REPORT OF THE
DEPARTMENT OF HEALTH

Final Report: Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines

TO THE GOVERNOR AND
THE GENERAL ASSEMBLY OF VIRGINIA

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Department of Health

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January 18, 2001

MEMORANDUM

TO: Members of Virginia General Assembly

FROM: E. Anne Peterson, M.D., M.P.H.
State Health Commissioner E. Anne Peterson, MD, MPH

SUBJECT: Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines (Final Report)

Enclosed is your copy of the final report on the "Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines." This is being submitted pursuant to Senate Bill No. 379 of the 1998 Session of the General Assembly. The cost incurred by the Virginia Department of Health in preparing this report was approximately $3,900, including 85 hours of staff time.

Enclosure

pc: The Honorable Bruce F. Jamerson
Clerk of the House

The Honorable Susan Clarke Schaar
Clerk of the Senate

Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines

(Final Report)

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Executive Summary

Pursuant to Senate Bill No. 379 of the 1998 session of the General Assembly, VDH submits this final report on monitoring of ongoing research on the human health effects of high voltage transmission lines to the members of the 2001 Virginia General Assembly. This report summarizes the results of the five-year Electric and Magnetic Fields Research and Public Information Dissemination (EMF-RAPID) Program mandated by the U.S. Congress under the 1992 Energy Policy Act. The Congress instructed the National Institute of Environmental Health Sciences (NIEHS) 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 risks from exposure to extremely low electric and magnetic fields (EMF) surrounding both the high voltage power or transmission lines and the smaller but closer electric lines in homes and appliances.

The EMF-RAPID program was funded jointly by federal and matching private funds. Authorized funding for this program was approximately $46 million. In addition, the NIEHS contributed $14.5 million for support of extramural grants and contracts and intramural research, as well as long-term toxicity studies conducted by the National Toxicology Program. The EMF-RAPID program ended December 31, 1998, and the results of the research were presented in three major reports: the NIEHS working group report "Assessment of Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields", dated August 1998; the follow up report by the NIEHS Director entitled "Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields" submitted to the U.S. Congress in May 1999; and the National Research Council (NRC) report reviewing and evaluating the EMF-RAPID program's scientific and technical content of research projects entitled "Research on Power Frequency Fields Completed Under the Energy Policy Act 1992" published in 1999.

The possible adverse health effects of EMF were first reported in literature from the former Union of Soviet Socialist Republics (USSR) in the mid-1960s. Several subjective complaints, involving the cardiovascular, digestive, and central nervous systems, were reported by electric switchyard workers. Subsequent studies of electric utility linemen in the United States failed to observe the same adverse health effects reported by their counterparts in the former USSR. In 1979, an epidemiological study conducted in the Denver, Colorado area implicated a possible association between childhood cancer mortality and proximity of homes to power distribution lines. Since that time, public concern as well as scientific uncertainty regarding potential health

effects from exposure to power frequency EMF emanating from nearby high voltage electrical transmission lines have generated considerable controversy among scientists, courts, regulatory bodies and public policy makers. Public concern was the major driving force for the enactment of the 1992 Energy Policy Act under which the EMF-RAPID program was established.

The NIEHS report (1998) concluded that the scientific evidence suggesting that extremely low frequency EMF exposures pose any health risk is weak. The strongest evidence for health effects comes from associations observed in human populations with two forms of cancer: childhood leukemia and chronic lymphocytic leukemia in occupationally exposed adults. While the support from individual studies is weak, the 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. In contrast, the mechanistic studies and the animal toxicology literature fail to demonstrate any consistent pattern across studies although sporadic findings of biological effects have been reported. No increase of leukemias in experimental animals has been observed. Epidemiologic studies have serious limitations in their ability to demonstrate a cause and effect relationship whereas laboratory studies, by design, can clearly show that cause and effect are possible. Virtually all of the laboratory evidence in animals and humans and most of the mechanistic work done in cells fail to support a causal relationship between exposure to EMF at environmental levels and changes in biological function or disease status. 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 epidemiologic findings.

