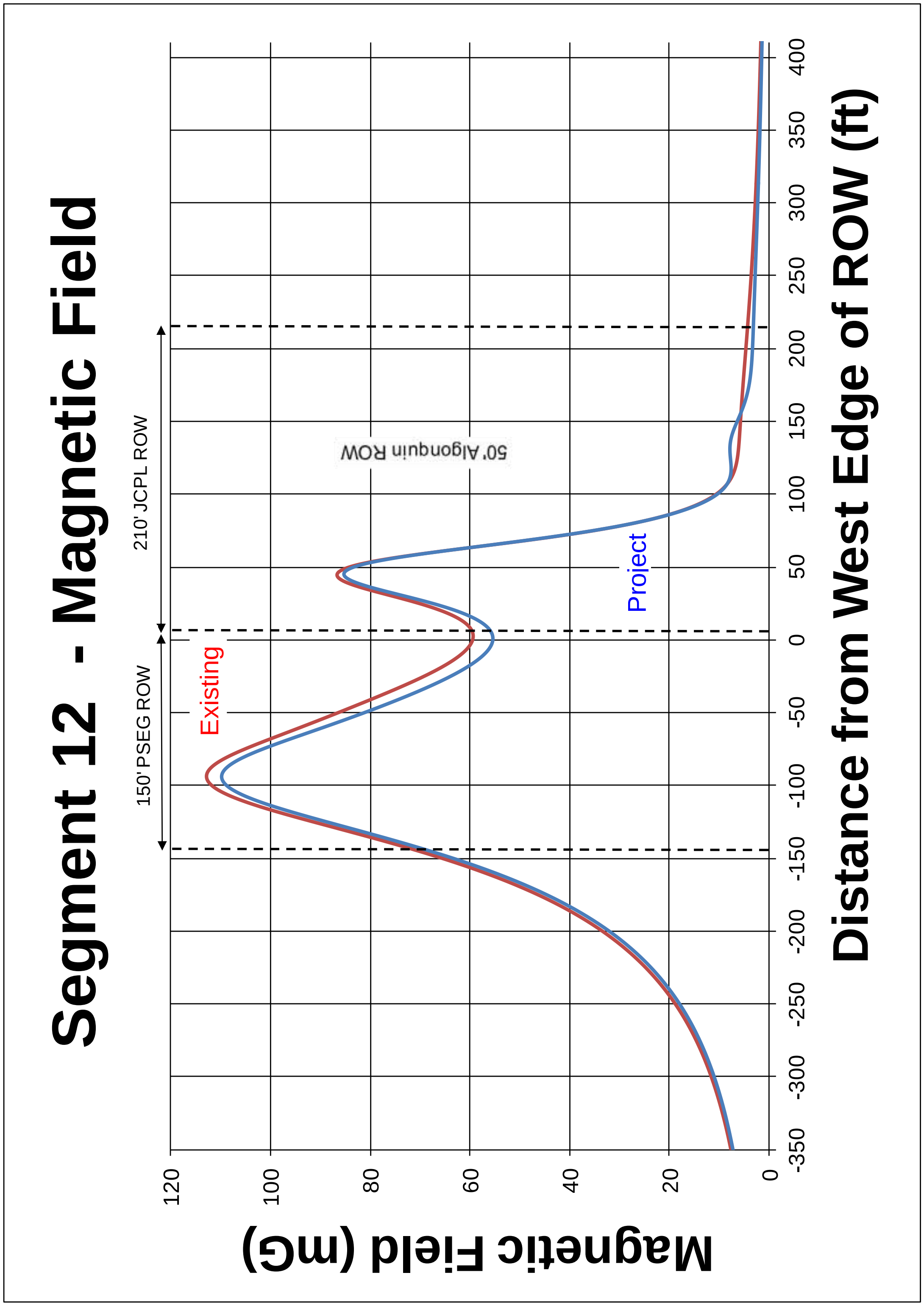


**Figure 25** – Calculated magnetic field profiles for the existing and proposed transmission lines for the Montville-Whippany Project in Segment 12 (corresponding to the configuration shown in Figure 12 and calculated with the 2014 and 2018 line currents from Table 4).

