NOBLE WETHERSFIELD WINDPARK, LLC

EXHIBIT___(PAV-1)

ELECTRIC AND MAGNETIC FIELDS (EMF) STUDY

230 kV TRANSMISSION LINE

WETHERSFIELD TO ORANGEVILLE

Transmission Line Electric and Magnetic Fields (EMF)

Gradient Corporation was asked to provide an EMF evaluation of the Wethersfield transmission line proposed for the Noble Environmental Power project, and the following report is Gradient's evaluation.

In accordance with PSL §122(1)(c) and 16 NYCRR §86.5(a), this report analyzes the electric and magnetic field (EMF) impact associated with the proposed Wethersfield transmission facilities. This EMF assessment provides calculations of maximum future EMF levels from the transmission lines under two different power-loading scenarios. This includes an analysis under both maximum projected loads for the Noble Environmental Power generating facility, as well as under and assumption where the transmission circuit is running at the winter-normal conductor ratings, irrespective of other factors that would normally limit the flows to lower levels.

This section provides a discussion that addresses: (a) the State of New York Public Service Commission's (NYSPSC) applicable electric field strength standards set forth in Opinion No. 78-13 issued on June 19, 1978, and (b) the applicable provisions of the NYSPSC's Interim Policy Statement on Magnetic Fields, dated September 11, 1990 (Interim Policy). The EMF modeling for the transmission line under the Article VII Application requires simultaneous consideration of both existing and proposed transmission lines. In this case there are no existing transmission lines. Other guidelines relevant to EMF levels are shown in Table 1.

The EMF analysis provided in this section incorporates the single circuit, H-frame design depicted in Figure 1. The transmission line will be centered in the Right-of-Way (ROW), and only a single transmission line will be installed.

The parameters relevant to the EMF calculation are provided in Table 2. While the design clearance of the conductors is listed at 28 feet, for the purposes of the EMF calculations we used the NESC minimum ground clearance of 22 feet, which would be worst case. The phase conductor separation is 19.5 feet, and there are two ground wires eight feet above the phase conductors, which are optical ground wire (OPGW), *i.e.*, shield wires with fiber optic cables in the center, diameter 0.472 inches. The phase conductors are 795 kcmil ACSR, with 26/7 stranding, 1.108 inches diameter. The normal winter rating of these conductors is 1350 amps. The short-term emergency limits (STE) are 1430 amps summertime and 1620 amps wintertime. Typically, the line voltage was modeled at 230kV. The maximum projected current load is 360 amps per phase which is based on the proposed number of 1.5 MW turbines (86) operating at 90% power factor. The phasing is A-B-C left to right. The Right-of-Way (ROW) width is 150 feet.

Introduction and Summary of Results

The NYSPSC Interim Policy guidelines specify that EMF levels must be determined and comply with estimates based on the actual winter-normal conductor ratings that are being installed. Hence, both this rating and the maximum expected load were modeled. Under the magnetic field strength guidelines established by the NYSPSC, a magnetic field at the edge of a right-of-way (measured about 3 feet above ground level, IEEE, 1995a, 1995b) may not exceed 200 mG. For all locations that were modeled for the proposed transmission line, magnetic field strengths at the edge of the Right-of-Way (and beyond) were substantially less than this guideline (see Figures 2 and 3).

The results are summarized in Table 3. The highest modeled ROW magnetic field strength 3 feet above grade for the transmission lines running at maximum winter normal loading was 53 mG (at 75 feet from the circuit centerline). The modeled field strengths drop rapidly as the distance off the transmission line centerline increases (being 30 mG at 100 feet from the circuit centerline, maximum conductor loading). Below the conductors (inside the ROW), the highest modeled magnetic field strength at 3 feet above grade is 416 mG (maximum conductor loading).

Because the current on the lines is limited by the generating capacity of the Noble Environmental Power turbines, we also calculated the anticipated field at maximum generation load. The highest modeled ROW magnetic field strength 3 feet above grade for the transmission lines was 14 mG (at 75 feet from the circuit centerline). The modeled field strengths drop rapidly as the distance off the transmission line centerline increases (being 8 mG at 100 feet from the circuit centerline). Below the conductors (inside the ROW), the highest modeled magnetic field strength at 3 feet above grade is 111 mG.

