Appendix 5 – Contents

Tables

Appendix 5 – EMF Data

The existing conditions and project-related changes of electric and magnetic fields (EMF) are discussed in Section D.9, Public Health and Safety. This appendix provides a summary of EMF modeling data, attached in Table Ap.5-2 of this appendix, and additional scientific background for informational purposes.

The following provides an overview of scientific and engineering fundamentals relevant to EMF and electric power systems. Information about health and safety is reviewed briefly and put into context by discussion of previous studies by public health experts. The reports referenced here reflect an emphasis on potential health effects from exposure to powerline magnetic fields in contrast to powerline electric fields. This same emphasis occurs in this discussion because there is a much greater breadth of research on magnetic fields, and transmission line electric fields can effectively be shielded by common materials such as trees, building materials, and roofs.

Ap.5.1 EMF Fundamentals

Operation of electric power transmission lines, substations, and associated equipment introduces electric and magnetic fields into the environment. Electric and magnetic fields appear as natural features of the earth and living systems and also accompany numerous technological applications. There are important technical differences in the characteristics of the many natural and manmade manifestations of EMF. As examples of this diversity, consider electrical storms (thunderstorms) in nature, weak magnetic fields used by animals for navigation, electric currents that are inherent to normal functions of biological cells and the nervous system, radio and television broadcasting, and the generation, transmission, and use of electric power. The principal distinctions among these diverse electrical and magnetic phenomena are found in the strength and frequency of the associated fields and the electrical and magnetic properties of the materials affected by these fields.

Electric charge is a fundamental property of matter. Its existence is the reason for electric and magnetic fields. Electric fields, measured in volt per meter (V/m), originate from electric charges, Electric fields near high voltage devices such as power transmission lines often are measured in a unit one-thousand times larger, the kilovolt per meter (kV/m). Magnetic fields originate with electric currents, which consist of moving electric charges. These fields are measured in tesla (T) or gauss (G). Magnetic fields near power transmission lines often are measured in smaller units, the microtesla (μT) or milligauss (mG), where 1 μT equals 10 mG. Although scientific literature prefers the tesla, this report adopts the custom of the EMF health effects literature in using milligauss, where one milligauss is one-thousandth gauss.

Frequency

Frequency is a measure of the rate of change for a cyclic process, such as an alternating electric current (AC) and its associated fields. The hertz (abbreviated as Hz) is the unit of frequency. One hertz indicates a rate of one cycle per second. The frequency at which electric charges go through a cycle of changes in direction as they move in a transmission line conductor is 60 Hz. Electric power often is at 50 Hz in parts of the world outside North America. In contrast, AM radio operates at frequencies near one million hertz, FM radio near one-hundred million hertz, TV over a range from approximately 50 million to 800 million hertz, and cellular telephones in a range surrounding 850 MHz and 1900 MHz.

The great difference in frequency for communications systems and power systems causes significant differences in the effects of fields on the human body. However, there is an even greater difference in frequency when making comparisons to those types of electromagnetic fields such as x-rays (ionizing radiation), which are known hazards to biological tissues. X-rays typically are at frequencies billions of times higher than the frequencies used for TV and cellular telephones and therefore more than ten million billion times (10,000,000,000,000,000 or 10^{16} times) greater than 60 Hz. This frequency difference translates into a vast difference in energy that is the root of the distinction between the known harmful effects of ionizing radiation and the types of effects possible with 60-Hz electric and magnetic fields.

Electric Fields

As noted above, electric fields originate on electric charges and therefore exist near any object that is energized by applying a voltage. Electric field strength decreases rapidly with distance from a source and in addition, electric field strengths are reduced significantly (shielded) by common materials used in building construction and to a variable degree by foliage on trees and shrubs between the source and measurement site. Strong electric fields in the range of 1 kV/m and higher are common beneath high voltage transmission lines, but typically fall to levels below 0.01 kV/m about 300 feet from the center of the line. Household and office wiring and appliances also give rise to electric fields with similar properties of rapid decay from the source and also are shielded by common materials. Typical residential and commercial voltages of 120, 208 and 240 V are much lower than those on transmission lines so that for the same distance from a wire, electric fields are much weaker. The opportunity to be close to indoor wiring creates exposures to indoor electric fields over 0.1 kV/m, although levels below 0.02 kV/m and averaging 0.01 kV/m are more typical.

Electric Discharges

Sufficiently strong electric fields can cause electric discharges similar to the nuisance of commonplace "static electricity" that occurs with friction between dry nonconducting objects such as rubber shoes on a carpet, clothing on a fabric car seat, clothing in a dryer, and combing dry hair. Unlike these examples, electric discharges from 60-Hz electric fields can be repetitive and, under unusual circumstances such as a long ungrounded metal fence running parallel to a transmission line, ungrounded metal rain gutters, or a long vehicle, the 60-Hz discharges can rise above the nuisance level and require mitigation.