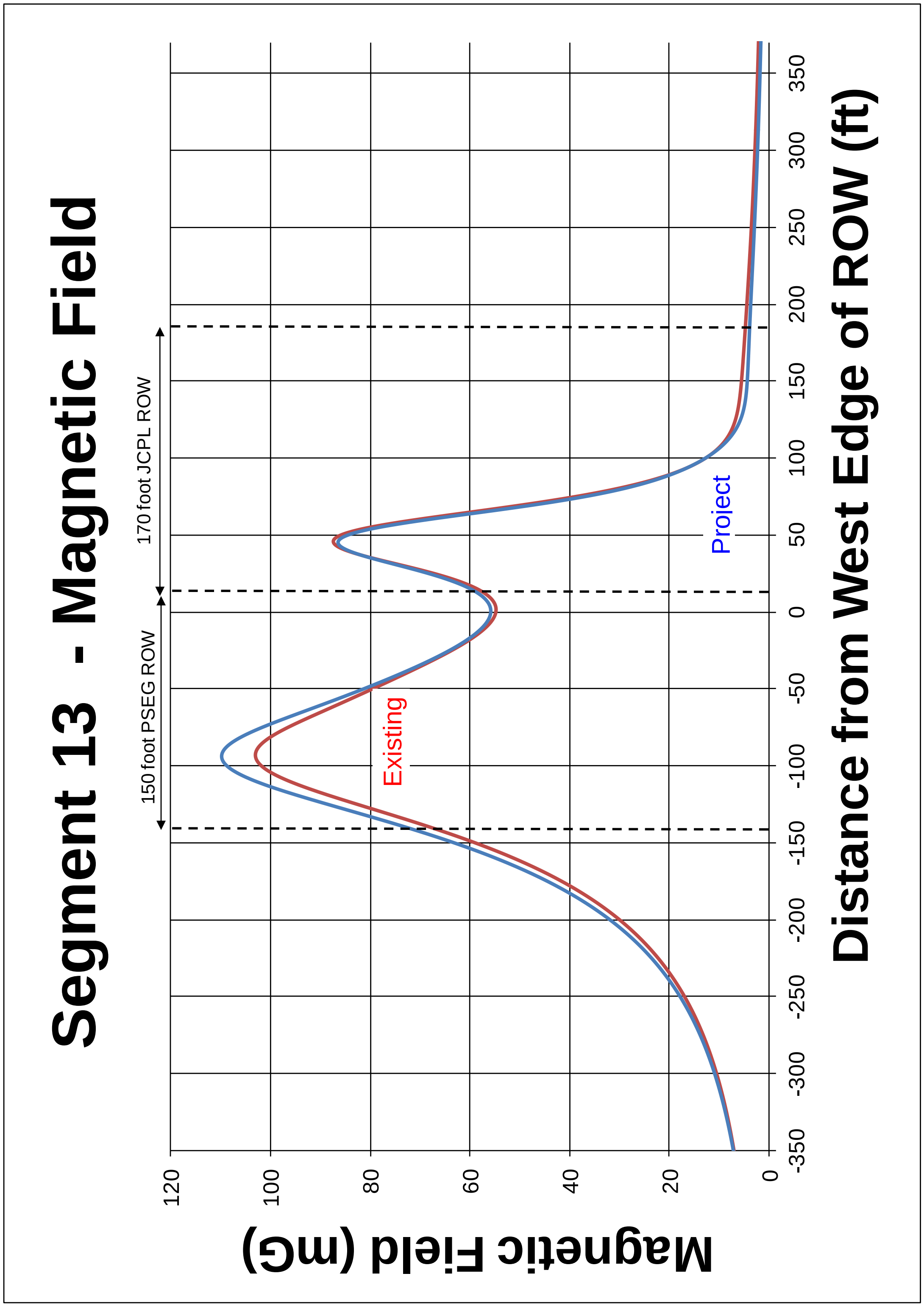


**Figure 26** – Calculated magnetic field profiles for the existing and proposed transmission lines for the Montville-Whippany Project in Segment 13 (corresponding to the configuration shown in Figure 13 and calculated with the 2014 and 2018 line currents from Table 4).

