APPENDIX B

Electric and Magnetic Fields (EMF) and Other Field-Related Concerns

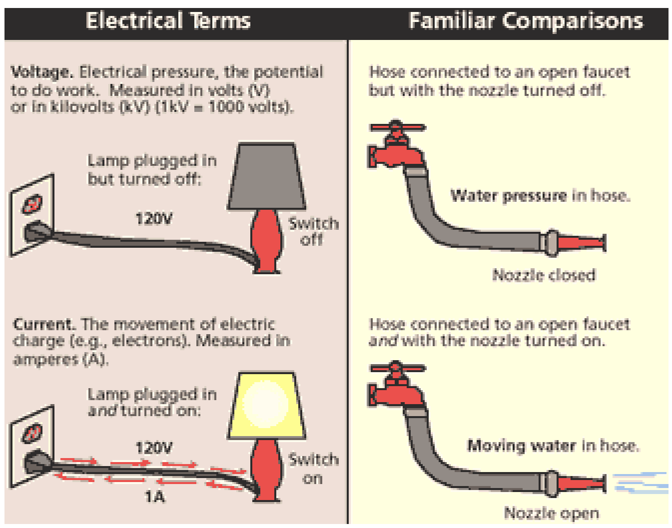
Appendix B

Electric and Magnetic Fields (EMF) and Other Field Related Concerns

EMF is an acronym for "electric and magnetic fields." As explained by the National Institutes of Health, electric and magnetic fields (EMF) are "…invisible lines of force that surround any electrical device. Power lines, electrical wiring, and electrical equipment all produce EMF." [1] EMF has two distinct components: **electric fields** (created by **electric voltage,** measured in *volts [V] or kilovolts [Kv]*), and **magnetic fields** (created by **electric current,** *measured in amperes [A]*).

Figure B-1 below illustrates the electrical *voltage* and *current* concepts:

FIGURE B-1
VOLTAGE VS. CURRENT



SOURCE: National Institutes of Health EMF RAPID Website

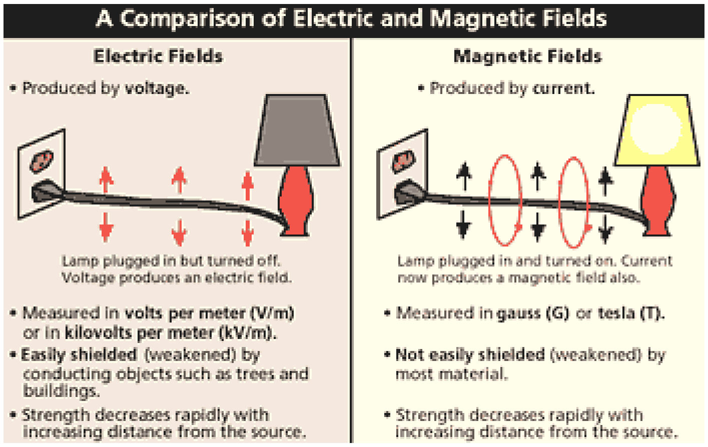
As explained by the National Institutes of Health, "…electric fields are produced by voltage and increase in strength as the voltage increases. The electric field strength is measured in units of volts per meter (V/m). Magnetic fields result from the flow of current through wires or electrical devices and increase in strength as the current increases. Magnetic fields are measured in units of gauss (G) or tesla (T)."[2]

Figure B-2 below illustrates the difference between *electric* and *magnetic* fields:

1 From the National Institute of Environmental Health Web Site on EMF, the EMF RAPID (Research and Public Information Dissemination) project, http://www.niehs.nih.gov/emfrapid/booklet/basics.htm

2 *Ibid.*

FIGURE B-2
ELECTRIC VS. MAGNETIC FIELDS



SOURCE: National Institutes of Health EMF RAPID Website

At low frequencies (such as those associated with EMF from transmission lines), the electric and magnetic fields are separable. By contrast, at high and super high frequencies, the fields are inseparable.[3]

EMF can occur naturally and/or result from human activities. Examples of **naturally-occurring EMF** are found in lightning and in the Earth's magnetic field, which causes a compass needle to point north.[4] Naturally-occurring electromagnetic fields also exist in the human body and allow messages to flow through the nervous system.[5] EMF can also be generated as a result of **human activities** such as communications, appliances, and the generation, transmission, and local distribution of electricity.

Electromagnetic fields are divided into several different categories, driven by their **frequencies.** Electromagnetic fields regularly change direction. The rate of change in direction is referred to as **frequency**, and represents the number of times the field changes direction each second. In the United States, the frequency of change in common household current is 60 times per second, commonly known as 60 Hertz (Hz) power. In Europe, the frequency is 50 Hz. By comparison, radio and communication waves operate at much higher frequencies (500,000-1,000,000,000 Hz.) **Table B-1** outlines the basic categories of electromagnetic fields:

3 "Are Electromagnetic Fields Dangerous to Your Health?", Ohio State University Extension Fact Sheet, http://ohioline.osu.edu/cd-fact/0185.html
4 The geomagnetic field of the earth ranges from 500-700 mG. (Carstensen, 1987).
5 *Ibid.*

TABLE B-1
CATEGORIES OF ELECTROMAGNETIC FIELDS

Description	Acronym	Examples
Extremely Low Frequencies	ELF	Appliances and power lines
High and Low Frequencies	HF and LF	AM radio transmission
Very Low Frequencies	VLF	TVs and video display terminals
Very High Frequencies	VHF	TV and FM radio transmissions
Super High Frequencies	SHF	Microwaves

SOURCE: "Are Electromagnetic Fields Dangerous to Your Health?", Ohio State University Extension Fact Sheet

This document focuses mainly on EMF associated with electricity transmission. The information presented in this analysis is limited to EMF from power lines operating at frequencies of 50 or 60 Hz.

Electric power flows across transmission systems from generating sources to serve electrical loads in a community. A transmission lines' *voltage* and *current* determine the **apparent power** flowing over the transmission line. In general terms, the higher the voltage level of a transmission line, the lower the current needed to deliver the power. For example, a 115 kV transmission line with 200 amps of current will transmit approximately 40,000 kilowatts (kW) of *apparent power* (enough to power approximately 40,000 homes), while a 230 kV line requires only 100 amps of current to deliver the same 40,000 kW. By contrast, a 500 kV transmission line would only require 46 amps of current to deliver the same amount. Since there continue to be public health concerns associated with exposure to EMF from electrical transmission lines, it is the primary focus of this analysis.

B.1 – Components of EMF

B.1.1 – Electric Fields

As mentioned above, the National Institute of Environmental Health Science has noted that, "…electric fields are produced by voltage and increase in strength as the voltage increases. The electric field strength is measured in units of volts per meter (V/m). Electric fields are often present even when the equipment is switched off, as long as it remains connected to the source of electric power".[6] **Table B-2** outlines the strength of typical electrical fields for common household appliances, at a distance of 12 inches.

6 National Institute of Environmental Health Website at http://www.niehs.nih.gov/emfrapid/booklet/basics.htm.

TABLE B-2
TYPICAL ELECTRIC FIELD VALUES FOR APPLIANCES, AT 12 INCHES

Appliance	Electric Field Strength (kV/m)
Electric blanket	0.25 *
Broiler	0.13
Stereo	0.09
Refrigerator	0.06
Iron	0.06
Hand mixer	0.05
Phonograph	0.04
Coffee Pot	0.03

* 1 to 10kV/m nest to blanket wires (Enertech, 1985)

Electric fields are created when an electrical line is energized with voltage. The strength of the field is directly dependant upon the voltage of the line and decreases with distance from the source of the EMF. The strength is likewise affected by surrounding objects: electric fields are shielded or weakened by materials that conduct electricity, even if they are materials that are traditionally known as poor conductors, such as trees, buildings, and human skin."[7]

At close distances, electric fields near power lines can result in phenomena similar to static electricity from clothes removed from a dryer or shuffling feet on a carpet, and may result in electric discharge (or "nuisance shock") when metal objects are touched.[8] Electric shock from transmission lines is acknowledged as a potential impact to public health, and is generally the result of accidental contact with energized wires.

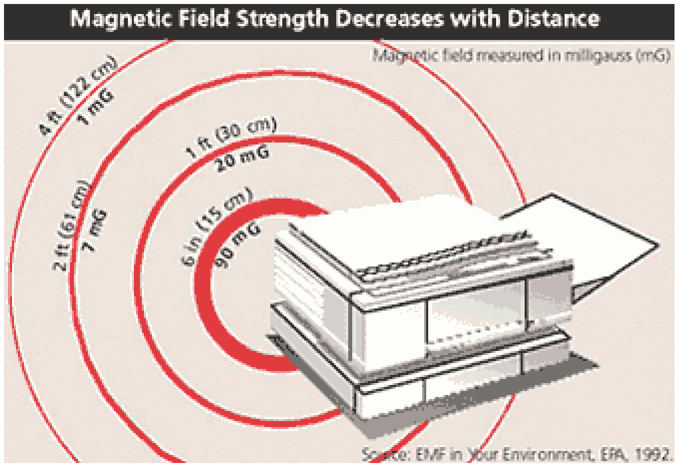
B.1.2 – Magnetic Fields

A current flowing through power lines at any voltage creates a magnetic field. The strength of the field is directly dependant on the current in the line. As mentioned earlier, the strength of this field is typically measured in gauss (G) or milligauss (mG). As with electric fields, magnetic field strength decreases rapidly with distance from the source, however unlike electric fields, magnetic fields are not easily shielded by objects or materials.