Electric Shock

Electric shock is a more serious phenomenon that generally requires contact with a conductor. Contact with high voltage conductors causes serious electrical and burn injuries that often are fatal. High voltage systems pose the additional hazard of arcing from a conductor to the body, called "flashover", that can occur even if there has been no direct contact with a conductor. Electric power facilities are built to standards that have strong safeguards from accidental electrocution, but such events occasionally occur nevertheless. Kite flying and tree trimming too close to powerlines are typical causes of powerline electrical accidents affecting the public. Because high voltage transmission lines are on dedicated rights-of-way, public risks of electrical accidents from these causes are reduced.

Magnetic Fields

Powerlines, like other current-carrying wires, create magnetic fields. Magnetic field strength depends directly on the current, not the voltage. If the current is doubled, the magnetic field also will double. Magnetic field strength, like electric field strength, decreases rapidly with distance from the source. Unlike electric fields, magnetic fields are not shielded by common objects or materials, including rock and soil.

The fields of a household electric lamp illustrate the relationship between electric and magnetic fields and also between magnetic fields and power consumption. No current flows when a lamp is plugged into an outlet but not turned on and therefore no magnetic field is created. Nonetheless, there is an electric field near the wire because of the voltage on the wire. When switched on, the electric field on the wire remains unchanged, but a magnetic field now exists. Its strength is proportional to the current. If, for example, a more powerful 100 W light bulb is used to replace a 25 W bulb, the current in the wire will increase four-fold, causing a four-fold increase in the magnetic field. This example also illustrates that, in general, a need for increased electric power results in higher currents and higher magnetic fields. Technical features of electric power transmission allow engineers to create designs that in some cases can reduce the increase in magnetic fields associated with the need for increased power.

Field Measurements

It is possible to accurately measure and calculate electric and magnetic fields from transmission lines and in homes. Measurements can be made with instruments designed for instantaneous readings or recording instruments that can acquire data over a period of hours or days. The spatial variation of electric and magnetic fields near sources indicates the need for proper use of field measuring instruments in order to obtain meaningful data. Accurate calculations require knowledge of the voltages, currents, and locations for all conductors. However, in the home, the strong effect of distance on fields from home wiring and appliances have made it difficult to estimate household magnetic fields, a factor that has affected epidemiologic investigations of possible health effects.

Electric Power Systems and Phasing

Electric power is transmitted at three electrical phases, each carried on a conductor (wire) or group of conductors. The phases are conventionally labeled A, B, C, which designate currents (or voltages) that are timed so that they reach their peaks one-third cycle apart. A set of conductors for the three phases constitutes a three-phase circuit. For both electric and magnetic fields, the fields from different phases, and importantly for this report, two or more circuits, can add or cancel, depending on the relative electrical phase of the conductors, line current, their spatial configuration (that is, placement of cross arms and insulators on poles and towers), and height above the ground. For example, placing a conductor of A-phase near a C-phase conductor with similar current will result in lower fields than if two A-phases were adjacent.

Some transmission lines use two or more conductors for a single phase. Often these paired or multiple conductors of the same phase are placed close together (“bundled conductors”). The wires of bundled conductor of one phase are much closer to each other than the wires of another phase bundle. Twin circuit configurations use two conductors per phase, but the conductors are placed on opposite sides of the tower arm and are not close enough to be considered a bundle.

Electric power flows along high voltage transmission lines from generating stations for eventual delivery to loads in homes, offices, factories, and other sites. High voltages are used to transport large amounts of electricity efficiently. A single phase wire carrying 500 amperes (A) on a 69 kV transmission line transports approximately 20 million watts of power (20 MW) whereas the same 500 amperes on a 230 kV line transports 66 MW, more than three times as much power. Neighborhood distribution systems often operate at 12 kV and carry currents that rarely exceed 100 A per phase, which would provide 1.2 MW per phase, enough to power more than 1,000 average homes.

Unlike voltages, which are stable for a given line, currents can vary significantly over the day. Consequently, magnetic field strength near powerlines, which is determined by the line current, also can vary significantly over the day. Some transmission lines, such as those carrying power from a large electric generator, carry a system's "base load" so that currents will vary little throughout the year, whereas others that interconnect parts of a system may have currents that frequently change in magnitude and the direction of power flow (for example, northward or southward). Changes in power use and sites of power generation are often the reason for changing transmission line currents.

Ap.5.2 Background on EMF Research

For more than thirty-five years scientists have questioned the biological and health consequences of powerline EMFs. The scientific basis for numerous investigations, spanning over 1,000 research papers, was the knowledge that electric and magnetic fields in the environment cause small electric currents to flow in body tissues. It was immediately apparent that for environmental exposures, the currents were very weak when compared to natural currents caused by the heart and other muscle activity, or the electrical activity of nerves and brain cells (Sheppard and Eisenbud, 1977; Carstensen, 1987). This comparison with the body's natural electrical environment led many scientists to conclude there was little chance for harmful effects from powerline fields. To test this preliminary conclusion, extensive research has been conducted over the past three decades.