**Table 3** - Calculated edge of ROW magnetic field for all circuits at conductor thermal ratings (as shown in Table 4) for each unique Project ROW cross section configuration.

| **Line Segment** | **2018 Circuit Maximum Current - Magnetic Field (mG)** | |
|---|---|---|
| | **Western** | **Eastern** |
| #1 - (shown in Figure 1) | 113.8 | 45.3 |
| #2 - (shown in Figure 2) | 141.2 | 44.9 |
| #3 - (shown in Figure 3) | 102.0 | 54.4 |
| #4 - (shown in Figure 4) | 56.8 | 37.9 |
| #5 - (shown in Figure 5) | 152.4 | 69.5 |
| #6 - (shown in Figure 6) | 54.0 | 69.5 |
| #7 - (shown in Figure 7) | 270.2 | 43.1 |
| #8 - (shown in Figure 8) | 194.9 | 84.9 |
| #9 - (shown in Figure 9) | 96.6 | 97.2 |
| #10 - (shown in Figure 10) | 256.5 | 41.3 |
| #11 - (shown in Figure 11) | 224.1 | 65.5 |
| #12 - (shown in Figure 12) | 216.8 | 64.1 |
| #13 - (shown in Figure 13) | 256.5 | 41.3 |

**Table 4** - Transmission line current summary for pre and post Project, and circuit rating currents provided by JCP&L and used for magnetic field calculations.

| Circuit | 2014 Pre-Project (A) | 2018 Post-Project (A) | Circuit Maximum Rating (A) |
|---|---|---|---|
| Whippany-Eden Mill I-61 | 249 A | 190 A | 1054 A |
| Whippany-Leslie D-4 | 602 A | 639 A | 1071 A |
| Whippany-Pine Brook K115 | 116 A | 124 A | 954 A |
| Whippany-Chapin O93 | 185 A | 209 A | 1054 A |
| Whippany-Montville New | 0 A | 32 A | 2588 A |
| Whippany-Stoney Brook B1016 | 634 A | 395 A | 2588 A |
| Whippany- Stoney Brook G943 | 51 A | 148 A | 1024 A |
| Whippany-Greystone Q1031 | 1250 A | 946 A | 2588 A |
| Whippany-Greystone J1024 | 648 A | 234 A | 2588 A |
| Montville-Changebridge K115 | 331 A | 322 A | 2588 A |
| Montville-Changebridge O93 | 414 A | 428 A | 2588 A |
| Montville-Roseland E2205 | 296 A | 193 A | 2000 A |
| Hopatcong-Roseland SR500 | 1352 A | 1352 A | 3000 A |

## Electric and Magnetic Field Measurements

Electric and magnetic fields for the Project were measured at the standard height one meter above the ground as recommended in the IEEE Standard Procedures for Measurement of Power Frequency Electric and Magnetic Fields from AC Power Lines (ANSI/IEEE Std. 644-1994). Measurements were performed at the edges of the ROW along five segments of the existing ROW.

The magnetic field generated by electrical currents on transmission line conductors extends from the conductors through the air and into the ground. The magnitude of the field at a height of one meter is frequently used to describe the magnetic field under transmission lines. The magnetic field is not influenced by humans or vegetation on the ground under the line. The direction of the maximum field varies with location. (The electric field is essentially vertical near the ground.) The most important transmission line parameters that determine the magnetic field at one meter height are conductor height above ground and magnitude of the currents flowing in the conductors. As distance from the transmission-line conductors increases, the magnetic field decreases. The magnetic field produced by an individual transmission line is directly proportional to the line electrical current, so the magnetic field on the existing line segments is highest when the electrical current is highest. Table 5 shows the measurement locations and times.

Tables 6 through 10 and Figures 27 through 31 show the measured edge of ROW electric and magnetic fields and site photos for each location. The measurements were completed on August 8, 2014.

**Table 5** - Locations of electric and magnetic field measurements performed on August 8, 2014 along the existing Montville - Whippany 230 kV Project ROWs.

| Location | Line Segment | Approximate Time |
|---|---|---|
| Troy Road, East Hanover Township | 1 | 12:50 PM |
| Route 46, Parsippany-Troy Hills Township | 4 | 1:15 PM |
| River Road, Montville Township | 7 | 1:50 PM |
| Chase Run, Montville Township | 11 | 2:00 PM |
| Miller Lane, Montville Township | 12 | 2:20 PM |

**Table 6** - Measured electric and magnetic fields for the existing transmission lines along Troy Road in East Hanover Township at approximately 12:50 PM on August 8, 2014. The measurement location is shown in Figure 27.

| Location | Measured Magnetic Field (mG) | Measured Electric Field (kV/m) |
|---|---|---|
| West side of ROW | 12.1 | 0.1 |
| East side of ROW | 16.7 | 0.2 |

**Figure 27** – Photograph looking north of electric and magnetic field measurement location along Troy Road in East Hanover Township at approximately 12:50 PM on August 8, 2014 (corresponding to Table 6).