Figure B-3 illustrates the rapid decrease in magnetic field strength as one moves farther away from a common household photocopy machine.

7 *Ibid.*
8 An interesting demonstration of "ambient" EMF in the immediate vicinity of high-power transmission lines occurred in 2004 in the UK by Richard Box, the Artist in Resident of the Dept. of Physics at the University of Bristol, which is famous for its pioneering work on the effects of magnetic and electrical fields on human health. Box created an artistic display of 1301 fluorescent light bulbs that lit up, powered solely by the transmission line's ambient power. See http://www.pureenergysystems.com/news/exclusive/2004/pylon_ambience.

FIGURE B-3
DECREASING MAGNETIC FIELD LEVELS OVER VARIOUS DISTANCES



SOURCE: National Institute of Environmental Health EMF RAPID Website

Household appliances provide an illustrative example of magnetic fields. **Table B-3** outlines the typical magnetic field strengths for common appliances at distances of 1 and 3 feet.

TABLE B-3
MAGNETIC FIELD FROM HOUSEHOLD APPLIANCES

Appliance	Magnetic Field (mG)	
	At 1 foot distance	At 3 feet
Can opener	0.35 - 18.21	1.30 – 6.44
Clothes iron	1.66 - 2.93	0.25 – 0.37
Coffee machine	0.09 - 7.30	0 – 0.61
Computer monitor	0.20 – 134.7	0.01 – 9.37
Copier	0.05 – 18.38	0 – 2.30
Desktop light	32.81	1.21
Dishwasher	4.98 – 8.91	0.84 – 1.63
Fax machine	0.16	0.03
Food processor	6.19	0.35
Microwave oven	0.59 – 54.33	0.11 – 4.66
Mixer	0.49 – 41.21	0.09 – 3.93
Printer	0.74 – 43.11	0.18 – 2.45
Portable fan	0.04 – 85.64	0.03 – 3.12
Radio	0.34 – 4.07	0.03 – 0.98
Scanner	2.18 – 26.91	0.09 – 3.48
Television	1.80 – 12.99	0.07 – 1.11
Vacuum Cleaner	7.06 – 22.62	0.51 – 1.28

SOURCE: L. Zaffanella, School Exposure Assessment Survey, California EMF Program, interim results, November 1977.

If an appliance is plugged in to an outlet but not turned on, no current is flowing and only an electric field is generated around the appliance. No magnetic field would be present. However, when the appliance is switched on, both an electric field *and* a magnetic field will be created. The strength of the magnetic field is directly related to the extent of the *current* flowing in the appliance and the cord.

For areas where no major transmission lines exist, EMF is still present due to neighborhood electrical distribution lines, household wiring, and other electrical equipment and wiring. Generally speaking, the magnetic field returns to "background" level (i.e., a level no greater than normally occurs in nature) at distances of approximately 3–4 feet from an typical household appliance. The distance required to return to "background" level is much higher with respect to electrical power lines: approximately 60–200 feet from a distribution line and 300–1,000 feet from a transmission line. Fields and currents that occur in the same place can interact to strengthen or weaken the total overall effect. Therefore, the strength of the fields depends not only on the distance to the source but also the distance to and location of other nearby sources.

It can sometimes be difficult to determine the cause of elevated magnetic fields in or around a residence. Currents in grounding paths and common wiring errors can make locating source of magnetic fields only possible by a trained technician. However, these errors can be repaired easily by an electrician. In some cases, simple measurements can identify internal and external sources of elevated magnetic fields. Turning the power off at a residence can rule out indoor power sources. Measurements taken from varying distances at power lines can also help to pinpoint the cause of elevated sources.

It is estimated that the average individual encounters about 1mG during a 24 hour period. Forty percent of this exposure comes from nearby power lines, while 60 percent come from other sources, such as those in the home described above and/or exposure to appliances and electrical tools.

Considerable recent research has focused on the potential adverse health effects of magnetic field exposure. The primary reason for the focus on *magnetic* fields is because some scientific studies have reported an increased cancer risk associated with estimates of magnetic field exposure. No similar associations have been reported for electric fields. In fact, many of the studies examining the biological effects of electric fields were essentially negative.[9] The results of many major studies as they relate to EMF health effects are discussed later in this appendix section.

B.2 – Other Field Related Public Concerns

There are several other public concerns related to electric power facility projects. These concerns are both safety and nuisance issues and include: radio/television/electronic equipment interference; induced currents (i.e., power-line-related electric and magnetic fields that create

9 National Institute of Environmental Health Web Site, at http://www.niehs.nih.gov/emfrapid/booklet/basics.htm

weak electric currents in humans[10]) and shock hazards; and potential effects on cardiac pacemakers. Each of these is described below.

B.2.1 – Radio, Television, and Electronic Equipment Interference

Overhead transmission lines do not, as a general rule, interfere with normal radio or TV reception. However, there are two potential sources for interference: corona and gap discharges.

Corona Discharge

Whenever high voltages are present in electrical systems, there is the possibility that the high electric fields that exist close to the conductors may cause an electrical breakdown of the surrounding air. This effect is known as "corona discharge".[11] Corona discharges can sometimes generate unwanted radio frequency electrical noise. Several factors, including conductor voltage, shape and diameter, and surface irregularities such as scratches, nicks, dust, or water drops can affect a conductor's corona performance.

A working group of the Radio Noise Subcommittee of the Institute of Electrical and Electronics Engineers (IEEE) has developed a Radio Noise Design Guide for High-Voltage Transmission Lines (IEEE Section 1971). This guide is useful for evaluating the performance of a high-voltage transmission line before it is built. The design guide is applicable to overhead A/C transmission lines in the voltage range of 115 kV to 800 kV. This guide is a valuable tool for the design of overhead high-voltage transmission lines because it provides electrical guidelines that engineers can use to evaluate design alternatives. The IEEE guide is based on many years of research and practical experience. The concept is to design high-voltage transmission lines efficiently to help reduce corona activity and its associated "noise."

Gap Discharges

Gap discharges are different from corona discharges. Gap discharges can develop on power lines at any voltage and are more frequently found on smaller low voltage distribution lines. Gap discharges can take place at locations where tiny electrical separations (or "gaps") develop between mechanically-connected metal parts (for example, on broken or poorly-fitting line hardware, such as insulators, clamps, or brackets). A small electric spark discharge across the gap can create unwanted electrical noise. In addition, tiny electrical arcs can develop on the surface of dirty or contaminated insulators, but this interference source is less significant than gap discharge. Hardware is designed to be problem-free, but corrosion, wind motion, gunshot damage and insufficient maintenance contribute to gap formation.

Radio and Television Interference

The potential for radio and television interference is associated with transmission and distribution line electrical conductors of any voltage, configuration, or location. However, there has been a significant amount of work done to quantify radio and TV noise and provide design methods for electrical transmission lines to mitigate this phenomenon (e.g., EPRI §1982, IEEE §§1971, 1972,

10 *Ibid.*
11 "Electric and Magnetic Fields", National Grid EMF, http://www.emfs.info/sci_elecNRPB_keypoints.asp

and 1976). Corona-generated electrical noise decreases with distance from a transmission line and also decreases with higher frequencies. When a problem exists, it is usually for AM radio, and not the higher frequencies associated with TV signals. Corona interference to radio and television reception is usually not a design problem for transmission lines rated at 230 kV and lower. In addition, radio and TV interference levels are typically extremely low at the right-of-way edge for 230 kV and lower transmission lines both in fair weather and in rain, and will usually meet or exceed established guidelines of the Federal Communications Commission (FCC).

With respect to gap discharge, the severity of potential interference depends on external factors such as the strength and quality of the transmitted radio or TV signal, the quality of the receiving radio or TV set and antenna system, and the distance between the receiver and power line. The vast majority of interference complaints are found to stem from causes other than power lines, such as poor signal quality, poor antennae, and interference from household items including door bells and appliances. (Interference from household items has been noted from such diverse sources as heating pads, sewing machines, freezers, ignition systems, aquarium thermostats, fluorescent lights, etc.) (IEEE § 1976).

In contrast to corona-generated interference, interference due to gap discharges is generally *less* frequent for high voltage transmission lines than for lower voltage distribution lines. Some of the reasons that these transmission lines have fewer gap-related problems include: predominate use of steel structures, fewer structures, greater mechanical load on hardware, and different design and maintenance standards. Gap discharge interference can be avoided or minimized by proper design of the transmission line hardware parts, use of electrical bonding where necessary, and by careful tightening of fastenings during construction. Individual sources of gap discharge noise can also be located and corrected using documented repair and maintenance procedures.

Personal Computer (PC) Monitor Interference

Personal computer monitors using cathode ray tubes (CRTs) can be susceptible to magnetic field interference. Magnetic field interference results in disturbances to the image displayed on the CRT monitor, often described as screen distortion, “jitter,” or other visual defects (Banfi, 2000). In most cases it can be annoying, and at its worst, it can prevent use of the monitor. The extent of interference depends on magnetic field intensity, monitor orientation, monitor design, and the monitor’s vertical refresh rate.

The potential for computer monitor interference is associated with transmission and distribution lines of any voltage, configuration, or location. Heavily loaded transmission lines and lower conductor ground clearances generally produce higher magnetic fields, which, in turn, can potentially result in computer monitor interference.

CRT monitors can potentially experience image jitter due to magnetic fields at about 10 mG or less, depending upon such factors as the size and type of monitor. However, this image distortion does not occur on liquid crystal display (LCD) monitors, commonly used on most portable/notebook computers (ESAA, 1996).