Early interest focused on the health of electric utility workers exposed to strong electric and magnetic fields, with emphasis on electric fields. Research directions later turned to residential exposures to considerably weaker magnetic field strengths in the range of 0.1 to 10 milligauss (mG). This change was prompted by a 1979 study that indicated a possible association of childhood leukemia with 60-Hz magnetic fields, although the authors did not directly measure magnetic fields in homes (Wertheimer and Leeper, 1979). Intensive study did not begin until the mid-1980s. In a worldwide effort, there since have been many additional epidemiological studies of children, adults, and workers. These were accompanied by laboratory and theoretical research designed to establish conditions under which 50- and 60-Hz electric and magnetic fields might have adverse health effects on human beings and animals, or biological effects on cells and tissues studied in the laboratory. The overall research goal was to determine if adverse health effects occur from electric or magnetic field exposures in home or work environments.

Despite numerous studies over many years, there is still insufficient information to achieve closure on all questions. Nonetheless, consensus views have formed among scientists and public health experts. It is widely held among public health scientists that laboratory experiments do not demonstrate increased risk of cancer and other diseases in laboratory animals exposed to 50- and 60-Hz electric and magnetic fields and these fields do not affect cells and tissues disruptively. The results from epidemiologic studies are less certain as they leave unresolved the possibility of an increase in childhood leukemia rates, but give little evidence for increased risks for other childhood diseases. Studies of diseases in adults are generally judged as negative, with some uncertainty concerning occupational exposures. Conclusions that are more definite would require additional research. For all areas, the research now in progress is not likely to alter the balance of scientific judgment in the near future. These consensus views, which have evolved gradually as research data have accrued, are summarized below.

In addition, to research on health and biological effects, extensive engineering research gathered information on existing EMF levels, methods and instruments for measurement of fields for use by epidemiologists and laboratory scientists, and methods for mitigation of environmental fields.

Ap.5.3 Common EMF Levels in Homes and Buildings

A survey of ambient magnetic fields in 1,000 U.S. homes found the average magnetic field was 0.9 mG (Zaffanella, 1983). High average magnetic fields were uncommon: magnetic fields strengths exceeded 2.5 mG in 3.3% of homes and exceeded 5.0 mG in only 0.3% of homes. A survey of San Francisco Bay Area homes (Lee, 1996 cited in DHS, 2000 p 4) reported a slightly lower average field strength of 0.7 mG.

However, there is considerable variation within homes, especially when close to appliances and wiring. Table Ap.5-1 demonstrates that magnetic fields decline rapidly with distance from the source. At a distance of 25 cm from common appliances, median magnetic fields ranged from 1 to 210 mG.

Table Ap.5-1. Median Magnetic Field Strength (mG) Near Household Appliances in Use

	Distance	
Appliance	25 cm (10 in)	56 cm (22 in)
Can opener	210	24
Microwave oven	37	10
Clock radio (analog)	15	2
Electric range	9	2
Color TV	7	2
Ceiling fan	3	1
Refrigerator	3	1
Clock radio (digital)	1	0.2
Fan (non-ceiling)	3	0.4

Source: Adapted from (NIEHS, 1998 p 47) and (Zaffanella, 1993).

As an indication of magnetic field exposures in commercial buildings, Schiffman et al. (1998) reported that office workers had a workday average of 1.0 ± 1.1 mG (1998). The daily maximum measurements among these workers averaged 48 ± 113 mG, but these peaks were brief and had little influence on the workday average.

Ap.5.4 Reducing EMF

EMF from transmission lines can be reduced in three primary ways: increasing distance from the source, shielding, and field cancellation. SDG&E EMF guidelines, like similar sources of information, list several techniques that rely upon these primary methods (SDG&E, 1994 p14). Distances can be increased laterally and vertically. Vertical height can be affected by tower and pole design and by the effects of terrain. SDG&E EMF guidelines also indicate the possibility of fundamental design changes, such as specification of a line at a higher operating voltage to reduce currents and use of underground pipe-type cables that are magnetically shielded by the pipe in addition to achieving the field cancellation inherent in cable designs. In is important to recognize that rock, soil, and other common components of the ground do not shield magnetic fields. Excepting pipe-type cables, the changes in magnetic field strength patterns from buried circuits reflect the field cancellation that is created by placing the three electrical phases close to one another. Electric fields also can be reduced by distance, shielding and field cancellation. Electric fields are shielded considerably by building materials and to some extent by foliage, but common building materials and plants do not reduce magnetic fields.

Field cancellation occurs by combining fields of opposing phases. In principle, magnetic fields of two currents that are very close but flow in opposite directions would cancel almost completely. In practice, three-phase electric power transmission and distribution circuits allow designs that create partial field cancellation, sometimes referred to as "low-reactance phasing". In 50/60-Hz power transmission engineering, a "circuit" consists of three phases, for example, labeled by A, B, C, each designed to carry equal current. (In some cases, two or more conductors ["wires"] are used per phase. These "bundled conductors", which are at the same instantaneous voltage, are much closer to each other than the conductors of other phases.) Field cancellation also can be achieved when there are two or more transmission or distribution circuits located near each other. In all cases, the greatest magnetic field cancellation at a particular location occurs for specific currents on the conductors and for specific geometric positions of the conductors in space. In situations with multiple conductors, determination of the optimal arrangement for a given set of currents and geometries can be complicated.