**Table 7** - Measured electric and magnetic fields for the existing transmission lines along Route 46 in Parsippany-Troy Hills Township at approximately 1:15 PM on August 8, 2014. The measurement location is shown in Figure 28.

| Location | Measured Magnetic Field (mG) | Measured Electric Field (kV/m) |
|---|---|---|
| West side of ROW | 2.2 | < 0.1 |
| East side of ROW | 2.6 | < 0.1 |

**Figure 28** – Photograph looking north of electric and magnetic field measurement location along Route 46 in Parsippany-Troy Hills Township at approximately 1:15 PM on August 8, 2014 (corresponding to Table 7).

**Table 8** - Measured electric and magnetic fields for the existing transmission lines along River Road in Montville Township at approximately 1:50 PM on August 8, 2014. The measurement location is shown in Figure 29.

| **Location** | **Measured Magnetic Field (mG)** | **Measured Electric Field (kV/m)** |
|---|---|---|
| West side of ROW | 10.0 | 0.2 |
| East side of ROW | 26.7 | < 0.1 |

**Figure 29** – Photograph looking north of electric and magnetic field measurement location along River Road in Montville Township at approximately 1:50 PM on August 8, 2014 (corresponding to Table 8).

**Table 9** - Measured electric and magnetic fields for the existing transmission lines along Chase Run in Montville Township at approximately 2:00 PM on August 8, 2014. The measurement location is shown in Figure 30.

| **Location** | **Measured Magnetic Field (mG)** | **Measured Electric Field (kV/m)** |
|---|---|---|
| West side of ROW | 15.7 | 0.2 |
| East side of ROW | 15.5 | 0.1 |

**Figure 30** – Photograph looking north of electric and magnetic field measurement location along Chase Run in Montville Township at approximately 2:00 PM on August 8, 2014 (corresponding to Table 9).

**Table 10** - Measured electric and magnetic fields for the existing transmission lines along Miller Lane in Montville Township at approximately 2:20 PM on August 8, 2014. The measurement location is shown in Figure 31.
.

| Location | Measured Magnetic Field (mG) | Measured Electric Field (kV/m) |
|---|---|---|
| West side of ROW | 14.1 | 0.1 |
| East side of ROW | 12.1 | 0.1 |

**Figure 31** – Photograph looking south of electric and magnetic field measurement location along Miller Lane in Montville Township at approximately 2:20 PM on August 8, 2014 (corresponding to Table 10).

## Corona Effects

One of the phenomena associated with all energized electrical devices, including high-voltage transmission lines, is corona. The localized electric field near a conductor can be sufficiently concentrated to ionize air close to the conductors. This can result in a partial discharge of electrical energy called a corona discharge, or corona. Several factors, including conductor voltage, shape, diameter, and surface irregularities such as scratches, nicks, dust, or water drops, can affect a conductor's electrical surface gradient and its corona performance. Corona creates small energy loss in the form of sound, radio noise, heat, and light. Because power loss is uneconomical and noise is undesirable, corona on transmission lines has been studied by engineers since the early part of this century. Many excellent references exist on the subject of transmission line corona. Consequently, corona is well understood by engineers, and steps to minimize it are one of the major factors in transmission line design. The conductor bundles selected for the proposed transmission lines are of sufficient diameter and spacing to limit the localized electrical stress on the air at the conductor surface.

## Audible Noise

Audible noise ("AN") represents any unwanted sound. It may be produced by a transmission line, transformer, airport, or vehicle traffic. Sound is a pressure wave caused by a sound source vibrating or displacing air. The ear converts the pressure fluctuations into auditory sensations. AN from a source is superimposed on the background or ambient noise that is present before the source is introduced.