Computer monitor interference is a recognized problem in the video monitor industry. As a result, there are manufacturers who specialize in monitor interference solutions and shielding enclosures. Possible solutions to computer monitor interference issues include: relocation of the monitor, use of magnetic shield enclosures, use of software programs to adjust the monitor's vertical refresh rate, and replacement of cathode ray tube monitors with liquid crystal displays. It is important to note that use of flat screen LCD computer displays (immune to standard household current-created magnetic fields) has grown significantly in the past couple of years as unit prices have declined and image quality has improved.

B.2.2 – Induced Current and Shock Effects

Electric currents can be induced by electric and magnetic fields in conductive objects near to transmission lines. For magnetic fields, the concern is for very long objects parallel and close to the line. However, the majority of concern is related to the potential for small electric currents to be induced by electric fields in metallic objects close to transmission lines. Metallic roofs, vehicles, vineyard trellises, and fences are examples of objects that can develop a small electric charge in proximity to high voltage transmission lines.

Object characteristics, degree of grounding, and electric field strength affect the amount of induced charge. An electric current can flow when an object has an induced charge and a path to ground is presented. The amount of induced current that can flow is important to evaluate because of the potential for nuisance shocks to people and the possibility of other effects such as accidental ignition of fuel.

The amount of induced current can be used to evaluate the potential for harmful or other effects. Previous work on appliance leakage current can provide some insight into this issue. Leakage (and induced) current is commonly measured in units of milliamperes, or *mA* (One mA is 0.001 amperes of electric current). Most appliances have a leakage current that flows through to the body of the user. Usually the amount of current is very small and is below the threshold of perception. Many factors affect the leakage current levels. In addition to appliance design and age, contact resistance and insulation from the ground affect the magnitude of current that flows through to the user. Appliance leakage currents have been measured for a variety of appliances and levels ranged from 0.002 mA to tens of mA (Kahn, 1966; Stevenson, 1973).

There is a U.S. standard for leakage current from appliances that was developed to minimize the potential for electric shock hazards and sudden involuntary movements that might result in an accident (ANSI, 1992). The standard limits appliance leakage current to 0.5 mA for portable appliances and 0.75 mA for stationary or fixed appliances. The standard was developed with consideration of the variable threshold of human perception of electric current.

Different people and different situations produce a range of current perception values. As an example, when an average person grips an energized conductor, the median (50th percentile) threshold for perception of an A/C electric current is 0.7 mA for women and 1.1 mA for men (Dalziel, 1972; EPRI, 1982). If the current is gradually increased beyond a person's perception threshold, it becomes bothersome, and possibly startling. With sufficiently large currents, the muscles of the hand and arm involuntarily contract and a person cannot release the gripped object.

The reasonably safe value at which 99.5 percent of people can let go of a gripped energized object is 9 mA for men and 6 mA for women (Bridges, 1985). An equivalent let-go value of 5 mA has been estimated for children (EPRI, 1982). However, before the current flows in a shock situation, contact must be made, and in the process of *establishing* contact, a small arc occurs. This causes a withdrawal reaction that, in some cases, may be a hazard if the involuntary nature of the reaction causes a fall or other accident. Consideration of let-go currents was the basis for the National Electric Safety Code (NESC) to set an induced current limit of 5 mA for objects under transmission lines (ANSI, 2002).

B.2.3 – Cardiac Pacemakers

Another area of concern related to the electric and magnetic fields of transmission lines has been the possibility of interference with cardiac pacemakers. There are two general types of pacemakers: asynchronous and synchronous. The asynchronous pacemaker pulses at a predetermined rate and is practically immune to interference because it has no sensing circuitry and is not exceptionally complex. The synchronous pacemaker, on the other hand, pulses only when its sensing circuitry determines that pacing is necessary.

The concern is that interference could result from transmission line electric or magnetic fields, and cause a spurious signal in the pacemaker's sensing circuitry (Sastre, 1997). However, when these pacemakers detect a spurious signal, such as an induced 60 Hz current, they are programmed to revert to an asynchronous or fixed pacing mode of operation and return to synchronous operation within a specified time after the signal is no longer detected. The issue for pacemakers is if power line fields could adversely affect their operation.

The potential for cardiac pacemaker interference is associated with high voltage transmission lines along any section or location. Higher voltage transmission lines and lower conductor ground clearances generally produce higher electric fields, which can have the potential for pacemaker interference.

The potential for pacemaker interference from power line fields depends on the pacemaker's manufacturer, model, and implantation method, among other factors. Studies have determined that the thresholds for interference of the most sensitive units are about 2,000 to 12,000 mG for magnetic fields and about 1.5 to 2.0 kV/m for electric fields (University of Rochester 1985). Electric and magnetic fields at the edge of power line rights-of-way are generally below these values, but on the right-of-way the electric field threshold can be exceeded in some cases. The American Conference of Governmental Industrial Hygienists recommends not exceeding an electric field of 1 kV/m or magnetic field level of 1,000 mG for occupational exposure on workers wearing cardiac pacemakers (ACGIH, 2001).

It is unclear that reversion to a fixed pacing mode is harmful since pacemakers are routinely put into reversion with a magnet to test operation and battery life. Some new pacemaker models are dual chamber devices that can be more sensitive to external interference. Some of these dual chamber units may experience inappropriate pacing behavior (prior to reversion to fixed pacing mode) in electric fields as low as 1.5-2 kV/m, while other models appear unaffected in fields up to 20 kV/m. The biological consequences of brief, reversible pacemaker malfunction are mostly benign. An exception would be an individual who has a sensitive pacer and is completely dependent on it for maintaining all cardiac rhythms. For such an individual, a malfunction that compromised pacemaker output or prevented the unit from reverting to the fixed pacing mode, even for brief periods, could be life-threatening (Sastre, 1997). However, this precise collection of events (i.e., susceptible pacer model, favorable field characteristics, and biological need for full-function pacing) appearing simultaneously would appear to be a rare event.

B.3 – Miscellaneous, Non-Field-Related Public Concerns

B.3.1 – Lightning

Contrary to popular belief, transmission lines do not "attract" lightning. However, lightning does tend to strike taller objects more frequently. For objects less than 600 feet tall, the strike probability is directly related to height (i.e., an object twice as tall as another object will generally have twice as many strikes) although object shape can be a factor too. For objects over about 600 feet tall, the likelihood of lightning strikes increases exponentially (Veimeister, 1972).

A transmission line passing above the earth can be said to cast an "electrical shadow" on the land beneath it (EPRI, 1982). Lightning strokes that would generally terminate on the land inside the shadow will strike the transmission line instead and strokes outside this shadow will miss the line entirely. Therefore, a transmission line actually protects the land near it from lightning strikes.

B.4 – EMF Research

B.4.1 – Scientific Panel Reviews

Hundreds of EMF studies have been conducted over the last 20 years in the areas of epidemiology, animal research, cellular studies, and exposure assessment. A number of nationally-recognized, multi-disciplinary panels have performed comprehensive reviews of the body of scientific knowledge on EMF. These panels' ability to bring experts from a variety of disciplines together to review the research gives their reports recognized credibility. It is standard practice in risk assessment and policymaking to rely on the findings and consensus opinions of these distinguished panels.

Reports by the National Research Council/National Academy of Sciences, American Medical Association, American Cancer Society, National Institute of Environmental Health Sciences, World Health Organization – International Agency for Research on Cancer, and California Department of Health Services have all concluded that insufficient scientific evidence exists to warrant the adoption of specific health-based EMF mitigation measures. The potential for adverse health effects associated with EMF exposure is too speculative to allow the evaluation of impacts or the preparation of mitigation measures. The substantive conclusions reached by these various multi-disciplinary panels have been summarized below.

World Health Organization - International Agency for Research on Cancer

In June of 2001, the International Agency for Research on Cancer (IARC), a branch of the World Health Organization (WHO), evaluated the carcinogenic risk to humans of static and extremely low-frequency EMF. In October of 2001, the WHO published a Fact Sheet that summarized the IARC findings.

In June 2001, an expert scientific working group of IARC reviewed studies related to the carcinogenicity of static and ELF electric and magnetic fields. Using the standard IARC classification that weighs human, animal and laboratory evidence, ELF magnetic fields were classified as “possibly carcinogenic to humans,” largely based on epidemiological studies of childhood leukemia. Evidence for all other cancers in children and adults, as well as other types of exposures (i.e., static fields and ELF electric fields) was considered not classifiable either due to insufficient or inconsistent scientific information.

The table below outlines the classification conclusions reached by the IARC:

Static magnetic fields	Inadequate	Inadequate	3 (not classifiable)
Static electric fields	Inadequate	Inadequate	3 (not classifiable)
ELF magnetic fields	Childhood leukemia: limited All other cancers: inadequate	Inadequate	2B (possibly carcinogenic)
ELF electric fields	Inadequate	Inadequate	3 (not classifiable)

SOURCE: National Grid EMF, citing the IARC 2001 Report Results

“Possibly carcinogenic to humans” is a classification used to denote an agent for which there is limited evidence of carcinogenicity in humans and less than sufficient evidence for carcinogenicity in experimental animals. This classification is the weakest of three categories (“is carcinogenic to humans”, “probably carcinogenic to humans” and “possibly carcinogenic to humans”) used by IARC to classify potential carcinogens based on published scientific evidence. For comparison, some examples of well-known agents that have been classified by IARC are listed below:

Classification	Examples of Agents
Carcinogenic to Humans (usually based on strong evidence of carcinogenicity in humans)	Asbestos Mustard gas Tobacco (smoked and smokeless) Gamma radiation
Probably Carcinogenic to Humans (usually based on strong evidence of carcinogenicity in animals)	Diesel engine exhaust Sun lamps UV radiation Formaldehyde
Possibly Carcinogenic to Humans (usually based on evidence in humans which is considered credible, but for which other explanations could not be ruled out)	Coffee Styrene Gasoline engine exhaust Welding fumes ELF magnetic fields

British National Radiological Protection Board (NRPB)

In 1995, the NRPB joined the British Health Protection Agency to become the "Radiation Protection Division." In 2004, the NRPB released its most recent report addressing EMF-related health issues, *Advice on Limiting Exposure to Magnetic Fields (0-300 GHz)*, and its accompanying document, *Review of the Scientific Evidence for Limiting Exposure to Electromagnetic Fields (0–300 GHz)*.