Electric and magnetic fields at a distance from transmission and distribution circuits decrease with distance, approximately following an inverse square law (that is, field strengths are proportional to $1/\text{distance}^2$) at distances greater than the separation between phase conductors for balanced three-phase systems, but decreasing less rapidly closer to the tower or pole supporting the circuit and for unbalanced systems even at a distance. Balanced three-phase systems configured for low reactance are characterized by a more rapid decrease in magnetic field strength with distances that approximately follow an inverse cube law (that is, proportional to $1/\text{distance}^3$).

Ap.5.5 Summary of EMF Research

Numerous scientists and panels have examined whether exposure to power-frequency EMF causes adverse health effects. Evaluations have been conducted to give guidance to state and federal agencies in the USA and governmental agencies worldwide. These reviews and reports include those prepared by California (California Department of Health Services [CDHS, 2002]) and several states. The most recent and complete federal government report was prepared by the U.S. National Institute of Environmental Health Sciences (NIEHS, 1998; 1999). The World Health Organization (2001) and its affiliated International Agency for Cancer Research (IARC, 2002) also have sponsored in-depth reviews. Ministries and agencies of many countries also have contributed reports based on scientific expertise. Standards-setting organizations such as the International Non Ionizing Radiation Committee (ICNIRP, 1998), Institute of Electrical and Electronic Engineers (IEEE) International Committee on Electromagnetic Safety (ICES) (ICES, 2002), and American Conference of Governmental and Industrial Hygienists also have evaluated the literature in order to specify protective levels for workers and the general public.

Expert Panel Interpretations of the State of the Science — Expert panel reports offer consensus judgments on the quality of the evidence that EMF exposures could adversely affect health. A typical scientific panel has expertise in a number of disciplines relevant to scientific research on EMFs: epidemiology, medicine, physics and biophysics, laboratory animal studies, cellular physiology, cancer biology, and public health. Although biases cannot be entirely excluded, the consensus process adopted by most such bodies tends to ensure that the findings are representative, defensible scientific judgments based on currently available evidence. The similarity of conclusions expressed by the various panels indicates convergent views in the international scientific community. However, each panel reflects the influences of new research and therefore the conclusions from various reports have evolved over time. For that reason it is useful to consider these reports in date order.

California Department of Health Services — The California Department of Health Services (CDHS) conducted a comprehensive review and evaluation of studies relevant to potential health risks of EMF from power lines in response to an investigational order from the California Public Utilities Commission (Neutra et al., 2002). The conclusions of the three staff scientists who wrote the report were presented in terms of the likelihood that specific disease outcomes are caused by EMF. Their summary reported, "To one degree or another, all three of the DHS scientists are inclined to believe that EMF can cause some degree of increased risk of childhood leukemia, adult brain cancer, Lou Gehrig disease, and miscarriage." The individual authors came to differing conclusions concerning increased risks of breast cancer, heart disease, Alzheimer disease, depression, or symptoms attributed by some to sensitivity to EMF. All three scientists were "close to the dividing line between believing and not believing" concerning increased risk of suicide. For adult leukemia, two of the scientists were similarly undecided whereas the third was "prone to believe" that EMF exposure causes some increase in risk. On the other hand, all three expressed strong beliefs that EMF did not increase the risk of birth defects or low birth weight, and was not a cause of cancer in general ("universal carcinogen"). It may be noted that expression of conclusions in probabilistic terms that are summarized as beliefs of varying strength is unusual in the scientific literature and furthermore that the strength of these beliefs and terms such as "some degree" did not lead directly to quantitative risk estimates.

The CDHS conclusions exhibit stronger belief in a causal relationship between EMF exposure and increased risk of certain health problems than other scientific committees evaluating the EMF scientific literature. Neutra et al. (2002) offered possible reasons for their greater confidence in a causal influence of EMF on risk of specific diseases. These included less confidence in negative results from laboratory studies because of their insensitivity to weak effects. This allowed the authors greater trust in the positive associations observed in epidemiological studies of human populations, despite the absence of scientific experiment or theory to support the associations. For childhood leukemia, the overall epidemiological evidence was neither conclusive nor could it be readily explained as the result of chance associations (Greenland et al., 2000).

International Agency for Cancer Research (IARC) — The "overall evaluation" from a comprehensive investigation of laboratory and epidemiological data (IARC, 2002) was that "Extremely low frequency magnetic fields are *possibly carcinogenic to humans (Group 2B)*", and secondly, "Static electric and magnetic fields and extremely low-frequency electric fields are *not classifiable as to their carcinogenicity to humans (Group 3)*" (emphasis in original text). The impetus for this Group 2B classification was the "*limited evidence* in humans for the carcinogenicity of extremely low frequency magnetic fields in relation to childhood leukaemia" based on two pooled analyses that were consistent in finding elevated risk for exposures above 3 to 4 mG. This association was "unlikely to be due to chance, but may be affected by selection bias." Selection bias describes a form of error that may be present in studies because of inherent flaws, which epidemiologists may infer, but find difficult to eliminate or measure their influence. In contrast to the findings on childhood leukemia, IARC (2002) concluded there was "*inadequate evidence*" that electric and magnetic fields cause other human and animal cancers.

