

**ATTACHMENT 3-C: ELECTRIC AND MAGNETIC FIELDS**



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### **1.0 ELECTRIC AND MAGNETIC FIELDS**

#### **1.0.0 Electrical Effects**

This section describes potential effects from exposure to electric and magnetic fields (EMF) associated with the proposed East County Substation Project.

EMFs are present wherever electricity flows—around appliances and transmission lines, in offices, schools, and homes. Electric fields are invisible lines of force created by voltage and are shielded by most materials. Magnetic fields are invisible lines of force created by electric current, and magnetic fields are not shielded by most materials. These fields are low-energy, extremely low-frequency, and should not be confused with high-energy or ionizing radiation such as X-rays and gamma rays.

Some studies have reported a weak association between estimates of residential magnetic field exposure and childhood leukemia. These epidemiological (human statistical) studies have not shown that the exposure to magnetic fields from powerlines actually causes leukemia because other explanations for the association, such as study bias, cannot be ruled out. And virtually all controlled laboratory studies on animals, tissues and cells fail to support a causal association. Some studies on workers have also found associations between estimated magnetic field exposure and some forms of cancer and other disorders, but these results have been highly inconsistent.

#### **1.0.1 Background**

The transport of electricity is described in terms of both its voltage and current flow. Using these terms, the transport of electricity is analogous to the flow of water through a pipe. The pressure driving the water is the counterpart to the voltage on the powerline, and the amount of water flowing in the pipe is the counterpart to the amount of electric current on the line.

Electrical lines and equipment produce an electric field as a result of the voltage applied to their wiring. The strength of the electric field is expressed in volts per meter (V/m) or kilovolts per meter (kV/m). The electric field strength falls off sharply with distance from the source. Objects such as trees, houses, concrete and other building materials shield electric fields. Thus, even in proximity to powerlines or substations, the electric field in nearby residences is largely a result of internal sources; external sources of electric fields are effectively shielded from indoor environments.

The flow of current in electrical lines and equipment produces a magnetic field. The strength of the magnetic field is measured in units called Gauss (G) or Tesla (T). Because these units are much too large for expressing magnetic field intensities encountered in daily life, magnetic field intensities are most often expressed in milligauss (mG), which is one-thousandth of a Gauss, or microtesla ( $\mu\text{T}$ ), which is one-millionth of a tesla. Ten mG is equal to 1.0  $\mu\text{T}$ . The unit  $\mu\text{T}$  generally is used internationally and in technical literature. The field intensity varies with the amount of current flow. Like electric fields, the intensity of the magnetic field decreases as

distance from the source increases. But unlike electric fields, magnetic fields are not shielded by buildings, trees, and most other objects.

Electrical transmission and distribution systems are not the only sources of magnetic fields. Within homes and workplaces, local sources of magnetic fields include building wiring and plumbing, electric blankets, electric stoves, computer terminals, bedside clocks, ceiling fans, and other appliances that people may use for prolonged periods. Indeed, some of the common sources of higher magnetic fields are appliances and electrical devices found within the home. The magnetic field levels from such sources in typical use can range up to thousands of mG or higher; however, the duration of exposure from many appliances is typically much shorter than that from other sources. Thus, exposure to both electric and magnetic fields occurs continuously and is not simply a function of living or working near a powerline or electrical facility. Exposure depends on the many sources and field strength present where a person lives, works, or otherwise spends time.

### **1.0.2 History**

In the late 1960s and early 1970s, the possibility of adverse health effects resulting from exposures to electric fields received considerable attention. This attention was motivated by reports from the Soviet Union of various health complaints among utility workers in high-voltage switchyards. Subsequent research on electrical utility workers in Europe and North America failed to confirm the complaints; Soviet investigators later indicated that their concerns had been “overstated.”