The NYSPSC electric-field limits at the edge of the Right-of-Way are 1.6 kV/m, and the modeling shows that the ROW electric fields will be considerably below this value. The highest modeled ROW electric field strength at 3 feet above grade for the transmission lines was 0.5 kV/m (at 75 feet from the circuit centerline). The modeled electric field strength drops rapidly as the distance off the transmission line centerline increases (being 0.2 kV/m at 100 feet from the circuit centerline). Even with a maximum over voltage of 5% above the nominal 230 kV (*e.g.*, 242 kV), ROW electric field levels are considerably below the 1.6 kV/m guideline. That is, a 5% over voltage increases the electric fields by 5%.

EMF Description

Electric power transmission lines create EMF because they carry electric currents at high voltages. The voltages and currents are produced by electric charges. Electric charges (electrons and protons) are present in all matter, and can give rise to electrical effects. Most objects are electrically neutral because positive and negative charges are present in equal numbers. When the balance of electric charges is altered, we experience electrical effects such as the attraction between a comb and our hair, the drawing of sparks after walking on a synthetic rug in the wintertime, or the presence of EMFs from power lines. The work put into separating electric charges is measured by *voltage*. The units of work-per-unit-charge are *volts* (V) or *kilovolts* (kV; 1 kV = 1000 V). Voltage is the "pressure" of electricity, and is analogous to the pressure of water in a plumbing system.

Electric charges push and pull on other charges and, therefore, each electric charge generates an *electric field* that exerts a force on nearby charges. Opposite charges (i.e., + and –) attract, and like charges (i.e., + and +) repel. Electric fields are equal to the "force per unit charge" and are measured in units of *volts/meter* (V/m) or *kilovolts/meter* (kV/m).

The movement of electric charges is called *electric current* and is measured in *amperes* (amps). Current measures the "flow" of electricity, which is analogous to the flow of water in a plumbing system. The moving charges in an electric current produce a *magnetic field* which exerts force on other moving charges. Wires carrying currents running in parallel attract, while wires carrying currents in opposite directions repel. This is the principle by which electric motors generate force.

Magnetic fields are measured in *gauss* (G) or *tesla* (T) (1 T = 10,000 G). Smaller fields are measured in *milligauss* (1 mG = 0.001 G) or *microtesla* (1 μT = one-millionth of a tesla). Milligauss is the unit most often used to measure the strength of magnetic fields in electric transmission lines. Permanent magnets contain electrical currents at the atomic level that can generate strong magnetic fields, approximately 100 to 500 G (i.e., 100,000 to 500,000 mG). Thus, magnetic fields from permanent magnets can exert forces on electric currents, or on other magnetic objects, as for example, when a compass needle orients toward a magnet.

EMFs decrease in size as the distance from the source (the electric charges or currents) increases. For an electric transmission line, EMF levels are highest next to the transmission lines (typically near the center of the right-of-way) and decrease as the distance from the transmission corridor increases. Electric fields are attenuated by objects such as trees and walls of structures, and are completely shielded by electrically conducting material such as metal, the earth, or the surface of the body. Magnetic fields, on the other hand, penetrate most materials (ORAU, 1992).

Humans are exposed to a wide variety of natural and man-made electric and magnetic fields. The earth's atmosphere produces slowly-varying electric fields (about 0.1 to 10 kV/m) that occasionally manifest themselves as lightning. The earth's core produces a steady magnetic field, as can easily be demonstrated with a compass needle. The earth's magnetic field ranges in strength from about 470 mG to 590 mG over the United States, and is about 560 mG in the Northeast. Knowing the strength of the earth's fields provides a perspective on the size of the magnetic field measurements from an electric transmission line.

Man-made magnetic fields are common in everyday life. Many childhood toys contain magnets, and many of us use magnets to hold items on the metallic surface of refrigerators. These permanent magnets typically have fields in excess of 100,000 mG. An increasingly common diagnostic procedure, magnetic resonance imaging (MRI), uses fields of 20,000,000 mG on humans and is considered safer than X-rays. Magnets and steady electric currents, i.e., direct currents (DC), produce steady magnetic fields.