Group 2B denotes the existence of "limited evidence" for carcinogenicity (cancer causation) in humans and "less than sufficient evidence" that EMFs cause cancer in laboratory animal experiments. IARC also places coffee (with respect to urinary bladder cancer only), styrene, gasoline engine exhaust, and welding fumes among the 233 other agents presently listed in Group 2B, the weakest of three categories that IARC uses for potential carcinogens. In contrast, Group 2A, "probably carcinogenic to humans", is distinguished by the existence of strong evidence for carcinogenicity from animal experiments but limited evidence (or in cases, insufficient evidence) for carcinogenicity in humans. Group 2A includes agents such as diesel engine exhaust, certain viruses, ultraviolet light, and certain solvents, drugs and industrial chemicals. The highest category, Group 1, applies to agents such as alcoholic beverages, asbestos, benzene, tobacco, certain viruses, and x- and gamma radiation, for which there is "sufficient evidence of carcinogenicity in humans". The lowest two categories are Group 3 ("not classifiable as to carcinogenicity in humans") and Group 4 ("probably not carcinogenic to humans").

International EMF Project — The World Health Organization (WHO) program on Protection of the Environment includes an initiative concerning potential health effects of powerline electric and magnetic fields. The International EMF Project (IEMFP) was begun in 1996 to identify research needs that were presented in a research agenda (IEMFP, 2001). The IEMFP coordinates research, holds meetings to evaluate research issues, and publishes reports on technical topics, but does not sponsor research. In light of the evaluation of ELF EMF as a Group 2B carcinogen (IARC, 2002), this group has begun a comprehensive assessment that will include both cancer and non-cancer adverse health effects.

IEEE Standards Board — The International Committee on Electromagnetic Safety (ICES), a group sponsored by IEEE, develops standards for exposure to electric and magnetic fields. A subcommittee completed standard C95.6 for frequencies below 3,000 Hz, including exposures to 60 Hz electric and magnetic fields (ICES C95.6, 2002). Frequency-dependent standards were set on the basis of established short-term electrical responses of nerve, muscle and synapses in the nervous system. Synapses are the microsocpic electrochemical connections between nerve cells in the brain and between nerve and muscle cells. The committee noted awareness of "epidemiological associations between long-term exposure to magnetic fields and disease, including childhood leukemia in residential environments and chronic lymphocytic leukemia in occupational environments," but found that their interpretation was unclear because there was no evidence from laboratory animal studies that magnetic fields can cause cancer and other diseases. ICES C95.6 (2002) found no reason for a standard based on long-term exposure because the scientific literature did not show harmful effects below the standard set by short-term effects.

National Radiological Protection Board — A seven member Advisory Group on Non-ionising Radiation was formed by the National Radiological Protection Board (NRPB) to make a comprehensive re-evaluation for United Kingdom (UK) health authorities of the experimental and epidemiological research on EMFs and cancer (NRPB, 2001). In recognition of better evidence from recent epidemiological studies on childhood leukemia and exposure to power frequency magnetic fields, the group concluded that "Taken in conjunction [the studies on childhood leukemia] suggest that relatively heavy average exposures of 4 mG or more are associated with a doubling of the risk of leukaemia in children under 15 years of age. The evidence is, however, not conclusive" (NRPB, 2001). They concluded there was "no comparable evidence of an association" concerning leukemia in adults and for brain tumors in children and adults.

The Advisory Group found that laboratory studies on animals and cellular systems did not provide clear and convincing evidence for biological effects, particularly for cancer in animals or DNA effects in cells exposed to EMFs at "levels likely to be encountered" (NRPB, 2001) The report noted that that results on cellular studies were often contradictory and confirmations between laboratories were "lacking", and that some animal data were "equivocal." The group identified a few areas of in vitro study where findings were more suggestive of effects than elsewhere, but commented that these often occurred using laboratory magnetic fields more than one thousand times stronger than common average household fields in the UK.

These observations led to this overall conclusion: "In the absence of clear evidence of a carcinogenic effect in adults, or of a plausible explanation from experiments on animals or isolated cells, the epidemiological evidence is currently not strong enough to justify a firm conclusion that such fields cause leukaemia in children. Unless, however, further research indicates that the finding is due to chance or some currently unrecognised artefact, the possibility remains that intense and prolonged exposures to magnetic fields can increase the risk of leukaemia in children." (NRPB, 2001)

National Institute of Environmental Health Sciences (USA) — The National Institute of Environmental Health Sciences (NIEHS) was charged by Congress under the EMF-RAPID Program to evaluate potential health effects of EMF exposure. Following detailed technical reviews, a 1998 working group reported its findings using the IARC criteria for cancer assessment (NIEHS, 1998). The Working Group's overall evaluation was that EMFs were "possibly carcinogenic" (Group 2B) based on limited evidence concerning childhood leukemia and residential exposures and an increased incidence of one type of adult leukemia (CLL or chronic lymphocytic leukemia) among occupationally exposed adults. The more recent IARC (2001) and NRPB (2001) assessments are consistent with the NIEHS (1998) assessment on childhood leukemia, but did not cite the evidence for an association with adult CLL leukemia as sufficient for a Group 2B classification. The NIEHS Working Group found that the animal and cell research done in the laboratory neither supported nor refuted the conclusions drawn from epidemiological studies, a position similar to that in later assessments discussed above.