In the 1980s, interest shifted primarily to magnetic fields for two major reasons. First, Wertheimer and Leeper in 1979 published a paper reporting a statistical association between childhood cancer and the apparent current-carrying capacity of the powerlines near the study residences. Second, it was recognized that exposure to electric fields from outside sources is limited because of effective shielding by most materials. This was confirmed in studies that failed to find associations between the capacity of outside powerlines and electric fields levels within homes. The shift away from electric field research has been further justified by subsequent residential studies that fail to report an association between measured electric fields and cancer in either children or adults.

### **1.0.3 Current Research**

To assess potential health risks from an environmental agent such as power frequency EMF, interdisciplinary groups of scientist must consider the results from epidemiological investigations and laboratory research on cells, tissues, and a variety of animal species.

### **Epidemiology**

Epidemiology investigates the distribution, patterns, and potential causes of disease within human populations. The objective of epidemiology is to evaluate and measure the association between exposures to environmental factors (e.g., asbestos, benzene) and health outcomes (e.g., lung disease, leukemia). Epidemiological studies look for associations between the exposure of a group of people to an agent (possible risk factor) and the occurrence of disease in that group. Epidemiology deals with people in their natural environments, so exposures cannot be controlled

or limited to the factors being studied. Thus, epidemiology addresses associations with disease outcomes; generally, it does not establish whether a particular agent causes disease.

Some documented epidemiological studies conducted in community settings have reported weak associations between childhood cancer and estimates of exposure to magnetic fields. Other epidemiological studies, equally well-designed and well-conducted, have reported no associations between proximity to powerline sources of magnetic fields and cancer. Those studies reporting associations are not consistent with respect to cancer type. Two pooled analyses, which combined data from multiple studies, reported an association between rates of childhood leukemia and measured magnetic fields above 3 or 4 mG, but found little or no association with so-called "wire codes" (proximity and current-carrying capacity of nearby powerlines). In earlier individual studies, the opposite pattern seemed to predominate: "wire codes" showed a significant association, while measured fields did not.

Exposure assessment is a universal deficiency in the epidemiological literature. The ability of surrogate measures—such as wire codes, proximity, and current-carrying capacity of powerlines—to predict power-frequency magnetic field exposures is limited. In the occupational setting, some studies have reported weak associations between work in electrical occupations and some health outcomes such as leukemia or brain cancer, but the findings are inconsistent. And, in many occupational studies, exposure is inferred from job title classifications.

### **Laboratory Studies**

A wide range of magnetic field intensities at extremely low frequency (ELF) exposures have been studied in the laboratory to attempt to elicit biological responses and identify the conditions and mechanisms under which they can be produced. No accepted biophysical mechanism currently exists that can readily explain how a cell could respond to low-intensity, low-frequency magnetic fields. Any imposed external electric and magnetic fields must compete with fundamental physical fluctuations (e.g., thermal noise) and endogenous background biological fields (e.g., those generated by the normal activity of the heart, brain, skeletal muscle, and smooth muscle in the gut and airways). Most laboratory studies have involved exposures hundreds to thousands of times higher than those typically found in residential backgrounds and some occupational settings. From several thousand studies in the literature, relatively few biological responses are confirmed to occur with exposure to time-varying magnetic fields at intensities of less than 1,000 mG, and those that have been confirmed have not been linked to adverse health effects. Although there is considerable interest in determining whether there is any biological basis for a cause-and-effect relationship between exposure to power frequency magnetic fields and cancer, the available laboratory data have not provided substantive support for this hypothesis.

### **Research Conclusions**

Nationally and internationally recognized scientific organizations and independent regulatory advisory groups have been organized to conduct scientific reviews of the EMF research and peer reviewed publications. Their ability to assemble experts from a variety of disciplines to review the full body of research on this complex issue gives their reports credibility. Without exception, these major reviews have reported that the body of data, as large as it is, does not demonstrate that exposure to power-frequency magnetic fields causes cancer or poses other health risks,

although the possibility cannot be dismissed. Because of the uncertainty, most reviews recommend further research, and, appropriately, research is ongoing worldwide. The weakness of the reported epidemiological associations, the lack of consistency among studies, and the severe limitations in exposure assessment in the epidemiological studies, together with the lack of support from laboratory research, were key considerations in the findings of the scientific reviews. Examples of these advisory groups and summaries of their findings are provided below.