The Board acknowledged that there are concerns that prolonged, low-level exposure to EMFs may be linked to long-term health effects, in particular, cancer. However, the *Review of the Scientific Evidence* document concluded that there was "…no firm evidence of such adverse health effects at the levels of EMF's to which people are normally exposed."[12]

Specifically, in the *Review of the Scientific Evidence* document, the panel found that, "…having considered the totality of the scientific evidence in the light of uncertainty and the need for a cautious approach, [the] NRPB recommends that restrictions on exposure to EMFs in the UK should be based on the guidelines issued by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) in 1998.[13] This provides for basic restrictions on exposures of members of the public that are a factor of five lower than for those who are occupationally exposed". The report further noted that an association between prolonged exposure to intense power frequency magnetic fields and a small raised risk of childhood leukemia has been found, the scientific reasons for which were uncertain. Because of those findings and the requirement for additional research, the Board noted that "…further precautionary measures should be considered by the government".[14]

In reaching its conclusions, the NRPB sought input from numerous divergent sources, such as individual UK and international scientific experts, published comprehensive reviews by expert groups, and from an *ad hoc* expert group on weak electric field effects in the body.

National Institute of Environmental Health Sciences/RAPID Program

The National Institute of Environmental Health Sciences (NIEHS) and the Department of Energy (DOE) coordinated the implementation of the Electric and Magnetic Fields (EMF) Research and Public Information Dissemination (RAPID) Program, established by the 1992 Energy Policy Act. This was a six-year, federally-coordinated effort designed to evaluate developing technologies and research the potential adverse health effects on biological systems from exposure to 60 Hz electric and magnetic fields.[15], and to communicate these results to the public sector.

Overall, following the 6-year, $60-million study, the NIEHS concluded that the evidence for a risk of cancer and other human disease from EMF around electric power lines was "weak.[16]"

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12 From the *Statement by the National Radiological Protection Board ,Advice on Limiting Exposure to Electromagnetic Fields (0-300 GHz)* Abstract, at phttp://www.hpa.org.uk/radiation/publications/documents_of_nrpb/abstracts/absd15-2.htm

13 For a full discussion of the ICNIRP guidelines, see the section below entitled, "International Guidelines".

14 From the *Statement by the National Radiological Protection Board*, cite above.

15 As mentioned previously, 60Hz fields are those produced by the generation, transmission and use of electric energy

16 From NIEHS press release entitled *Environmental Health Institute Report Concludes Evidence is 'Weak' that EMF's Cause Cance*r, dated June 15, 1999, electronically at http://www.niehs.nih.gov/oc/news/emffin.htm

The report applied to the extremely low frequency electric and magnetic fields associated with both the larger transmission lines (that distribute power regionally) and the smaller distribution lines that provide power directly to homes.

While sections of the report did say that EMF exposure "cannot be recognized as entirely safe," the report concluded that the"…probability that EMF exposure is truly a health hazard is currently small. The weak epidemiological associations and lack of any laboratory support for these associations provide only marginal scientific support that exposure to this agent is causing any degree of harm."[17] Nonetheless, research has continued on some "lingering concerns" cited in the report, and the NIEHS noted that "…efforts to reduce exposures [to EMF] should continue…"[18]

The NIEHS said that the "strongest evidence" for health effects comes from statistical associations observed in human populations with childhood leukemia and chronic lymphocytic leukemia[19] in "occupationally-exposed" adults (such as electric utility workers, machinists and welders). "While the support from individual studies is weak," according to the report, "these epidemiological studies demonstrate, for some methods of measuring exposure, a fairly consistent pattern of a small, increased risk with increasing exposure that is somewhat weaker for chronic lymphocytic leukemia than for childhood leukemia."[20] However, laboratory studies and investigations of basic biological function do not support these epidemiological associations, according to the report. It says, "Virtually all of the laboratory evidence in animals and humans and most of the mechanistic studies in cells fail to support a causal [cause and effect] relationship."[21]

NIEHS Director Kenneth Olden, Ph.D., said, "The lack of consistent, positive findings in animal or mechanistic studies weakens the belief that this association is actually due to EMF, but it cannot completely discount the epidemiological findings. For that reason, and because virtually everyone in the United States uses electricity and therefore is routinely exposed to EMF, efforts to encourage reductions in exposure should continue. For example, industry should continue efforts to alter large transmission lines to reduce their fields and localities should enforce electrical codes to avoid wiring errors that can produce higher fields."[22]

The studies reviewed and conducted by NIEHS and its grantees focused on the possibility of an EMF-related link to cancer, largely in response to a leukemia study in Denver, Colorado in 1979, and to subsequent attempts to duplicate or refute it. But the NIEHS report also found inadequate evidence of any link to non-cancer diseases such as Alzheimer's, depression and birth defects. Christopher Portier, Ph.D., the associate director of the Environmental Toxicology Program at NIEHS who coordinated the evaluation effort, said, "This risk assessment gains strength and

[17] *Ibid.*
[18] *Ibd.*
[19] *Chronic Lymphocytic Leukemia* (or "CLL") is a rare condition characterized by an accumulation of abnormal lymphocytes in the blood and the bone marrow. CLL results from an acquired (not inherited) injury to the DNA of a single cell in the bone marrow. Scientists do not yet understand what produces this change in the DNA of CLL patients.
[20] *Ibid.*
[21] *Ibid.*
[22] *Ibid.*

reliability from the conduct of extensive new research focused to support the evaluation and through obtaining the opinion of hundreds of scientists who participated in the evaluation. The novel methods used in this risk assessment can serve as a blueprint for resolving other difficult issues."[23]

To assist the NIEHS in reaching its conclusions, several panels of scientists reviewed the data in open, public hearings. One such panel assembled to advise the NIEHS rejected EMF as a "known" or proven, or even "probable" carcinogen, but a majority of the panel said a role in cancer could not be ruled out and should therefore be regarded as a "possible" carcinogen. The NIEHS report also recommended that the fields continue to be recognized as a "possible" cancer hazard, but emphasized the weakness of the data and the low risk that may be involved. The report went on to say that the evidence does not seem to meet the standard for listing as a known or even "anticipated" human carcinogen in the National Toxicology Program's Report on Carcinogens.[24]

In 2002, as a follow-up to the report referenced above, the NIEHS released its "Questions and Answers About EMF' booklet to the public. Available on-line at http://www.niehs.nih.gov/emfrapid/, the booklet was designed to help inform the public about the basics of EMF, the potential adverse health effects, the research conducted to date, typical levels of appliance-related EMF exposure in the household, and standards and guidelines that have been developed both nationally and internationally to help regulate EMF exposure.[25]

U.S. National Research Council/ National Academy of Sciences

In 1997, the National Academy of Sciences/National Research council released a report entitled, "Possible Health Effects of Exposure to Residential Electric and Magnetic Fields". In essence, the report concluded that EMF exposure at normal residential levels did not constitute a public health hazard. Specifically, the report stated, "Based on a comprehensive evaluation of published studies relating to the effects of power-frequency electric and magnetic fields on cells, tissues, and organisms (including humans), the conclusion of the committee is that the current body of evidence does not show that exposure to these fields presents a human-health hazard. Specifically, no conclusive and consistent evidence shows that exposures to residential electric and magnetic fields produce cancer, adverse neurobehavioral effects, or reproductive and developmental effects… An association between residential wiring configuration (called wire codes…) and childhood leukemia persists in multiple studies, although the causative factor responsible for that statistical association has not been identified. No evidence links contemporary measurements of magnetic-field levels to childhood leukemia.[26]"

American Cancer Society

The most recent reference by the American Cancer Society to EMF-related health issues was in an article dated in January of 2000. In the article, the ACS cited a reputable *British Lancet* article authored by Nick Day, PhD, professor of epidemiology at Cambridge University which found, in

23 *Ibid.*
24 *Ibid.* This finding is consistent with the WHO's classifications discussed above.
25 Many of these topics are also discussed and summarized throughout this document.
26 "National Grid EMF", citing the National Academy of Sciences, http://www.emfs.info/expert_NAS.asp

essence, that there was "no link between electromagnetic fields and childhood cancer"[27]. The study followed 2,226 children in the UK "with a confirmed cancer" beginning in infancy and continuing through age 14. The children were compared to a cancer-free control group of children with comparable birth dates and genders.