Using criteria developed by the International Agency for Research on Cancer (IARC), the NIEHS working group did not consider the scientific evidence strong enough to label extremely low frequency EMF as a "known human carcinogen" or "probable human carcinogen. However, a majority of the working group concluded that exposure to extremely low frequency EMF is a "possible human carcinogen" based largely on "limited evidence of an increased risk for childhood leukemias with residential exposure and increased occurrence of chronic lymphocytic leukemias associated with occupational exposure." For other cancers and for non-cancer health endpoints, the working group categorized the experimental data as providing much weaker evidence or no support for effects from exposure to EMF. The NIEHS emphasized that the probability that EMF exposure is truly a health hazard is currently small. The weak epidemiologic associations and lack of any laboratory support for these associations

provide only marginal, scientific support that exposure to EMF is causing any degree of harm.

At the request of the DOE, following the directive of the 1992 Energy Policy Act, the NRC reviewed and evaluated the scientific and technical contents of the projects completed under the EMF-RAPID program. The NRC established a committee of scientists and engineers to review the activities conducted under the EMF-RAPID program. The NRC committee disagreed with the conclusion drawn by the NIEHS with respect to classification of EMF as a "possible human carcinogen." In its report, the NRC committee noted "The NIEHS working group produced an extensive, updated review of the entire literature related to all aspects of research on the effects, if any, of magnetic fields – a useful accomplishment that unfortunately was overshadowed by the use of the IARC method to review the status of magnetic fields as a potential human carcinogen. Labeling power-frequency EMF as a possible human carcinogen conveys to the public a conclusion that our committee believes is not supported by the underlying research." The NRC committee concluded that the results of the EMF-RAPID program do not support the contention that the use of electricity poses a major unrecognized public health danger.

Weak associations between exposure to EMF and cancer observed in some epidemiologic studies provide the strongest evidence for adverse health effects of EMF. Epidemiology can be a powerful tool for identifying potential risks when there is a strong correlation between increased risk of disease and specific environmental conditions. Epidemiology is most successful in cases where there are large differences in exposure, where the adverse effects are not rare, and when large samples can be studied prospectively. However, when the association is weak, interpretations are more difficult, and conclusions concerning risk less convincing. Epidemiologic studies are at a serious disadvantage if they are used in an effort to prove that weak associations exist or do not exist.

Epidemiologic studies examining the possible association between EMF and cancer have some inherent strengths and weaknesses. In order to detect an association between a given risk factor and disease, an epidemiologic study must control for other potential risk factors that may be confounding this association. Even when all potential risk factors are known and controlled to the maximum extent possible, it is frequently impossible to rule out confounding when the strength of an association observed between the risk factor of interest and disease is weak. In reality, it is seldom possible to control for all other potential risk factors, because for many diseases, like various forms of cancer, those other risk factors are unknown. Some epidemiologic studies have

found that exposure to EMF may confer a two- to three-fold increased risk of certain cancers. This is a fairly small increase when compared to the association between cigarette smoking and cancer, where the risk is increased by ten-fold or greater.

Furthermore, exposure to EMF is universal and unavoidable. Thus, it is not possible to find a control group of individuals who would be unexposed; only populations with relatively greater or lesser exposure can be compared. Also, past exposure can only be estimated based on electrical wiring configurations found in the homes of study participants. There is no biological test to assess past exposure and current environmental measurements may be misleading. The assumption that the exposed group would have had a higher exposure to EMF than the rest of the population may not be true and, therefore, may skew the interpretation of the results of studies.

Although epidemiologic studies may fail to find an association between a given risk factor and disease, it is practically impossible for any epidemiologic study to rule out the possibility of a weak association. This is because the power of a study to confirm a negative association hinges on the prevalence of the disease of interest and the size of the study population. Because of the rarity of most tumors, any competent epidemiologic study that attempts to rule out very small associations between EMF and one type of cancer would have to include an exceedingly large population. Such a study would almost certainly be cost-prohibitive.