The amplitude of a sound wave is the incremental pressure resulting from sound above atmospheric pressure. The sound-pressure level is the fundamental measure of AN; it is generally measured on a logarithmic scale with respect to a reference pressure. The sound-pressure level ("SPL") in decibels (dB) is given by:

$$\text{SPL} = 20 \log (P/Po)\text{dB}$$

where P is the effective rms (root-mean-square) sound pressure, Po is the reference pressure, and the logarithm (log) is to the base 10. The reference pressure for measurements concerned with hearing is usually taken as 20 micropascals (μPa), which is the approximate threshold of hearing for the human ear. A logarithmic scale is used to encompass the wide range of sound levels present in the environment. The range of human hearing is from 0 dB up to about 140 dB (a ratio of 10 million to 1).

Logarithmic scales, such as the decibel scale, are not directly additive. To combine decibel levels, the dB values must be converted back to their respective equivalent pressure values, the total rms pressure level found, and the dB value of the total recalculated. For example, adding two sounds of equal level on the dB scale results in a 3 dB increase in sound level. Such an increase in sound pressure level of 3 dB, which corresponds to a doubling of the energy in the sound wave, is barely discernible by the human ear. It requires an increase of about 10 dB in SPL to produce a subjective doubling of sound level for humans.

Humans respond to sounds in the frequency range of 15 to 20,000 Hz. The human response depends on frequency, with the most sensitive range roughly between 2000 and 4000 Hz. The frequency-dependent sensitivity is reflected in various weighting scales for measuring audible noise. The A-weighted scale weights the various frequency components of a noise in approximately the same way that the human ear responds. This scale is generally used to measure and describe levels of environmental sounds such as those from vehicles or occupational sources. The A-weighted scale is also used to characterize transmission-line noise. Sound levels measured on the A-scale are expressed in units of dB(A) or dBA.

AN levels and, in particular, corona-generated audible noise vary in time. In order to account for fluctuating sound levels, statistical descriptors have been developed for environmental noise. Exceedence levels (L levels) refer to the A-weighted sound level that is exceeded for a specified percentage of the time. Thus, the L5 level refers to the noise level that is exceeded only 5% of the time. L50 refers to the sound level exceeded 50% of the time. Sound level measurements and predictions for transmission lines are often expressed in terms of exceedence levels, with the L5 level representing the maximum level and the L50 level representing a median level. For comparison with the calculated noise levels, Table 12 shows audible noise levels from various common sources.

Corona is the partial electrical breakdown of the insulating properties of air around the conductors of a transmission line. In a small volume near the surface of the conductors, energy and heat are dissipated. Part of this energy is in the form of small local pressure changes that result in audible noise. Corona-generated audible noise can be characterized as a hissing, crackling sound that, under certain conditions, is accompanied by a 120-Hz hum. Corona-generated audible noise is of concern primarily for transmission lines operating at voltages of 345 kV and higher during foul weather. The conductors of high-voltage transmission lines are designed to be corona-free under most conditions. However, protrusions on the conductor surface, particularly water droplets on or dripping off the conductors, cause electric fields near the conductor surface to exceed corona onset levels, and corona occurs. Therefore, audible noise from transmission lines is generally a foul weather (wet-conductor) phenomenon. Wet conductors can occur during periods of rain, fog, snow, or icing.

Corona generated audible noise levels were calculated for the maximum voltage and midspan conductor heights for foul weather conditions. The predicted levels of audible noise for the existing and new 230 kV circuit are shown in Table 13.

**Table 12** – Common sound levels for comparison with calculated transmission line audible noise levels during foul weather

| **Sound Pressure Level (dBA)** | **Noise Source (for comparison)** |
|---|---|
| 120 | Jet takeoff at 200 feet |
| 100 | Shouting at 5 feet |
| 80 | Urban street |
| 70 | Gas lawnmower at 100 ft. |
| 60 | Normal conversation indoors |
| ***50*** | Moderate rainfall on foliage<br>***(New Jersey night time limit)*** |
| 40 | Refrigerator, soft whisper |
| 30 | Bedroom at night |
| 0 | Hearing threshold |

For all line segments and configurations, the proposed transmission line upgrades have calculated audible noise levels during rain far below the New Jersey limit of 50 dBA.