According to the article, "The researchers took measurements of EMF exposures at the children's homes – including the proximity and type of overhead power lines nearby and electrical appliances in the homes. They also measured exposures at schools or other institutions attended by the children."[28] The researchers found "no evidence that magnetic fields associated with the electricity supply increase risk of childhood leukemia, malignant brain tumors, or any other childhood cancer."[29]

The American Cancer Society gave particular credence to Day's study, since it was a "very nice, large population-based study." The conclusions were clear that there was "…no evidence of an association of EMF and acute lymphoclastic leukemia, all leukemias, central nervous system tumors, and all other malignant disease."[30] The conclusions reached in the Day study paralleled those cited in an earlier, 1997 ACS article on the same topic entitled, *New Study Finds Electrical Lines Cause No Increase in Childhood Leukemia*.[31]

Michael Thun, MD, vice president of epidemiology and surveillance research for the American Cancer Society (ACS), noted the difficulties associated with studying potential links between EMF and cancer, since measuring exposure levels is complicated. However, according to Thun, "... [the Day] study went to great lengths to capture the major sources of exposure."[32]

Since the study was unable to capture a significant sample of children with "high category exposures," a follow-up study currently underway in Japan is expected to be able to address that issue upon its completion.

National Cancer Institute

According to the National Cancer Institute, overall, "…there is limited evidence that magnetic fields cause childhood leukemia, and there is inadequate evidence that these magnetic fields cause other cancers in children. Studies of magnetic field exposure from power lines and electric blankets in adults show little evidence of an association with leukemia, brain tumors, or breast cancer. Past studies of occupational magnetic field exposure in adults showed very small

27 American Cancer Society Website, *Study Finds No Link Between Power Lines and Childhood Cancer,* *http://www.cancer.org/docroot/NWS/content/NWS_1_1x_Study_Finds_No_Link_Between_Power_Lines_and_Childhood_Cancer.asp*
28 *Ibid.*
29 *Ibid.*
30 *Ibid.*
31 For a full review of the 1997 article, see http://www.cancer.org/docroot/MED/content/MED_2_1X_New_Study_Finds_Electrical_Lines_Cause_No_Increase_in_Childhood_Leukemia.asp The 1997 study was conducted by the National Cancer Institute and the Children's Cancer Group, and was published in the New England Journal of Medicine.
32 American Cancer Society Website, *Study Finds No Link Between Power Lines and Childhood Cancer.*

increases in leukemia and brain tumors. However, more recent, well-conducted studies have shown inconsistent associations with leukemia, brain tumors, and breast cancer."[33]

The Institute itself conducted a comprehensive study to assess the potential relationship between EMF and the childhood risk of acute lymphoblastic leukemia, a rare but quickly-progressing disease in which too many immature white blood cells (called lymphoblasts) are found in the blood and bone marrow. The study found that children living in homes with high magnetic field levels did not have an increased risk of developing the disease. According to the article, "…the one exception may have been children living in homes that had fields greater than 0.4 microtesla (µT), a very high [magnetic field] level that occurs in few residences."[34] A second study conducted by NCI researchers reported that children living close to overhead power lines based on distance measurements were not at greater risk of leukemia.[35]

A third major study also cited by the Institute addressed the potential relationship between EMF and breast cancer in adult women living in Nassau and Suffolk counties in New York State. Released in 2003, the study followed 576 women who had been diagnosed with breast cancer during the period from August 1, 1996, and June 20, 1997, along with 585 "controls" (women who did not have the disease). The study, entitled, *Electromagnetic Fields and Breast Cancer on Long Island: A Case-Control Study*, did not find "…an association between exposure to EMFs and increased risk for breast cancer."[36]

American Medical Association

Resolution 511, amended and adopted at the 1993 American Medical Association Annual Meeting, asked that a review be conducted to describe the potential adverse health effects of exposure to extremely-low frequency electric and magnetic fields. In response to that request, the Council on Scientific Affairs (CSA) prepared an extensive report reviewing some of the prominent scientific and medical literature available on the topic of EMF as of December, 1994.[37]

The report considered basic principles relating to electromagnetic fields (EMF), summarized known effects, reviewed some studies related to EMF, and made recommendations about preventing possible adverse effects from EMF-related exposure. According to the report, "…Some studies of the past 15 years have associated exposures to 50 or 60 Hz electric and magnetic fields with slightly elevated risks of developing cancer or leukemia in children or adults. However, the inconsistency of the results and the shortcomings of most of the studies, in terms of selecting test and control groups, estimating exposures, and accounting for key variables that might affect outcomes, detract from the studies' conclusions… It is not certain that

33 National Cancer Institute, "Magnetic Field Exposure and Cancer: Questions and Answers – Cancer Facts 3.46", http://cis.nci.nih.gov/fact/3_46.htm
34 *Ibid.*
35 *Ibid.*
36 *Ibid,* at http://www.cancer.gov/cancertopics/factsheet/long-island-electromagnetic-qa
37 The full text of the article is available on the AMA web site at http://www.ama-assn.org/ama/pub/category/13682.html.

electromagnetic fields pose health risks, or if they do, which attribute or mechanism of action is responsible."[38]

Because of the minimal and inconclusive evidence connecting EMF with adverse health affects, the AMA agreed with other public entities in concluding that although it was premature to dismiss EMF as a health issue entirely, it was likewise unnecessary to take drastic public health protection measures such as outlawing all EMF exposures. Also, since the federal government lacked specific EMF guidelines, the Council suggested that convening a multi-disciplinary national committee to investigate whether such standards were warranted would be helpful. Finally, the Council stated in its Recommendations that it encouraged on-going research efforts, including examinations of exposures to electromagnetic fields and their effects, average public exposures, occupational exposures, and the effects of field surges and harmonics.[39]

California Department of Health

In the State of California, a joint program between the California Department of Health and the Public Health Institute has been developed to address the public's EMF-related concerns. The program, dubbed the "California Electric and Magnetic Fields Program" was undertaken to help provide research, education, and technical assistance related to the possible health effects of electric and magnetic fields from power lines, appliances, and other uses of electricity.[40]

As part of the DOH's research effort, a comprehensive report entitled, *An Evaluation of the Possible Risks from Electric and Magnetic Fields (EMFs) From Power Lines, Internal Wiring, Electrical Occupations and Appliances*, was prepared and finalized in June, 2002. The report was intended to provide an evaluation of the animal, laboratory and human evidence that shows how exposure to 50/60 Hz magnetic fields may or may not increase human health risks. The Risk Evaluation was based on the results of published research studies, with emphasis on new studies, the National Institute of Environmental Health Sciences (NIEHS) Working Group Report (referenced earlier in this paper), and the results of the California EMF Program Studies. Three epidemiological scientists with the DHS were asked to review this data and attempt to formulate reasonable inferences based on the weight of the available evidence. The following information summarizes the pertinent results discussed in that study.

In contrast to the results seen in the majority of the prior studies conducted (such as the National Academy of Sciences RAPID EMF program referenced earlier), the DHS report did find some correlations between EMF and potential adverse health effects. Notably, all 3 scientists said they were, "…inclined to believe that EMF's can cause some degree of increased risk of childhood leukemia, adult brain cancer, Lou Gehrig's Disease, and miscarriage… ."[41] The report went on to state that all 3 scientists had "…judgments that were 'close to the dividing line between believing and not believing' that EMF's cause some degree of increased risk of suicide."[42]

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38 Excerpted from the AMA's Report 7 of the Council on Scientific Affairs (I-94) Full Text, at http://www.ama-assn.org/ama/pub/category/13682.html .

39 *Ibid.*

40 California EMF Program, http://www.dhs.ca.gov/ehib/emf/

41 Executive Summary, *California EMF Risk Evaluation for Polictymakers and the Public*, California Department of Health, June 2002 Report, pg. 3.

42 *Ibid.*

Furthermore, with respect to adult leukemia, 2 of the 3 scientists were "close to the dividing line between believing or not believing" that EMF's cause some degree of increased risk, with the third being "prone to believe" that such a link exists.[43]

Conversely, with respect to birth defects, low birth weight, breast cancer, heart disease, Alzheimer's Disease, and depression, the 3 scientists did *not* believe (to varying degrees) that the research supported a connection between EMF and an increased risk for these maladies. Furthermore, the panel noted that they "strongly believe[d]" that EMF's are *not* "universal carcinogens"[44], largely due to the fact that there are so many other cancer types [beyond those already mentioned] that were not shown to be connected in any way with EMF exposure.[45]

In addressing the apparent inconsistencies between the conclusions reached by the prior reports and the DHS study, the DHS report did acknowledge that the "…DHS scientists [were] more inclined to believe that EMF exposure increased the risk of…health problems than the majority of the members of the scientific committees convened to evaluate the scientific literature… ."[46] Several reasons for the differences were cited, including that the DHS scientists placed *less* emphasis on the negative findings in animal and test tube experiments than the majority of other scientists, and that the DHS scientists placed *more* emphasis on the epidemiological evidence that the others found less than compelling.

The DHS report stopped short of making any specific public policy related recommendations but, instead, deferred to the California Public Utilities Commission (CPUC) to decide what action, if any, to take based on the report's findings.[47]

B.5 – Policies Standards and Guidelines

B.5.1 – International Guidelines

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) is an organization of 15,000 scientists from 40 nations who specialize in radiation protection. In 1998, the ICNIRP adopted guidelines recommending limits to EMF exposure in both occupational and household settings. **Table B-4** summarizes the ICNIRP recommendations.

The ICNIRP concluded that available data regarding potential long-term effects of EMF exposure, such as increased risk of cancer, are insufficient to provide a basis for setting exposure restrictions.

43 *Ibid.* All of these findings are discussed in much further detail, with accompanying epidemiological data, in the full text of the report.

44 "Universal Carcinogen" can be defined as a substance that will "induce cancer in most tissues of most species at all ages…" See http://carcin.oupjournals.org/cgi/content/full/21/3/397 wherein the example of radiation exposure is cited as a "universal carcinogen".