#### **1.0.4 International Reviews**

In 2007, the World Health Organization (WHO) released its long-awaited review of EMF research, *Extremely Low Frequency Fields Environmental Health Criteria (EHC) Monograph No. 238*. In brief, the review updates and affirms the findings of the International Agency for Research on Cancer (IARC) in its 2002 classification of EMF as a "possible human carcinogen" with respect to childhood leukemia. The WHO document also affirms IARC's previous finding that evidence for all other childhood cancers and all adult cancers is "inadequate." Evidence for all other non-cancer diseases studied also is classified "inadequate."

The EHC reports that epidemiology (human statistical) studies show a "consistent" association between childhood leukemia and various surrogate measures of long-term residential exposure to low-level power frequency magnetic fields. This epidemiological evidence is classified as "limited" because other explanations, such as study bias, cannot be ruled out. And, "virtually all" controlled laboratory studies on animals, tissues and cells fail to support a causal association.

While rejecting exposure limits for ordinary residential environments, the WHO does recommend "precautionary approaches" to reduce exposure if it can be done without compromise to the "essential health, social and economic benefits of electric power." The EHC states, "Given the weakness of the evidence for a link between exposure to ELF ['extremely low frequency' includes power frequency] magnetic fields and childhood leukemia and the limited potential impact on public health, the benefits of exposure reduction on health are unclear and thus the cost of reducing exposure should be very low." More specifically, the EHC recommends that: "Changes to engineering practice to reduce EMF exposure from equipment or devices should be considered, provided that they yield other additional benefits, such as greater safety, or involve little or no cost."

In 2004, the National Radiological Protection Board (NRPB) in the United Kingdom published its *Review of the Scientific Evidence for Limiting Exposure to Electromagnetic Fields (0-300GHz)*. The report states:

“It is concluded that currently the results of these [epidemiological and experimental] studies on EMF’s and health, taken individually or as collectively reviewed by expert groups, are insufficient either to make a conclusive judgment on causality or to quantify appropriate exposure restrictions.”

The Health Council of the Netherlands released an Annual Update to the Dutch government in January 2004 on “the possible health effects of ELF electromagnetic fields”.

The (Health Council of the Netherlands) Committee, like the IARC itself, points out that there is no evidence to support the existence of a causal relationship here. Nor has research yet uncovered any evidence that a causal relationship might exist. Nevertheless, new suggestions for possible mechanisms ... are regularly put forward. However, none of these hypotheses can presently explain how ELF magnetic fields exposure might lead to cancer.

The IARC, a part of the WHO, conducted a major EMF review. The organization's Fact Sheet No. 263 on that review states:

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 based on epidemiological studies of childhood leukemia. Evidence for all other cancer 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.

“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.

Examples of “Possibly Carcinogenic to Humans” are: Coffee, styrene, gasoline engine exhaust, and welding fumes.

In March 2001, an independent advisory group to the NRPB in the United Kingdom (UK) published a wide-ranging and thorough review of scientific research on EMF. The review covers work published since the NRPB's first major review of the topic in 1992 and supplementary reports in 1993 and 1994. The report concludes that the possibility of an effect cannot be dismissed:

Laboratory experiments have provided no good evidence that extremely low frequency electromagnetic fields are capable of producing cancer, nor do human epidemiological studies suggest that they cause cancer in general. There is, however, some epidemiological evidence that prolonged exposure to higher levels of power frequency magnetic fields is associated with a small risk of leukemia in children. In practice, such levels of exposure are seldom encountered by the general public in the UK. 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 leukemia in children. Unless, however, further research indicates that the finding is due to chance or some

currently unrecognized artifact, the possibility remains that intense and prolonged exposures to magnetic fields can increase the risk of leukemia in children.