Electric transmission line currents are alternating currents (AC), because they change size and direction 60 times per second (60 cycles per second = 60 Hertz or 60 Hz). AC currents produce AC magnetic fields; however, aside from the variation in time (60 Hz) that characterizes electric transmission line fields, they are identical in nature to steady fields, such as those due to the earth's atmosphere, or geomagnetism. Moreover, as we move our bodies, the direction of the earth's magnetic field relative to us changes and our body experiences a time-varying magnetic field, as in the case of AC magnetic fields.

Electric power transmission lines, distribution lines, and the electric power lines that come into our homes and workplaces are sources of electric and magnetic fields that vary in time at a frequency of 60 Hz (in North America) or 50 Hz (abroad). Magnetic fields are proportional to the current, and electric fields are proportional to the voltage on the wires; both decrease as distance from the electrical wires increases. EMFs from different sources (e.g., adjacent wires) may partially cancel or may add to the EMF level at any location. For residences, typical baseline 60 Hz magnetic fields in the middle of rooms range from 0.5 to 2.0 mG. These fields are, to a large extent, produced by outdoor distribution wiring, indoor wiring, and electric currents in ground return pathways.

In the home, 60 Hz EMFs can also be found in the vicinity of electric appliances, including fans, electric ranges, microwave ovens, refrigerators, clothes washers and dryers, fluorescent lights, televisions, toasters, vacuum cleaners, etc. Appliances produce magnetic fields of 40 to 80 mG at distances of 1 foot, but the fields diminish quickly with distance. Personal electric appliances such as shavers, electric toothbrushes, hair dryers, massagers, electric toys, and electric blankets can produce fields measuring 100 mG or more in the vicinity of those using them. Computer video-display monitors create magnetic fields ranging from approximately 3 mG to 20 mG at a distance of 1 to 4 feet from the device (NIEHS, 2002).

In the school and work environment, copy machines, vending machines, video-display terminals, electric lights, tools, and motors are all sources of EMFs. In the United States, per capita electric power consumption has increased more than 20-fold over the last 50 years, and population exposure to EMFs at power-line frequencies has increased due to factors such as rural electrification, increased electric current service to residences, increased use of electrical office equipment, and increased use of appliances, electric toys, audio-video equipment, and power tools. The EMFs produced by transmission lines, as detailed elsewhere in this section, are well within the range of EMF exposures from other sources. Table 1 summarizes the strengths of magnetic fields associated with various devices and phenomena and several guidelines established by various organizations for certain occupations, individuals, and the general public.

Table 1: Examples of Magnetic Field Strengths in Milligauss (mG)

Device, Phenomenon, Location, or Standard	Magnetic Field Strength (mG)
Magnetic Resonance Imaging (MRI) scan	*20,000,000* (1)
Permanent magnet	*100,000* (1)
ACGIH standard	10,000
ICNIRP occupational guideline (1998)	4,167
ACGIH guideline for occupational exposures	10,000
ACGIH guideline for individuals with pacemakers	1,000
ICNIRP general public guideline (1998)	833
IEEE general public guideline (2002)	9040
Earth's magnetic field	*470 to 590* (1)
Hair dryers and electric blankets	100 to 500
Typical household appliance	40 to 80

Notes:

(1) These magnetic fields are steady fields (not time-varying) as opposed to the other fields listed which are low-frequency (60 Hz), time-varying fields.

Laws, Policies, and Regulations

Article VII of the PSL governs the siting of major utility transmission facilities in the State of New York. PSL §122 sets forth the requirements for an Application for an Article VII Certificate of Environmental Compatibility and Public Need. The Application requirements applicable to this section are set forth in PSL §122(1)(c), which requires a description of the studies which have been made of the environmental impact of the transmission.

The proposed Transmission Facility is subject to 16 NYCRR §86, which requires that an Article VII Application include studies of the expected environmental impact of the Transmission Facility and identify changes the construction and operation of the Transmission Facility might induce.

The applicable electric field strength standards established by the NYSPSC are set forth in Opinion No. 78-13 (issued June 19, 1978). The magnetic field standards established by the NYSPSC are set forth in the NYSPSC's Interim Policy Statement on Magnetic Fields, issued September 11, 1990, (Interim Policy).