45 From the CA Dept of Health 2002 EMF Study cited above, at pg. 3.

46 *Ibid.* Specifically, reference was made to the NIH RAPID Report from 1998, the International Agency for the Research on Cancer (IARC) report from 2001, and the British National Radiological Protection Board (NRPB) report from 2001.

47 See the latter section of this report for more details on the CPUC policies and approach to handling potential EMF-related health issues.

TABLE B-4
ICNIRP GUIDELINES FOR EMF EXPOSURE

Exposure (60 Hz)	Electric field	Magnetic field
Occupational	8.3 kV/m	4.2 G (4,200 mG)
General Public	4.2 kV/m	0.833 G (833 mG)

SOURCE: ICNIRP, 1998
Graphic Source: EMF Exposure Standards, EMF Questions and Answers Booklet[48]

B.5.2 – National Guidelines

As outlined earlier in this paper, many prominent national organizations have conducted research into EMF from power lines and potential health risks associated with exposure although, to date, no specific national standards have been established.

However, one national organization, the American Conference of Governmental Industrial Hygienists (ACGIH), a non-governmental, professional organization that facilitates the exchange of technical information about worker health protection, has published recommended "threshold limit values" (or TLV) for magnetic field exposures in an occupational setting. **Table B-5** summarizes the ACGIH recommendations.

According to the National Institute of Environmental Health Sciences, the TLVs for 60-Hz EMF shown in the table above were outlined as a guide to control EMF exposure, but were not intended to define safe versus dangerous EMF levels.[49]

TABLE B-5
ACGIH OCCUPATIONAL THRESHOLD LIMITS VALUES FOR 60-HZ EMF

	Electric Field	Magnetic Field
Occupational exposure should not exceed	25 kV/m	10 G (10,000 mG)
Prudence dictates the use of protective clothing above	15 kV/m	-
Exposure of workers with cardiac pacemakers should not exceed	1 kV/m	1 G (1,000 mG)

SOURCE: ACGIH, 2001.
Graphic Source: EMF Exposure Standards, EMF Questions and Answers Booklet[50]

48 EMF Exposure Standards - EMF Questions & Answers Booklet - June 2002, National Environmental Health Institute, http://www.niehs.nih.gov/emfrapid/booklet/standard.htm
49 *Ibid.*
50 EMF Exposure Standards - EMF Questions & Answers Booklet - June 2002, National Environmental Health Institute, http://www.niehs.nih.gov/emfrapid/booklet/standard.htm

B.5.3 – State Guidelines

Several states have adopted limits of electric field strength within transmission line rights-of-way[51] (ROW). Florida and New York are the only states that currently limit the intensity of magnetic fields from transmission lines. These regulations include limits within the ROW as well as the edge of the ROW and cover a broad range of values. **Table B-6** lists states that currently regulate EMF and their respective limits. Taken as a precautionary measure to prevent magnetic fields from increasing beyond "baseline" (i.e. beyond levels currently experienced by the public), the magnetic field limits were not actually based upon any link between scientific data and health risks (Morgan, 1991).

TABLE B-6
EMF REGULATED LIMITS (BY STATE) STATE TRANSMISSION LINE STANDARDS AND GUIDELINES

	Electric Field		Magnetic Field	
Florida	8 kV/m[a] 10 kV/m[b]	2 kV/m	-	150 mG[a] (max. load) 200 mG[b] (max. load) 250 mG[c] (max. load)
Minnesota	8 kV/m	-	-	-
Montana	7 kV/m	1 kV/m[e]	-	-
New Jersey	-	3 kV/m	-	-
New York	11.8 kV/m 11.0 kV/m[f] 7.0 kV/m[d]	1.6 kV/m	-	200 mG (max. load)
Oregon	9 kV/m	-	-	-

*R.O.W. = right-of-way (or in the Florida standard, certain additional areas adjoining the right-of-way).
kV/m = kilovolt per meter. One kilovolt = 1,000 volts.
[a] For lines of 69-230 kV.
[b] For 500 kV lines.
[c] For 500 kV lines on certain existing R.O.W.
[d] Maximum for highway crossings.
[e] May be waived by the landowner.
[f] Maximum for private road crossings.

Graphic Source: EMF Exposure Standards, EMF Questions and Answers Booklet[52]

In other states, several agencies and municipalities have enacted specific EMF policies[53]. These actions have been varied and sometimes include requirements that the fields be considered in the siting of new facilities. The manner in which EMF is considered has taken several forms. In a few instances, a concept referred to as "prudent avoidance" has been adopted. "Prudent Avoidance", a concept proposed by Dr. Granger Morgan of Carnegie-Mellon University, is defined as "limiting exposures which can be avoided with small investments of money and effort" (Morgan, 1991). Some municipalities or regulating agencies have proposed limitations on field strength, requirements for siting of lines away from residences and schools, and in some cases, prohibitions on the construction of new transmission lines. The origin of these individual actions has been

51 See Footnote 12 above for definition of "right of way".
52 EMF Exposure Standards - EMF Questions & Answers Booklet - June 2002, National Environmental Health Institute, http://www.niehs.nih.gov/emfrapid/booklet/standard.htm
53 Although the State of California has not specifically codified restrictions with respect to EMF limits, the CPUC has examined the issue. Please see the CPUC section of this document for more information.

varied, with some initiated by the regulators at the time of new transmission line proposals within their communities or through grassroots efforts.

B.5.4 – CPUC Guidelines

The California Public Utilities Commission (CPUC) regulates privately owned telecommunications, electric, natural gas and water utilities, as well as railroad, rail transit, and passenger transportation companies within the state of California. The CPUC is responsible for assuring safe services to consumers for reasonable rates.[54] With respect to electricity, the CPUC is charged with enacting public policies governing transmission and distribution lines (new and existing), electricity substations, etc. for the largest, investor-owned utilities (including Pacific Gas & Electric, Southern California Edison, San Diego Gas & Electric, Sierra Pacific Power, and Pacific Power & Light).

In 1991, the CPUC began an investigation to consider its potential role in mitigating health effects, if any, of EMFs created by electric utility power lines and by cellular radiotelephone facilities. All interested parties were notified that the CPUC would take appropriate action on EMFs in response to a conclusion, based on scientific evidence, which indicated that a health hazard actually exists, and that a clear cause and effect relationship between utility property or operations and public health was established.[55]

As discussed earlier, significant controversy exists as to whether EMF does or does not constitute a public health hazard. As such, the CPUC was reticent to enact restrictive regulatory requirements. Instead, they adopted seven "Interim Measures" aimed at concurrently protecting the public while avoiding overreaching and unduly expensive limitations on the investor-owned utilities.

As indicated on the CPUC website, the seven interim measures enumerated in the CPUC's November 1993 decision include:

- **No-Cost and Low-Cost Steps to Reduce EMF Levels:** For new and upgraded utility facilities, "no-cost" and "low-cost" measures should be implemented where feasible to reduce potential EMF exposure, with the goal of pursuing the "prudent avoidance"[56] strategy while simultaneously controlling costs. Whereas the "no-cost" mitigation measures should be undertaken immediately, the "low-cost" options should be pursued throughout the project certification process. The CPUC established a benchmark of up to four percent (4%) of the total budgeted project cost to be applied towards developing EMF mitigation measures, including both design and siting considerations.

- **New Designs to Reduce EMF Levels:** The CPUC's Advisory and Compliance Division and Safety Division held workshops for utilities to develop EMF design guidelines for their new

[54] California Public Utilities Commission Website, at http://www.cpuc.ca.gov/static/consumers/overview.htm
[55] California Public Utilities Commission Website, at http://www.cpuc.ca.gov/static/industry/environment/electromagnetic+fields/action.htm
[56] As an example, Southern California Edison has approached the "prudent avoidance" strategy by setting a policy to "Implement reasonable no cost and low cost steps to build new electric utility lines and substations in ways that reduce magnetic fields". http://www.emraa.org.au/powrlines/ESAA.htm

and rebuilt facilities. The guidelines incorporate alternative site selections, increasing the size of rights-of-way, placing facilities underground, and using other suggested methods for reducing EMF levels at transmission, distribution and substation facilities.

- **Measurement of EMFs:** Uniform residential and workplace EMF measurement programs were also designed in the workshops mentioned above. The guidelines are available to both utilities and their customers. The measurement considerations include sources of EMF beyond the control of utilities, such as appliances, house wiring, and grounding systems. Non-investor-owned utilities are also encouraged to use the measurement guidelines.

- **Education and Research:** The CPUC wants to encourage the public and groups having a financial or basic interest in EMFs to become involved in developing education and research programs. Established and managed by the DHS, the CPUC-regulated utilities and municipal utilities use ratepayer funds to pay for their share of development costs for education and research on EMF-related health issues.

- **EMF Education:** This $1.49 million program will provide credible, meaningful, consistent, and timely EMF information to electric utility customers, employees, and the public. DHS will coordinate a uniform EMF education program to supplement, but not duplicate, those that most electric utilities already have. Utilities without programs should implement one as soon as possible.

- **EMF Research:** A $5.6 million four-year non-experimental research program will be directed by DHS. This program will provide utility participation in state, national, and international research to be pursued to the extent that it benefits ratepayers.

- **Other Research**: Utilities are authorized to contribute to federal experimental research conducted under the National Energy Policy Act of 1992.