The Working Group report was followed by a summary report from the agency director (NIEHS, 1999) in which he transmitted the agency conclusions to Congress. NIEHS concluded, "The scientific evidence suggesting that ELF-EMF exposures pose any health risk is weak. The strongest evidence for health effects comes from … childhood leukemia and chronic lymphocytic leukemia in occupationally exposed adults" (NIEHS, 1999 p ii). NIEHS stated, "The lack of connection between the human data and the experimental data (animal and mechanistic) severely complicates the interpretation of these results. . . . [G]iven the weak magnitude of these increased risks, some other factor or common source of error could explain these findings. However, no consistent explanation other than exposure to ELF-EMF has been identified." Agency Director Kenneth Olden presented the NIEHS conclusion that "ELF-EMF exposure cannot be recognized at this time as entirely safe because of weak scientific evidence that exposure may pose a leukemia hazard. In my opinion, the conclusion of this report is insufficient to warrant aggressive regulatory concern. . . . [P]assive regulatory action is warranted such as a continued emphasis on education of both the public and the regulated community on means aimed at reducing exposures."

International Commission on Non-ionizing Radiation Protection — The International Commission on Non-ionizing Radiation Protection (ICNIRP) is an independent international group that prepared guidelines for EMF exposure in cooperation with WHO. The guidelines for exposure to power frequency (50 and 60 Hz) fields was based on "known adverse health effects", which, based on a review scientific literature, did not include the induction of cancer because ICNIRP concluded that cancer induction was "not considered to be established, and so these guidelines are based on short-term, immediate health effects such as simulation of peripheral nerves and muscles, shocks and burns….". (ICNIRP, 1998) Concerning long-term effects, ICNIRP concluded that "…epidemiological research has provided suggestive, but unconvincing, evidence of an association between possible carcinogenic effects and exposure at levels of 50/60 Hz magnetic flux densities substantially lower than those recommended in these guidelines." (ICNIRP, 1998) Weak epidemiological evidence in the absence of support from animal studies precluded ICNIRP from basing exposure guidelines on that evidence (ICNIRP 1998, p 499). Animal studies did not provide supporting evidence for effects reported in vitro, and taken alone, the results from in vitro research were not useful as a "primary basis for assessing possible health effects of EMF."

National Research Council (USA) — The National Research Council (NRC) prepared a report in response to Congressional legislation that established the EMF-RAPID program (NRC, 1996). The NRC reviewed and evaluated scientific information concerning residential EMF exposure and cancer incidence, reproduction and development, and neurobiological responses. The committee also was conducted a risk assessment. The committee concluded that "the current body of evidence does not show that exposure to these fields presents a human-health hazard."

Expert Panels in Canada, Europe, Australia, and Asia — Scientific expert panels in a number of countries have evaluated the state of the science and in cases developed regulations for exposure in Australia, Austria, Canada, China, Denmark, France, Germany, Italy, Japan, The Netherlands, New Zealand, Poland, Russia, Spain, Sweden, Switzerland, and the United Kingdom (incomplete listing). Many of these countries also have produced brochures and public information documents. The tone of many of the technical and public information reports is summarized in a public information brochure from the New Zealand Ministry of Health: "In recent years there has been concern that these fields may have effects on health. Most research into this question has concentrated on finding out whether the magnetic fields can cause cancer or could assist the development of a cancerous condition. Other effects investigated include miscarriages, Alzheimer's disease and depression. In spite of all the studies that have been carried out, it is still not clear whether the fields pose any health risks. If there are risks, the results obtained do show that they must be very small (National Radiation Laboratory, 2001)."

Ap.5.6 References

See Section D.9, Public Health and Safety, for references used in this appendix.