**Table 13** - Calculated edge of ROW audible noise levels (L50 rain level) for each unique Project ROW cross section configuration (New Jersey State limit of 50 dBA)

| Line Segment | 2014 Existing (dBA) | | 2018 Post-Project (dBA) | |
|---|---|---|---|---|
| | Western | Eastern | Western | Eastern |
| #1 - (shown in Figure 1) | 32.2 | 32.0 | 34.5 | 32.0 |
| #2 - (shown in Figure 2) | 33.3 | 32.0 | 36.1 | 32.0 |
| #3 - (shown in Figure 3) | < 25 | < 25 | 32.9 | 33.2 |
| #4 - (shown in Figure 4) | < 25 | < 25 | 32.1 | 31.9 |
| #5 - (shown in Figure 5) | < 25 | < 25 | 35.4 | 36.8 |
| #6 - (shown in Figure 6) | < 25 | < 25 | 36.1 | 36.8 |
| #7 - (shown in Figure 7) | 45.5 | 41.0 | 45.8 | 41.6 |
| #8 - (shown in Figure 8) | < 25 | < 25 | 39.5 | 39.5 |
| #9 - (shown in Figure 9) | < 25 | < 25 | 34.2 | 33.0 |
| #10 - (shown in Figure 10) | 45.5 | 41.0 | 45.8 | 41.6 |
| #11 - (shown in Figure 11) | 45.5 | 40.2 | 45.7 | 41.1 |
| #12 - (shown in Figure 12) | 45.5 | 40.2 | 45.7 | 41.1 |
| #13 - (shown in Figure 13) | 45.5 | 41.0 | 45.8 | 41.6 |

## Radio Noise / Electromagnetic Interference

In order to prevent interference to the reception of radio and TV broadcasts, and to protect other sensitive radio services such as aircraft navigation and emergency beacons, the Federal Communications Commission ("FCC") in 1975 established Part 15 of Title 47 of the Code of Federal Regulations (CFR 47 Section 15). These rules are directed at equipment that does not deliberately generate radio frequency ("RF") energy, as well as at low-power radio transmitters that do not require individual licensing. Part 15 affects a larger variety of electronic devices than does any other FCC regulation, imposing RF emissions limits on radios, personal electronics, and includes the electric power transmission and distribution system.

Electromagnetic interference ("EMI"), which includes both radio noise ("RN") and television interference ("TVI"), is created by two sources on overhead power lines. The EMI sources are conductor and hardware corona or gap discharges (sparks) due to loose fitting or floating hardware. The sources of interference that cause more than 90% of the EMI complaints received by utilities are gap discharges. The main source of gap discharges is loose hardware, and they can be found on any voltage powerline. They tend to be found most often on wood pole structures where hardware has a greater probability of becoming loose as the wood pole and crossarms dry out. Steel and concrete structures are much less likely to have loose hardware. EMI caused by corona has been thoroughly studied and documented over the past 40 years. Corona can be a source of severe EMI in the AM broadcast band, particularly during wet weather when corona can be as much as ten times greater than in dry weather. However, electric utilities have received very few EMI complaints in this frequency band that were due to corona. This trend is primarily because of the popularity of the FM broadcast band, which is not affected by powerline EMI and the fact that the AM bands tends to have a lot of static from atmospheric EMI, especially in low signal strength areas.

EMI is measured in terms of received signal strength, just like any other radio signal, at a particular location. The units most often discussed in EMI are decibels referenced to one microvolt per meter.

$$\text{dBu} = 20 \log (\text{interference signal level} / 1\ \mu\text{V/m})$$

Corona has more signal power in the lower (typically AM radio) frequency bands, while gap discharges can have a wide range of higher frequency content.

The conductor design for the Project will meet the stringent New Jersey Regulations for audible noise. The resulting low levels of corona will also produce very little radio and television band noise. The Project radio noise values presented in Table 14 are well below the IEEE Radio Noise Design Guideline of 40 dBμV/m measured at 100 feet from the outside conductor. PJM does not specify EMI limits for 230 kV circuits and below.