Opinion No. 78-13 established an electric field strength interim standard of 1.6 kV/m for Article VII electric transmission lines, at the edge of the right-of-way, one meter above ground level, with the line at the rated voltage. The Interim Policy establishes a magnetic field strength interim standard of 200 mG, measured at one meter above grade, at the edge of the right-of-way, at the point of lowest conductor sag. The measurement is based on the expected circuit phase currents being equal to the winter-normal conductor rating.

Modeling EMF Levels for the Proposed Electric Transmission Lines

The "FIELDS" computer program was used to project electric and magnetic field strengths associated with the proposed 230-kV electric transmission line configuration (Fig. 1). This program incorporates accepted and verified principles of physics that relate the size of electric currents to the magnetic field produced by those currents as a function of distance from the current-carrying conductors.

Table 2: Input Parameters Used for Modeling Maximum Magnetic and Electric Field Strengths for the Noble Wethersfield Transmission Line

Transmission Line Characteristics	Parameter Value
Line voltage	230 kV
Number of circuits	1
Number of phases per circuit	3 (0 degrees, 120 degrees, and 240 degrees)
Conductor diameter	1.108 inch
Optical ground wire diameter	0.472 inches
Transmission line configuration	See Figure 1
Distance between bundled conductors	19 feet 6 inches
Current capacity	360 amps (max anticipated load); 1350 amps (max conductor capacity)
Height of the transmission wires	Minimum ground clearance of 22 feet used
Height of optical ground wires	Minimum ground clearance of 40 feet used
Vertical height of field sensor	3 feet
Right-of-way (ROW) width	150 feet (± 75 ft)

Modeling Results

The modeling results are graphically depicted in Figures 2 through 5, showing both expected maximum load and winter-maximum-conductor-rating loading conditions. The results are also summarized in Table 3. The highest modeled ROW-edge magnetic field strength, 3 feet above grade, at the point of maximum sag is 53 mG (at 75 feet from the circuit centerline). Magnetic field strengths fall off quickly as one moves away from the centerline of the transmission line.

The ROW-edge electric fields generated by the transmission line are projected to be below the NYSPSC guideline of 1.6 kV/m for electric fields at 3 feet above grade at the edge of the Right-of-Way. The highest modeled ROW electric field strength (at the point of maximum conductor sag) at 3 feet above grade for the transmission lines is 0.5 kV/m (at 75 feet from the circuit centerline).

Conclusions

The NYSPSC guidelines for electric and magnetic fields will be met. Projected magnetic field strengths outside of the ROW were also within the range of EMF generated by other common sources. No adverse effects on human health and welfare can be expected from operation of the proposed transmission line, either on the basis of NYSPSC 1990 interim guidelines, or on the basis of conclusions reached by scientific review groups that have repeatedly examined the EMF studies reported in the scientific literature from the 1990's to the present day.

Because no significant impacts from EMF are expected, no mitigation is required. To reduce the potential effects of EMF from the Project to the maximum extent practicable, the Project Sponsor will adhere to the electric field strength interim standards established in the New York State Public Service Commissions (NYSPSC) Opinion No. 78-13, and the magnetic field strength interim standards established in the NYSPSC's Interim Policy on Magnetic Fields, issued September 11, 1990.

Table 3: Magnetic and Electric Field Values for Maximum Field Strength at the Right of Way centerline (Max ROW) and at the ROW edge (75 ft)

		Magnetic Field (mG)	Electric Field (kV/m)
Max. Anticipated Load	Max within ROW	111	4.21
	Field at ROW edge (75 ft)	14.3	0.45
Max. Conductor Capacity	Max within ROW	416	4.21
	Field at ROW edge (75 ft)	53.4	0.45