### **1.0.5 Federal Electric and Magnetic Fields Program**

In 1992, the U.S. Congress authorized the Electric and Magnetic Fields Research and Public Information Dissemination Program (EMF-RAPID Program) in the Energy Policy Act (PL 102-486, Section 2118). Congress instructed the National Institute of Environmental Health Sciences (NIEHS), National Institutes of Health and the U.S. Department of Energy (DOE) to direct and manage a program of research and analysis aimed at providing scientific evidence to clarify the potential for health risk from exposure to extremely low-frequency electric and magnetic fields (ELF-EMF). The EMF-RAPID Program had three basic components: 1) a program focusing on health effects research, 2) information compilation and public outreach, and 3) a health assessment for evaluation of any potential hazards arising from exposure to ELF-EMF. This program was completed in December 1998.

In June 1999, NIEHS published its report, *Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields*, with its findings and conclusions from this program of research. The Executive Summary of the report concluded that:

“The scientific evidence suggesting that ELF-EMF exposures pose any health risk is weak ... The NIEHS concludes the ELF-EMF exposure cannot be recognized an entirely safe because of weak scientific evidence that exposure may pose a leukemia hazard. In our opinion, this finding is insufficient to warrant aggressive regulatory concern.” Panels charged with recommending exposure limits for electric and/or magnetic fields have concluded that there are no meaningful experimental data (e.g., no dose-response information is available) on which to base standards or limits to which the public is exposed.

In 1999, the National Academy of Sciences published a report *Research on Power-Frequency Fields Completed Under the Energy Policy Act of 1992*. In response to a request from the DOE, following the directives of the Energy Policy Act of 1992, the National Research Council (NRC) established a committee of scientists and engineers to review the activities conducted under the EMF-RAPID program.

The 1999 NRC report concluded that:

An earlier Research Council assessment of the available body of information on biologic effects of power-frequency magnetic fields (NRC 1997) led to the conclusion "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". The new, largely unpublished contributions of the EMF-RAPID program are consistent with that conclusion. We conclude that no finding from the EMF-RAPID program alters the conclusions of the previous NRC

review on the Possible Effects of Electromagnetic Fields on Biologic Systems (NRC 1997).

### 1.0.6 California Electric and Magnetic Fields Policy

In January 1991, the California Public Utilities Commission (CPUC) issued an Order Instituting Investigation I.91-01-012 to develop policies and procedures for addressing potential health effect of magnetic fields from utility facilities. The CPUC formed the California Consensus Group (CCG), a committee of 17 stakeholders representing diverse interests and perspectives, to provide guidance on interim EMF measures the CPUC might adopt while waiting for resolution of scientific uncertainties.

In March 1992, the CCG issued its report. In part, the report recommended that the CPUC authorize utilities to implement magnetic field reduction techniques if those techniques could be implemented at little or no cost. In November 1993, the CPUC issued Decision D.93-11013 adopting an interim policy regarding EMF. The CPUC found that the scientific community had not concluded that an EMF health hazard actually exists.

Further, the CPUC stated, “It is not appropriate to adopt any specific numerical standard in association with EMFs (sic) until we have a firm scientific basis for adopting any particular value.” However, “public concern and scientific uncertainty remain regarding the potential health effects of EMF exposure.” In response, California’s electric utilities were authorized to implement no-cost and low-cost field management techniques to reduce EMF levels from new and upgraded electrical facilities if a noticeable reduction could be achieved.

The CPUC’s Commission Advisory and Compliance Division (CACD) set and chaired informational EMF Design Guideline workshops to incorporate concepts and criteria addressed in the Order and to share information on field reduction options. San Diego Gas and Electric’s *EMF Design Guidelines for Electrical Facilities* describe engineering techniques for reducing exposure to magnetic fields created by its electrical facilities.