Recent Reexamination of "Prudent Avoidance" and Low-Cost/No-Cost Policies

In August of 2004, the CPUC opened an "Order Instituting Rulemaking" inquiry[57] to determine if modifications needed to be made to the Commission's previous "prudent avoidance" and low-cost/no-cost policies with respect to EMF. The inquiry was opened for several reasons, including the fact that the Commission had not revisited the issue since its 1993 ruling coupled with the recent resurgence in public interest in the topic in the wake of the 2002 Department of Health Services EMF report.

In its inquiry, the CPUC thoroughly reviewed the updated EMF scientific analyses presented by the National Institutes of Environmental Health Services Working Group (NIEHS), the British National Radiological Protection Board (NRPB), the International Agency for Research on Cancer (IARC), and the California Department of Health Services 2002 report.[58] In its analysis, the CPUC noted that all the reports examined (including the DHS report, although to a lesser

57 *Order Instituting Rulemaking to Update the Commission's Policies and Procedures Related to Electromagnetic Fields Emanating from Regulated Utility Facilities,* Filed August 19, 2004 with the California Public Utilities Commission, Rulemaking 04-08-020.

58 *Ibid*, at pg. 3. Please see earlier in this analysis for a synopsis of the CPUC-reviewed sources.

degree) failed to find a definitive causational relationship between EMF exposure and adverse health effects.[59]

As a result, the Commission decided, that it was "…not in a position [to] develop a specific numerical standard or threshold".[60] The CPUC cited the 2002 DHS report's lack of substantive recommendations regarding policy implications as further evidence that more definitive action was not warranted.[61] Nonetheless, the Commission did leave open the possibility of revisiting the EMF health issue in the future as new scientific evidence was produced. In the meantime, the CPUC decided to focus its efforts on improving its "prudent avoidance" and no-cost/low-cost policies which, as of May, 2005, is still an on-going effort.

B.6 – Pacific Gas & Electric: Implementation of the CPUC's "Prudent Avoidance" and "No-Cost/Low-Cost" Strategies

As one of the largest investor-owned California utilities, Pacific Gas and Electric (PG&E) has adopted a detailed written strategy to implement the "prudent avoidance" guidelines outlined by the CPUC. [62] As part of the Proposed Project, PG&E "…will incorporate "no cost" and "low cost" magnetic field reduction steps [for] proposed transmission and substation facilities..." Potential measures to reduce magnetic field exposure "…will be consistent with PG&E's Transmission and Substation EMF Design Guidelines."[63] The design guidelines provide for all of the following potential proactive EMF reduction measures:

- Increase distance from conductors and equipment;
- Reduce conductor spacing;
- Minimize current; and
- Optimize phase configuration

Taking into account the four potential considerations above, the "final field management plan" will be provided to the CPUC for review. It will include the following project information:

- A description of the project (including cost, design, length, location, etc.);
- A description of the surrounding land uses using priority criteria classifications;
- No-cost options to be implemented;

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59 The CPUC Order also reviewed the 2002 DHS Report in detail and addressed the apparent inconsistencies between the DSH report and the other primary sources, noting that "…an independent review of the DHS study suggests that other reviewers might have reached different conclusions." From the *Order Instituting Rulemaking* cited above, at pg. 6.

60 *Ibid* at pg 7.

61 *Ibid.*

62 Specifically, PG&E has adopted a formal "Transmission and Substation EMF Design Guidelines" protocol.

63 *Ibid.*

- Priority areas where low-cost measures are to be applied;
- Measures considered for magnetic field reduction, percent reduction and cost; and
- Conclusion – (including a discussion of which options were selected and how areas were treated equivalently or why low-cost measures cannot be applied to this project due to cost, percent reduction, equivalence, environmental concerns or some other reason.)[64]

B.7 – PG&E's Proposed EMF Management Plan

Pursuant to the CPUC requirements, PG&E has submitted two EMF Management Plans for the proposed and amended project applications.[65] Calculated field strengths for the Proposed Project were provided by PG&E based on the following parameters:

- *Computer Program:* Southern California Edison Fields 3.0.A
- *Base Case Load Flow:* The projected 2009 normal summer peak load current (system peak, all lines in service) used for the base case calculation of the magnetic field is 335 Amps, flowing from the Lakeville Substation to the Sonoma Substation in both 115 kV circuits. Load currents are assumed to be balanced at 120 electrical degrees separation between the three phases. Conductor type is assumed to be 477 SSAC.
- *Base Case Phasing:* Both circuits are aligned ABC (Top, Middle, Bottom)
- *Base Case Height of Conductors:* Thirty feet
- *Location of Magnetic Field Calculation:* Three feet above ground adjacent to the minimum conductor clearance point, which is normally at midspan.

It was assumed that the projected peak summer loads for 2009 were used in order to provide a more conservative estimate of future line loadings and EMF levels by projecting 5 years ahead of currently available data (2004).[66] The area load levels represent summer peak loading conditions expected for a one-in-ten year heat wave, which occurs for a limited time each year.

Based on the calculations provided by PG&E, the maximum magnetic field strength varies from approximately 30.5 mG directly beneath the conductors, to 26.3 mG at the edge of the 40 foot wide right of way. This distribution appears reasonable for an overhead transmission line, with a high concentration of field strength directly below the conductors, and with a reduction of strength with distance due to the close spacing of the cables. The calculated field strength at the

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[64] Both the "potential measures" list and the list of details to be included in the "Final Field Management Plan" were taken directly from the *Proponent's Environmental Assessment* document cited above, at pg. H-5.

[65] Pacific Gas and Electric Company. 2004. Preliminary Transmission EMF Management Plan Lakeville-Sonoma 115 kV Transmission Line Project. November 16, 2004. *and* Pacific Gas and Electric Company. 2005. Draft Preliminary Transmission EMF Management Plan Lakeville-Sonoma 115kV Transmission Line Project (Assuming Project Approved with CPUC-Proposed Mitigation Measure Requiring Undergrounding in and near Sonoma. June 2005.

[66] ATI Architects and Engineers Technical Memorandum. Draft Electric and Magnetic Field Hazard Technical Memorandum. PG&E Lakeville-Sonoma 115kV project. Document Number E2106-MEM-002-RV1 June 3, 2005.

edge of the right of way also appears reasonable, since typical magnetic fields from power transmission lines range from 10 to 90 mG.[67]

The majority of the Proposed Project passes through open space, grazing lands, and vineyards. However, there are some residential areas along the alignment, particularly along Leveroni and Felder Roads in Sonoma. Residences on Leveroni Road are as close as 29 feet of the transmission line between Poles 117 and 119. The corresponding Base Case maximum magnetic field level at these locations is calculated to be approximately 22.9 mG. Residences on Felder Road are as close as 46 feet of the transmission line near Poles 83. At this location, the Base Case maximum magnetic field level is calculated to be approximately 16.6 mG.

At each existing substation, EMF levels at the property line are predominately the result of transmission and distribution lines that enter or exit the property. Changes to EMF levels would occur as a result of the proposed modifications to the transmission lines.

B.8 – Project EMF Levels with Implementation of Mitigation Measure 2.1-1

Implementation of Mitigation Measure 2.1-1 requires PG&E to underground a portion of the transmission line within Leveroni Road from approximately Fifth Street West to the Sonoma Substation. Under this Mitigation Measure, PG&E would construct a portion of the new transmission line underground along the Leveroni Road leading into the Sonoma Substation. The overhead line would be transitioned into a 115KV underground cable at Pole 108, approximately 150 feet west of the Fifth Street West intersection. A 3,060 foot long single-circuit 115 kV line would be installed underground along Leveroni Road between Fifth Street West and the Sonoma Substation. The 115 kV cables would be installed in a concrete encased duct bank in a 2 foot wide by 5 foot deep trench. The existing overhead 115 kV single-circuit transmission line, distribution lines, and communication wires on the existing poles along Leveroni Road would not be modified.

Calculated field strengths for the underground segment of the Amended Project were provided by PG&E based on the following parameters (PG&E, 2005):

- *Computer Program:* Southern California Edison Fields 3.0.A
- *Base Case Load Flow:* The projected 2009 normal summer peak load current (system peak, all lines in service) used for the base case calculation of the magnetic field is 335 Amps, flowing from the Lakeville Substation to the Sonoma Substation in both 115 kV circuits. Load currents are assumed to be balanced at 120 electrical degrees separation between the three phases. Conductor type is assumed to be 2500 kcmil Cu type XLPE cables.
- *Base Case Depth to Bottom of Trench:* Five feet

[67] *Ibid.*

- *Location of Magnetic Field Calculation:* Three feet above ground

Based on the calculations provided, the maximum magnetic field strength varies from approximately 40.6 mG directly above the conductors, to 4.5 mG at the edge of the 40 foot wide right of way. This distribution appears reasonable for an underground transmission line, with a high concentration of field strength directly above the cable since it is only a few feet from the ground surface, and with a rapid reduction of strength with distance due to the close spacing of the cables.[68] This results in a greatly reduced width of exposure compared to an overhead line.

The transition from overhead to underground occurs at Pole 108 and at the Sonoma Substation. The local EMF levels near Pole 108 may be higher than the Base Case calculations provided.

At the Sonoma Substation, EMF levels at the property line are predominately the result of transmission and distribution lines that enter or exit the property. Changes to EMF levels will occur as a result of the proposed modifications to the transmission lines.

Residences on Leveroni Road are as close as 29 feet to the existing transmission line between Poles 117 and 119. The maximum magnetic field level at these locations from the new underground transmission line are calculated to be approximately 2.3 mG, though depending on the placement of the duct bank Leveroni Road, it is likely that the distance to residences will be increased, and the corresponding field levels reduced.