Table Ap.5-2. Miguel-Mission 230 kV #2 Project – EMF Data

	2007 Existing Conf (mG)		2007 MM2 Proposed (mG)		% Chg (MM2 Prop./Exist)		2007 Low React'ce (mG)		% Chg (LowReact/MM2)		% Chg (LowReact/Exist)	
Segment	Left ROW	Right ROW	Left ROW	Right ROW	Left ROW	Right ROW	Left ROW	Right ROW	Left ROW	Right ROW	Left ROW	Right ROW
A1	55.13	94.97	60.79	32.80	-10.3%	65.5%	24.85	25.13	59.1%	23.4%	54.9%	73.5%
A2	55.13	94.97	37.90	16.29	31.3%	82.8%	11.40	9.12	69.9%	44.0%	79.3%	90.4%
A3	53.88	62.14	37.90	16.29	29.7%	73.8%	11.40	9.12	69.9%	44.0%	78.8%	85.3%
B1	49.77	110.93	43.88	43.05	11.8%	61.2%	26.62	24.03	39.3%	44.2%	46.5%	78.3%
B2	49.26	109.82	42.69	31.21	13.3%	71.6%	26.51	21.17	37.9%	32.2%	46.2%	80.7%
B3	85.32	97.98	59.95	24.10	29.7%	75.4%	38.23	19.96	36.2%	17.2%	55.2%	79.6%
C1	54.61	58.05	49.16	22.26	10.0%	61.7%	29.56	18.38	39.9%	17.4%	45.9%	68.3%
D1	21.31	190.78	35.82	70.18	-68.1%	63.2%	21.48	39.48	40.0%	43.7%	-0.8%	79.3%
E1	33.16	188.71	44.66	70.58	-34.7%	62.6%	18.99	40.89	57.5%	42.1%	42.7%	78.3%
E2	37.94	189.51	47.07	70.35	-24.1%	62.9%	22.25	41.35	52.7%	41.2%	41.4%	78.2%
E3	29.45	187.68	47.29	70.85	-60.6%	62.2%	31.68	40.62	33.0%	42.7%	-7.6%	78.4%
F1	15.00	81.14	4.17	35.32	72.2%	56.5%	10.30	24.00	-147.0%	32.0%	31.3%	70.4%
F2	11.73	80.53	3.32	35.58	71.7%	55.8%	4.46	24.63	-34.3%	30.8%	62.0%	69.4%
F3	15.42	80.41	4.55	35.72	70.5%	55.6%	7.18	24.89	-57.8%	30.3%	53.4%	69.0%
F4	30.05	80.67	27.47	35.37	8.6%	56.2%	26.25	24.50	4.4%	30.7%	12.6%	69.6%
F5	20.52	79.19	20.12	35.71	1.9%	54.9%	19.04	24.83	5.4%	30.5%	7.2%	68.6%
F6	37.60	73.36	22.57	53.01	40.0%	27.7%	22.67	44.84	-0.4%	15.4%	39.7%	38.9%
F7	15.96	48.85	26.90	56.10	-68.5%	-14.8%	26.11	47.09	2.9%	16.1%	-63.6%	3.6%
Average	37.29	106.09	34.23	41.93	8.2%	60.5%	21.05	28.00	38.5%	33.2%	43.5%	73.6%
Ave/Total	71.69		38.08		46.9%		24.53		35.6%		65.8%	

	2007 Peak Load with the Existing Configuration (mG)										
Segment	Left 250	Left 200	Left 150	Left 100	Left 50	CenterLine	Right 50	Right 100	Right 150	Right 200	Right 250
A1	12.99	20.58	37.75	82.20	54.31	167.73	240.28	55.51	74.13	32.90	18.43
A2	12.99	20.58	37.75	82.20	54.31	167.73	240.28	55.51	74.13	32.90	18.43
A3	12.32	19.69	36.57	81.35	56.82	165.44	256.89	99.61	41.80	22.34	13.83
B1	8.70	12.88	20.91	49.77	79.36	143.76	264.78	110.93	44.11	22.73	13.73
B2	8.52	12.63	20.54	49.26	79.20	142.36	269.52	109.82	40.02	21.18	12.96
B3	8.52	12.75	22.24	85.32	76.66	139.45	268.57	97.98	39.98	21.28	13.01
C1	9.74	14.81	27.76	70.57	117.24	249.68	204.37	108.64	26.40	15.94	10.52
D1	5.79	8.08	12.05	21.31	51.18	88.82	264.20	190.78	64.66	29.17	16.23
E1	6.08	8.68	13.30	22.81	59.72	184.54	268.73	105.78	40.67	20.49	12.17
E2	6.65	9.61	15.05	26.63	57.92	175.77	267.84	106.81	41.37	20.95	12.49
E3	5.35	7.48	11.05	18.35	67.61	196.02	269.95	104.46	39.76	19.89	11.76
F1	3.29	4.71	7.48	15.00	20.89	56.05	184.44	81.14	28.21	13.41	7.69
F2	2.82	3.95	6.06	11.73	24.79	62.32	186.39	80.53	27.68	13.05	7.44
F3	2.86	4.05	6.51	15.42	26.08	62.56	186.51	80.41	27.64	13.03	7.43
F4	2.61	3.78	7.48	30.05	24.71	61.90	186.88	80.67	27.60	12.95	7.36
F5	1.63	2.25	4.78	20.52	62.11	70.86	190.45	79.19	26.53	12.25	6.87
F6	1.91	3.34	9.03	37.60	49.52	65.97	188.20	73.36	20.42	10.04	5.79
F7	2.28	3.48	6.32	15.96	39.81	82.72	172.84	48.85	22.28	10.79	6.18
Average	6.39	9.63	16.81	40.89	55.68	126.87	228.40	92.78	39.30	19.18	11.24
Average	58.83										