**Table 14** Calculated Edge of ROW L50 Fair Weather Radio Noise Levels at Maximum Voltage for each unique Project ROW cross section configuration (IEEE Radio Noise Design Guideline of 40 dBµV/m measured at 100 feet from the outside conductor)

| Line Segment | 2014 Existing (dBµV/m) | | 2018 Post-Project (dBµV/m) | |
|---|---|---|---|---|
| | **Western** | **Eastern** | **Western** | **Eastern** |
| | | | | |
| #1 - (shown in Figure 1) | 24.3 | 22.1 | 30.4 | 22.1 |
| #2 - (shown in Figure 2) | 27.0 | 22.1 | 33.3 | 22.1 |
| #3 - (shown in Figure 3) | < 20 | < 20 | 29.1 | 28.3 |
| #4 - (shown in Figure 4) | < 20 | < 20 | 29.6 | 29.2 |
| #5 - (shown in Figure 5) | < 20 | < 20 | 33.3 | 27.5 |
| #6 - (shown in Figure 6) | < 20 | < 20 | 25.6 | 27.5 |
| #7 - (shown in Figure 7) | 36.2 | 26.3 | 36.0 | 26.3 |
| #8 - (shown in Figure 8) | < 20 | < 20 | 35.0 | 29.0 |
| #9 - (shown in Figure 9) | < 20 | < 20 | 33.0 | 29.7 |
| #10 - (shown in Figure 10) | 36.0 | 26.3 | 36.0 | 26.3 |
| #11 - (shown in Figure 11) | 36.0 | 25.0 | 36.0 | 28.3 |
| #12 - (shown in Figure 12) | 36.0 | 25.0 | 36.0 | 28.3 |
| #13 - (shown in Figure 13) | 36.0 | 26.3 | 36.0 | 26.3 |

## Federal and State Regulations

There are currently no national standards in the United States for 60-Hz electric and magnetic fields. New Jersey has a guideline of 3 kV/m for electric fields at the edge of the ROW. This guideline was established by the New Jersey Department of Environmental Protection on June 4, 1981. New Jersey also has published limits for Audible Noise. The New Jersey Administrative Code Section 7:29-1.2 (a) (2) (i) established a limit of 50 dBA for "continuous airborne sound" between the hours of 10:00 P.M. and 7:00 A.M. The Audible Noise has been interpreted as applying to the median rain rate level for power lines. Finally, New Jersey does not have a limit for magnetic fields from transmission lines.

Although New Jersey has not enacted magnetic field regulations, several states have been active in establishing mandatory or suggested limits on 60-Hz electric and (in two cases) magnetic fields. Five other states have specific electric-field limits that apply to transmission lines. These states include Florida, Minnesota, Montana, New York, and Oregon. Florida and New York also have established regulations for magnetic fields. These regulations are summarized in Table 15 below.

## Application of Regulations to the Project

As shown in Table 1, the Project will produce a maximum electric field of approximately 0.7 kV/m on the western side of Segment 8. This level is well below the New Jersey State guideline of 3 kV/m.

As shown in Table 13, the Project design will limit audible noise levels to below approximately 46 dBA on for all thirteen line segments between Whippany and Montville. These levels are well within the New Jersey State Limits of 50 dBA.

As shown in Table 14, the Project design will limit radio noise levels to approximately below 36 dBμV/m at the edge of the ROW. These levels are well below the IEEE Radio Noise Design Guideline of 40 dBμV/m measured at 100 feet from the outside conductor. PJM does not specify EMI limits circuit voltages below 345 kV.

## Summary

Electric and magnetic fields, and corona effects, for the Project have been characterized using well-known methods accepted within the scientific and engineering community. The calculated levels from the existing and new transmission lines are well below the New Jersey guidelines for both electric fields and audible noise at the edge of the ROW.

By using existing ROWs for the majority of the Project and selecting the phasing of the new transmission circuit, JCP&L has applied Prudent Avoidance principles and limited magnetic field levels under summer loading conditions for the Project.

**Table 15 –** United States electric and magnetic field regulations

| State Agency | Within the Right of Way | Edge of Right of Way |
|---|---|---|
| **Electric Field Regulations (kV/m)** | | |
| Florida Department of Environmental Regulation | 8 ( 230 kV) 10 (500 kV) | 2 |
| Minnesota Environmental Quality Board | 8 | — |
| Montana Board of Natural Resources and Conservation | 7 | 1 |
| New Jersey Department of Environmental Protection | — | 3 |
| New York State Public Service Commission | 11.8 | 1.6 |
| Oregon Facility Siting Council | 9 | — |
| **Magnetic Field Regulations (mG)** | | |
| Florida Department of Environmental Regulation | — | 150 ( 230 kV) 200 (500 kV) |
| New York State Public Service Commission | — | 200 |