The CPUC acknowledged in its order that the feasibility and cost of implementing specific magnetic field reduction techniques vary among utility systems and from project to project. Therefore, the CPUC provided that the manner in which individual utilities apply design guidelines must be determined within the constraints of each new construction project.

The CPUC charged the California Department of Health Services (CDHS) with managing the California EMF Program. As a key work product of that program, the CDHS EMF Risk Evaluation report was issued in October, 2002. The report was written by three CDHS staff scientists whose opinions were expressed in terms of the degree to which each “believed” EMF was likely to cause various health effects. They report that “[t]o one degree or another all three of the CDHS scientists are inclined to believe that EMFs can cause some degree of increased risk of childhood leukemia, adult brain cancer, Lou Gehrig’s Disease, and miscarriage.” The three epidemiologists report that “[t]hey strongly believe that EMFs are not universal carcinogens...” and that “[t]o one degree or another they are inclined to believe that EMFs do not cause an increased risk of breast cancer, heart disease, Alzheimer’s Disease, Depression, or symptoms attributed by some to a sensitivity to EMFs.”

The CDHS report is consistent with other agency reviews in that it concludes that an EMF health risk has not been scientifically established and that additional research is necessary to resolve the question. However, the CDHS differs from all other reviewing agencies in the increased likelihood it places on the existence of an EMF health risk for some diseases, and the CDHS report acknowledges this disparity. Other agencies find EMF health risks ‘possible’ but not ‘probable.’ Agencies that have expressed an opinion as to the strength of evidence for a risk have neither found EMF risks to be likely, nor the evidence to be strong.

In January, 2006, the CPUC issued its Decision D.06-01-042, *Opinion On Commission Policies Addressing Electromagnetic Fields Emanating From Regulated Utility Facilities*. The decision concludes that "a direct link between exposure to EMF and human health effects has yet to be proven despite numerous studies including a study ordered by this Commission and conducted by [C]DHS."

The Decision also affirms the Commission’s November 1993 decision on "low-cost/no-cost Policy" to reduce EMF levels from new utility transmission and substation projects. The Commission retained cost guidance, stating, "[a]s a measure of low-cost mitigation, we continue to use the benchmark of 4% of transmission and substation project costs for EMF mitigation, and combine linked transmission and substation projects in the calculation of the 4% benchmark." Finally, the ruling "adopted rules and policies to improve utility design guidelines for reducing EMF and called for a utility workshop to implement these policies and standardize design guidelines."

### **1.0.7 EMF Summary**

After several decades of study regarding potential public health risks from exposure to power line EMF, research results remain inconclusive. Several national and international panels have conducted reviews of data from multiple studies and state that there is not sufficient evidence to conclude that EMF causes cancer or other adverse health effects. The IARC and the CDHS both classified EMF as a possible carcinogen. The WHO review, Environmental Health Criteria Monograph 238, affirms IARC's classification of EMF as a possible carcinogen regarding childhood leukemia and agrees that evidence for all other childhood cancers and all adult cancers is "inadequate." And the WHO classified evidence "inadequate" for all non-cancer diseases studied. Neither California nor the U.S. Federal government has developed EMF exposure guidelines, standards or regulations related to EMF levels from power lines. The WHO Environmental Health Criteria Monograph 238 recommends that: “changes to engineering practice to reduce EMF exposure from equipment or devices should be considered, provided that they yield other additional benefits, such as greater safety, or involve little or no cost .” CPUC Decisions D.93-11-013 and D.06-01-042 implemented rules and policies for low-cost and no-cost magnetic field reduction measures, and this project incorporates measures consistent with these decisions.

### **California Environmental Quality Act**

Given the uncertainty of EMF effects and the inability of scientific investigations to identify any unsafe level or component of EMF exposure, potential EMF impacts are appropriately addressed

as speculative in accordance with the California Environmental Quality Act Guidelines, Section 15145:

"If after thorough investigation a particular impact is found to be too speculative for evaluation, the conclusion shall be noted, and the discussion terminated."

### **1.0.8 References**

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