Segment	2007 Peak Load with the Proposed Miguel-Mission # 2 Configuration (mG)										
	Left 250	Left 200	Left 150	Left 100	Left 50	CenterLine	Right 50	Right 100	Right 150	Right 200	Right 250
A1	4.97	8.91	23.83	93.66	96.01	89.41	118.54	32.70	11.92	4.75	2.98
A2	5.01	9.21	21.55	73.18	95.35	65.98	118.17	29.16	10.22	5.09	3.07
A3	5.01	9.21	21.55	73.18	95.35	65.98	118.17	29.16	10.22	5.09	3.07
B1	3.24	5.74	12.37	43.88	120.06	74.05	149.31	43.05	11.56	4.92	2.71
B2	3.01	5.39	11.78	42.69	122.38	82.53	134.53	31.21	6.04	2.97	1.79
B3	2.91	5.16	11.39	59.95	129.89	83.96	128.12	24.10	7.30	3.48	2.03
C1	3.92	7.65	20.41	101.72	100.33	129.41	75.00	31.49	11.03	2.51	1.27
D1	3.02	4.72	8.26	35.82	113.15	62.28	124.46	70.18	18.13	7.49	4.07
E1	2.79	4.44	8.05	19.17	96.20	94.74	125.26	34.33	11.60	5.59	3.28
E2	3.28	5.35	10.17	25.33	93.56	97.40	124.24	34.56	11.88	5.81	3.44
E3	2.24	3.42	5.70	14.35	100.51	91.79	126.42	34.09	11.27	5.35	3.10
F1	0.32	0.48	1.08	4.17	8.33	41.22	135.85	35.32	9.27	3.69	1.87
F2	0.67	1.04	1.90	3.32	18.10	45.30	134.18	35.58	9.65	3.96	2.08
F3	0.67	1.03	1.84	4.55	20.00	45.38	134.01	35.72	9.71	3.99	2.09
F4	0.90	1.83	5.50	27.47	24.28	44.50	134.74	35.37	9.49	3.85	2.00
F5	1.55	2.85	6.42	20.12	38.51	32.41	138.01	35.71	8.84	3.25	1.53
F6	1.58	3.09	7.67	22.57	32.71	31.90	139.44	53.01	11.21	3.83	1.75
F7	1.43	2.89	7.45	26.90	49.44	9.16	140.76	56.10	10.06	3.57	1.67
Average	2.58	4.58	10.38	38.45	75.23	65.97	127.73	37.82	10.52	4.40	2.43
Average	34.55										

Segment	2007 Peak Load, Miguel-Mission # 2 with Miguel-Sycamore Canyon # 2 in a Low-Reactance Configuration (mG)										
	Left 250	Left 200	Left 150	Left 100	Left 50	CenterLine	Right 50	Right 100	Right 150	Right 200	Right 250
A1	1.63	3.40	12.09	16.20	97.54	67.17	69.92	23.17	8.08	2.26	1.35
A2	0.91	1.67	5.04	30.39	94.74	53.36	67.82	16.68	5.57	2.63	1.51
A3	0.91	1.67	5.04	30.39	94.74	53.36	67.82	16.68	5.57	2.63	1.51
B1	0.91	2.02	6.17	26.62	96.65	52.21	92.56	24.03	5.67	2.08	0.99
B2	1.04	2.22	6.47	26.51	93.21	56.34	79.05	21.17	3.03	1.03	0.48
B3	1.36	2.90	8.60	38.23	91.73	58.91	72.77	19.96	4.50	1.77	0.89
C1	1.46	3.66	14.16	46.02	81.37	80.92	44.87	23.68	9.42	2.17	0.80
D1	1.37	2.43	5.76	21.48	60.61	74.24	83.03	39.48	9.76	3.87	2.03
E1	0.92	1.48	2.89	8.24	45.70	71.49	70.41	19.86	6.43	2.96	1.68
E2	0.34	0.75	2.14	8.99	53.42	70.21	72.25	19.51	5.94	2.59	1.39
E3	1.47	2.48	5.22	16.61	45.11	72.49	69.24	20.10	6.76	3.21	1.86
F1	0.42	0.82	2.23	10.30	12.49	23.90	96.32	24.00	5.87	2.16	1.02
F2	0.71	1.14	2.25	4.46	17.14	33.53	91.96	24.63	6.83	2.87	1.53
F3	0.71	1.13	2.18	7.18	20.49	33.69	91.66	24.89	6.94	2.92	1.56
F4	0.92	1.83	5.38	26.25	24.00	32.77	92.42	24.50	6.71	2.78	1.46
F5	1.47	2.69	6.04	19.04	38.67	21.15	95.58	24.83	6.09	2.22	1.04
F6	1.49	2.92	7.33	22.67	33.00	20.96	97.40	44.84	9.34	3.07	1.38
F7	1.49	3.02	7.91	26.11	51.52	11.93	98.35	47.09	8.22	2.82	1.30
Average	1.09	2.12	5.94	21.43	58.45	49.37	80.75	25.51	6.71	2.56	1.32
Average	23.20										