Scientific proof of a cause and effect relationship cannot be readily inferred from epidemiologic studies alone. Causality is established using multiple criteria, only one of which is epidemiologic association. Other important factors in confirming a cause and effect relationship include strength of association, consistency and specificity of observations, appropriate temporal relationship, dose-response relationship, biological plausibility, and experimental verification. None of these factors by itself is sufficient to prove or disprove that an observed association represents a true cause and effect relationship. In the case of EMF, these tests for causality have not been satisfied for the implicit deleterious health effects.

Introduction

During the 1984 session of the Virginia General Assembly, Senate Joint Resolution 26 was adopted, pursuant to which the General Assembly resolved to establish a joint subcommittee to study the adequacy of the State Corporation Commission (SCC) oversight, the health and safety rules and regulations, and the statutes in the *Code of Virginia* in protecting the citizens of the Commonwealth when high voltage transmission lines are constructed and maintained. During the first meeting of this subcommittee, June 8, 1984, the Virginia Department of Health (VDH) was asked to review the human health effects of high voltage transmission lines. VDH submitted a report dated August 15, 1984, to the members of the subcommittee during a meeting held on November 16, 1984.

During the 1985 session of the Virginia General Assembly, Senate Joint Resolution 126 (see Appendix A) was adopted requesting the SCC and VDH to monitor the ongoing research on the health and safety effects of high voltage transmission lines. A report on this monitoring was to be submitted annually to the General Assembly.

During the 1993 session of the General Assembly, Senate Joint Resolution 278 (see Appendix B) was adopted requesting that the SCC and VDH continue monitoring ongoing research and reporting annually. This resolution also specified that the agencies should monitor and, if feasible, participate in the study of electric and magnetic fields pursuant to the federal Energy Policy Act of 1992.

During the 1998 session of the General Assembly, Senate Bill 379 (see Appendix C) was passed to rescind and terminate the annual monitoring and reporting requirements initiated by Senate Joint Resolution 126 (1985) and continued by Senate Joint Resolution 278 (1993). Additionally, Senate Bill 379 requested that a final report be submitted by VDH to the General Assembly summarizing the results of the studies conducted by the National Electric and Magnetic Fields Research and Public Information Dissemination program, created by the federal Energy Policy Act of 1992, which were expected to be reported to Congress by the end of 1998.

In accordance with the General Assembly actions, thirteen annual updates of the 1984 report were submitted and are listed in Appendix D. In this report, VDH has summarized the views and expert opinions of the NIEHS working group which were published in the report "Assessment of Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields", dated August 1998; the follow up report

"Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields" prepared by the NIEHS and submitted to the U.S. Congress in May 1999; and NRC report reviewing and evaluating the EMF-RAPID program's scientific and technical content of research projects entitled "Research on Power Frequency Fields Completed Under the Energy Policy Act 1992" published in 1999. These three reports were prepared in response to the federal Energy Policy Act of 1992.

Background

Electric and magnetic fields, often referred to as electromagnetic fields or EMF, occur both naturally and as a result of the generation, delivery, and use of electric power. In our society, where the use of electric power is pervasive, exposure to EMF is common from the vast array of electrical appliances and equipment, building wiring, distribution lines, and transmission lines.

EMF are fields of force and are created by electric voltage and current. They occur around electrical devices or whenever power lines are energized. Electric fields are due to voltage so they are present in electrical appliances and cords whenever the electric cord to an appliance is plugged into an outlet (even if the appliance is turned off). The strength of the electric field is typically measured in volts per meter (V/m) or in kilovolts per meter (kV/m). Electric fields are weakened by objects like trees, buildings, and vehicles. Burying power lines can eliminate human exposure to electric fields from this source.

Magnetic fields result from the motion of the electric charge or current, such as when there is current flowing through a power line or when an appliance is plugged in and turned on. Appliances which are plugged in but not turned on do not produce magnetic fields. Magnetic fields are typically measured in tesla (T), or more commonly, in gauss (G) and milligauss (mG). One tesla equals 10,000 gauss and one gauss equals 1,000 milligauss. The strength of an EMF decreases significantly with increasing distance from the source.