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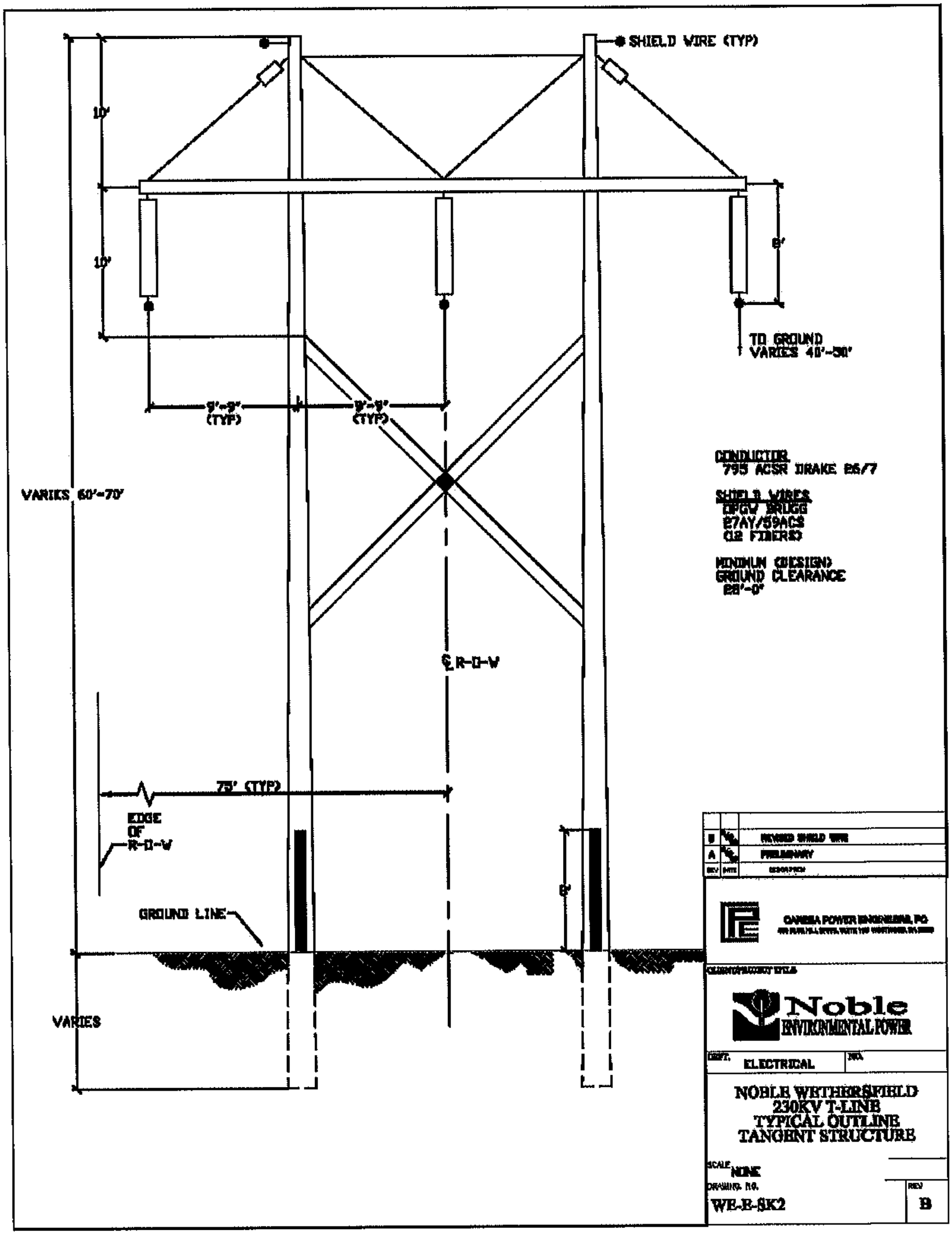