The existing EMF levels induced by other utilities in the project vicinity are not known, and the cumulative effect of the underground and overhead circuits operating in parallel have not been provided. Further assessment of these effects may be warranted.

B.9 – EMF Mitigation Measures

In accordance with CPUC Decision 93-11-013 (CPUC, 1993), PG&E is required to consider no-cost and low cost measures, where feasible, to reduce EMF exposure from new or upgraded utility facilities. The magnetic field reduction techniques that are typically considered in electric power transmission facilities include the following:

- Optimize phase configuration
- Increase distance from conductors
- Reduce conductor spacing
- Minimize current

As previously mentioned, PG&E has presented two Preliminary Transmission EMF Management Plans, and has evaluated various EMF reduction measures, as described below.

[68] *Ibid.*

Proposed Project - Optimized Phase Configuration

Cross phasing circuits in a double circuit transmission line can be used as a field cancellation technique, where the phases from one circuit in a multi-circuit line are used to reduce the fields from another circuit, thereby reducing the total magnetic field strength. Relative to the Base Case described above, the revised analysis of EMF levels for the Proposed Project using this reduction measure incorporates the following modifications:

Phasing Modifications:
- Lakeville-Sonoma Circuit #1 is arranged ABC (Top, Middle, Bottom)
- Lakeville-Sonoma Circuit #2 is arranged CBA (Bottom, Middle, Top)

Based on the calculations provided, the revised maximum magnetic field strength using the cross phasing reduction measure varies from approximately 7.7 mG directly beneath the conductors, to 6.0 mG at the edge of the 40 foot wide right of way. This represents a 77.2 percent reduction in EMF levels at the edge of the right of way relative to the Base Case condition described above. This is considered a “no-cost” field reduction measure that PG&E has indicated will be incorporated into the Proposed Project. PG&E’s graphic representation of EMF levels for both overhead and underground portions of the line with and without EMF reduction measures are shown on **Figure B-4**.

Increasing Distance from Conductors

EMF levels decrease as the distance from the conductors increases. For overhead lines, this may be accomplished by raising the height of the poles and by reducing the sag of the conductors between poles. For the Proposed Project, PG&E has evaluated the effect on EMF levels considering increasing the height of the conductors first by 5 feet, then by 10 feet. The calculations that were performed also incorporated the cross phasing technique for reducing EMF levels as described above.

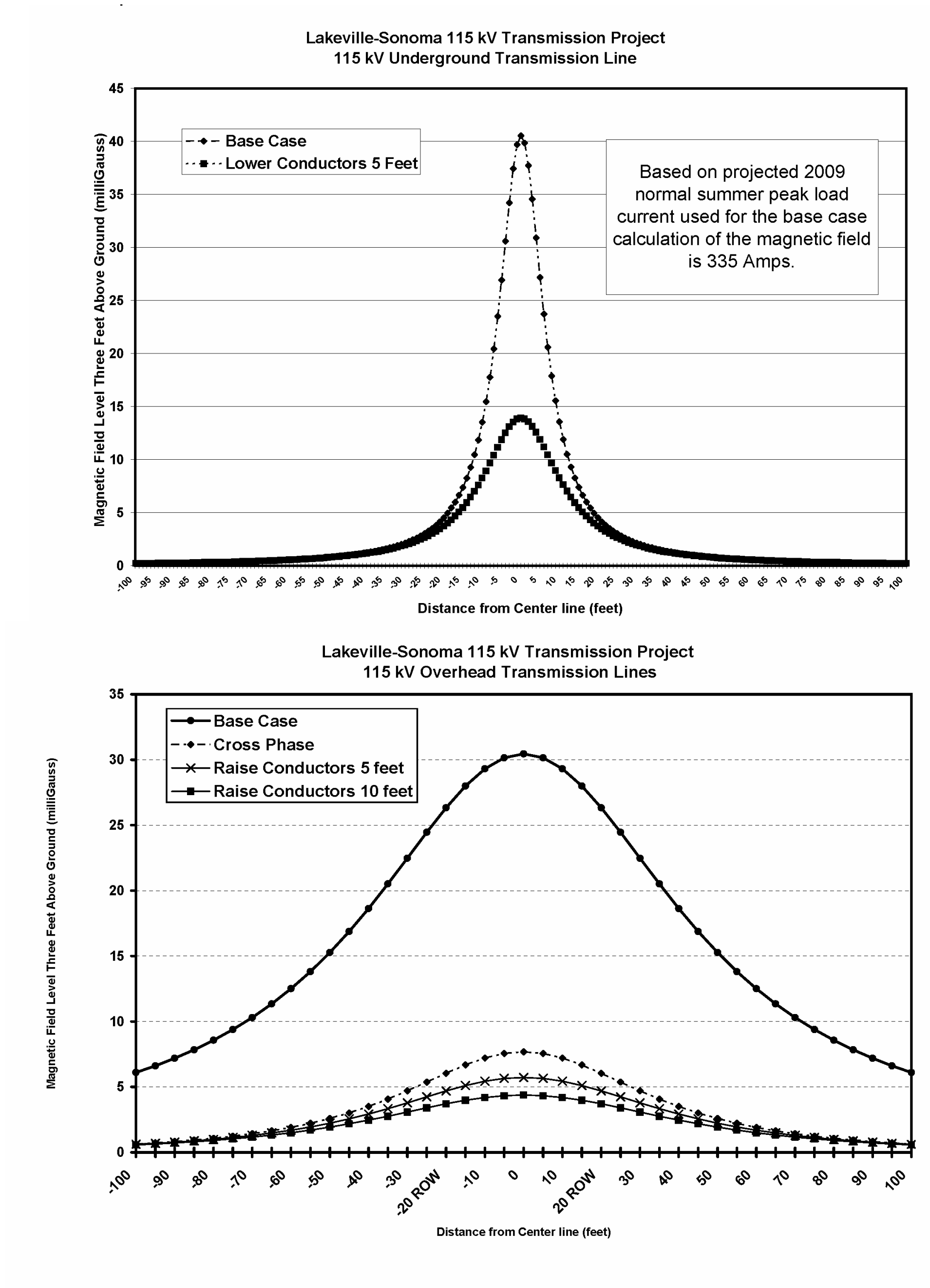
Based on the calculations provided, the revised maximum magnetic field strength using both the cross phasing reduction measure and the conductor height increase is shown in **Table B-7**:

TABLE B-7
REVISED MAXIMUM MAGNETIC FIELD STRENGTH

Conductor Height Increase	Magnetic Field		
	Beneath Conductors	Edge of Right of Way	% Reduction at Edge of Right of Way
Base Case	7.7 mG	6.0 mG	-
5 foot height increase	5.7 mG	4.7 mG	21.7%
10 foot height increase	4.4 mG	3.7 mG	38.3%

PG&E has indicated that the height of the conductors will be raised by ten feet adjacent to residential areas along Felder and Leveroni Roads as a “low-cost” field reduction measure for the Proposed Project.

FIGURE B-4
PG&E ESTIMATED EMF LEVELS WITH AND WITHOUT REDUCTION MEASURES



SOURCE: PG&E (2004) and PG&E (2005)

Proposed Project with Underground Segment (Mitigation Measure 2.1-1)

In the second EMF management plan, PG&E has evaluated various EMF reduction measures for the underground duct bank along Leveroni Road, as described below.

Triangular Configuration

The proposed duct bank will include three solid dielectric cables, with each cable installed in separate conduits and carrying different phases of the three-phase circuit. In lieu of arranging the three cables in the same horizontal or vertical plane, PG&E intends to place the three cables in a triangular distribution within the duct bank, where one cable is located above or below the other two cables. This no-cost measure can reduce field levels by as much as 35 percent.

Strategic Line Placement

EMF levels decrease as the distance from the conductors increases. One method of achieving this for the underground duct bank is to strategically place the conductors in the right of way to maximize the distance to residences. While consideration must be given to existing underground utility locations, PG&E has indicated their intention to strategically locate the duct bank as a no-cost measure to minimize EMF exposure.

Lowering Depth of the Trench

Lowering the trench depth of the underground conductors has the same effect on EMF levels as increasing the height of an overhead system. For the Amended Project, PG&E has evaluated the effect on EMF levels considering lowering the trench depth by 5 feet. The calculations that were performed also incorporated the triangular configuration technique for reducing EMF levels as described above.

Based on the calculations provided, the revised maximum magnetic field strength using both the triangular configuration reduction measure and lowering the trench depth is as follows:

Lowering Trench Depth	Magnetic Field		
	Above Conductors	Edge of Right of Way	% Reduction at Edge of Right of Way
Base Case	40.6 mG	4.5 mG	-
Lowering Trench 5 feet	13.9 mG	3.7 mG	17.5%

PG&E has indicated that the trench will be lowered by five feet adjacent to residential areas along Felder and Leveroni Roads as a “low-cost” field reduction measure for the Amended Project.

B.10 – Final EMF Management Plan

Pursuant to CPUC regulations, PG&E shall submit a final field management plan to the CPUC for review at least 60 days prior to construction. This plan shall at least include the following:

- A description of the project.

- A description of the surrounding land uses considering priority criteria classifications per PG&E guidelines.
- An assessment of total EMF exposure levels along the route and at the substation fence lines.
- No-cost options to be implemented.
- Priority areas where low-cost measures are to be applied.
- Measures considered for magnetic field reduction, percent reduction, and cost.
- Identification of mitigation options selected and how areas were treated equivalently, as well as an explanation of which low-cost measures cannot be applied due to cost, percent reduction, equivalence, or other reason.