Figure 1: Schematic of phase conductor layout

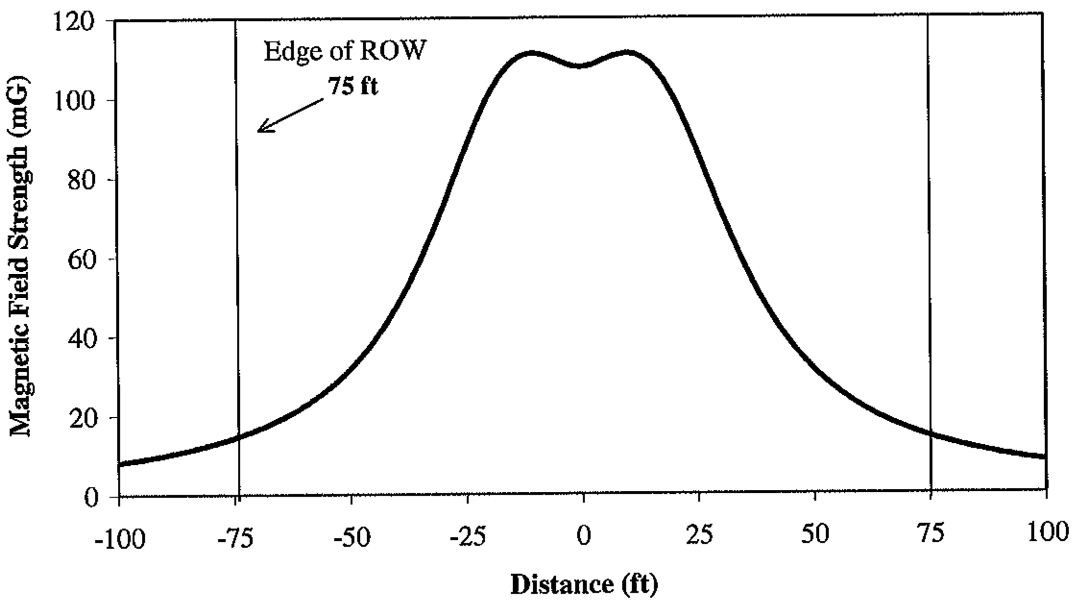

Figure 2: Modeled Magnetic Field Strength for Noble Wethersfield 230 kV Transmission Line at a Maximum Anticipated Load of 360 amps

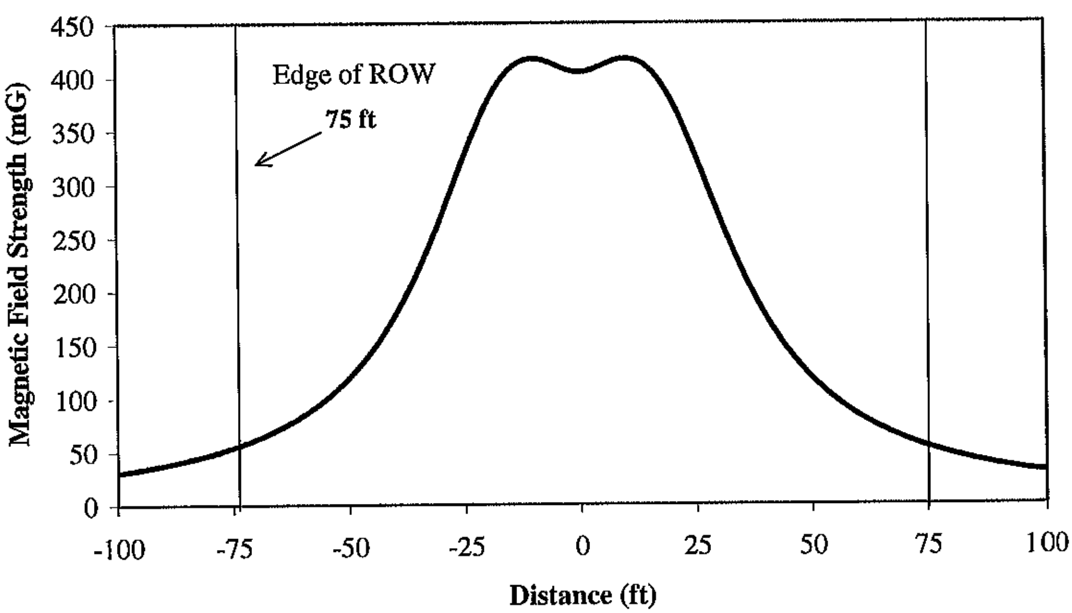

Figure 3: Modeled Magnetic Field Strength for Noble Wethersfield 230 kV Transmission Line at a Maximum Winter-Normal Conductor Rating of 1350 amps

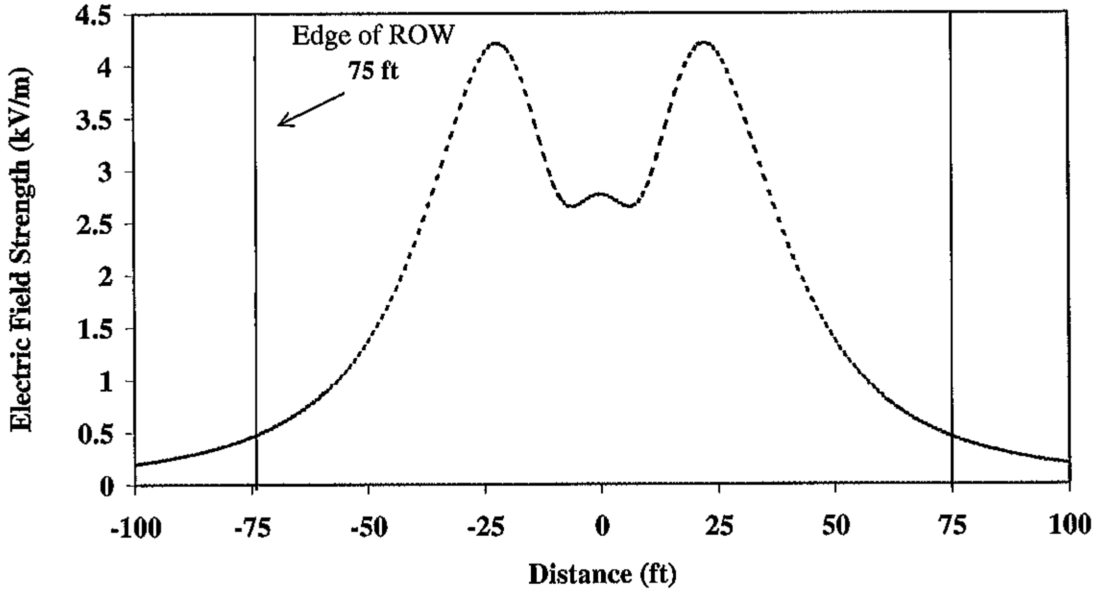

Figure 4: Modeled Electric Field Strength for Noble Wethersfield 230 kV Transmission Line

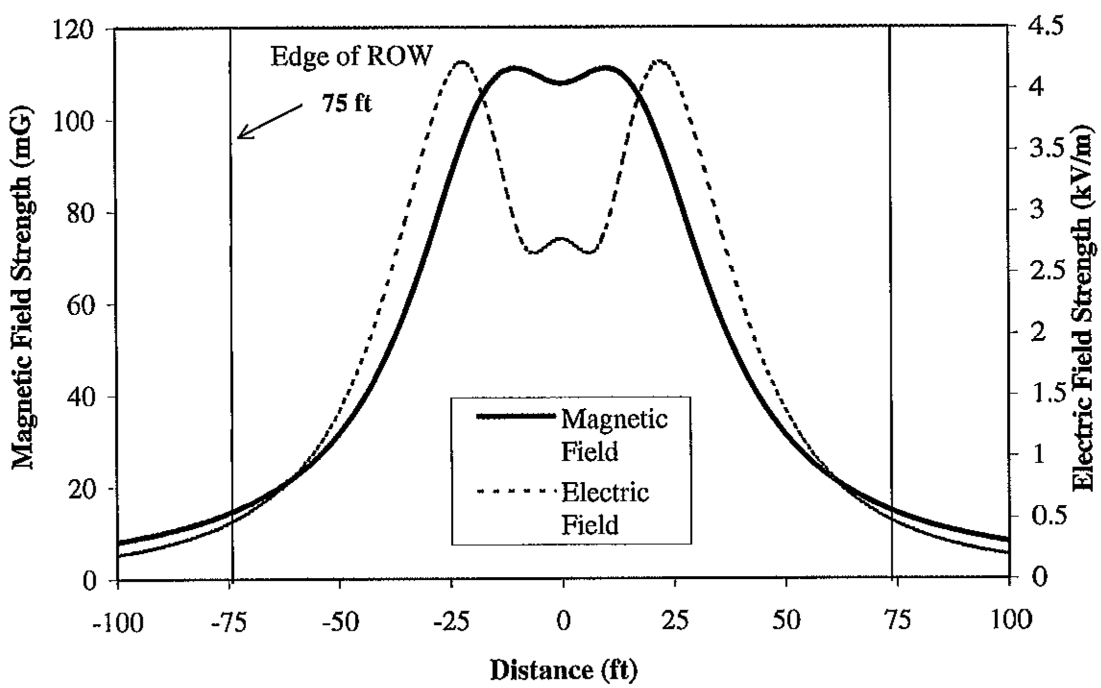

Figure 5: Modeled Electric and Magnetic Field Strengths for Noble Wethersfield 230 kV Transmission Line at a Maximum Anticipated Load of 360 amps