The Earth's natural electric field is essentially static (non-alternating) and is about 130 V/m. The Earth's magnetic field is also static and is about 0.5 G or 500 mG. In the United States, the electric power system uses alternating current (AC) that alternates back and forth (frequency) 60 times each second and is called 60-Hertz (60-Hz; cycles per second) power. In Europe and many other parts of the world, the frequency of electric power is 50-Hz.

There are basically three stages in generating electricity, or power, and moving the electricity from the electric stations to the end user. First, electricity is generated at an electrical generating station at about 20,000 volts or 20 kilovolts (kV). The power is then passed through a transformer which increases the voltage so that the power can be transported with minimum losses. In the second stage, electricity is transported over high voltage transmission lines ranging from 69 to 765 kV. Transmission lines connect

to substations where the voltage is reduced and power is transferred to lower-voltage distribution lines. In the third stage, distribution lines deliver power locally to individual users. The distribution system is composed of two voltage levels. One is a "primary" circuit (2 to 59 kV) that delivers power from a substation to a distribution transformer. From there the power flows through a "secondary" circuit to an end user. The "secondary" circuit voltage is low enough (120 to 240 volts) to operate household electrical appliances, lights, etc. The amount of power that a line transmits is the product of its voltage and current. Power systems are designed to hold voltages relatively constant, while currents increase and decrease depending on the power demand. For a given voltage, the electric field remains relatively constant over time, but the magnetic field increases or decreases depending upon power demand.

The EMF from power lines and appliances are of extremely low frequency and low energy. They are non-ionizing and are markedly different in frequency from ionizing radiation such as X-rays and gamma rays. As a comparison, transmission lines have a low frequency of 60-Hz while television transmitters have higher frequencies in the 55-890 million Hz (MHZ) range. Microwaves have even higher frequencies, 1,000 MHZ and above. Ionizing radiation, such as X-rays and gamma rays, has frequencies above 10^{15} Hz. The energy from higher-frequency fields is absorbed more readily by biological material. Microwaves can be absorbed by water in body tissues and cause heating which can be harmful, depending upon the degree of heating that occurs. X-rays have so much energy that they can ionize (form charged particles) and break up molecules of genetic material (DNA) and nongenetic material, leading to cell death or mutation. In contrast, extremely low frequency EMF do not have enough energy to heat body tissues or cause ionization.

Currently in the United States, there are more than 300,000 miles of AC power transmission lines ranging from 115 to 765 kV. In Virginia, the highest voltage on transmission lines is 765 kV. A typical home in the United States has a background magnetic field level (away from any appliances) that ranges from 0.5 mG to 4 mG, with an average level of 0.9 mG. Magnetic fields very close to most electrical appliances are often stronger than the fields directly beneath transmission lines. However, appliance fields decrease in strength with distance more quickly than do transmission line fields.

The strength of an electric field is proportional to the voltage of the source. Thus, the electric fields beneath high voltage transmission lines far exceed those below the lower voltage distribution lines. The magnetic field strength, by contrast, is proportional to the current in the lines, so that a low voltage distribution line with a high current load may produce a magnetic field that is as high as those produced by some high voltage

transmission lines. In fact, electric distribution systems account for a far higher proportion of the population's exposure to magnetic fields than the larger and more visible high voltage transmission lines.

Over the past three decades, both public controversy and scientific uncertainty have surrounded the subject of potential adverse human health effects from exposure to power frequency EMF. The first studies of possible health effects of EMF exposure in an occupational environment were reported from the former Union of Soviet Socialist Republics (USSR) in the mid-1960s. Several subjective complaints, involving the cardiovascular, digestive, and central nervous systems, were reported by electric switchyard workers. Subsequent studies of electric utility linemen in the United States failed to observe the same adverse health effects reported by their counterparts in the former USSR. Since that time, enormous strides have been taken to explore the nature of any association between residential and occupational exposures to EMF and deleterious health effects.

Recently, there has been a growing concern about the possible carcinogenic effects of EMF associated with such exposures. Since 1979, several epidemiologic studies have explored the association between exposure to EMF and increased risk of leukemia in children. Other epidemiologic studies have examined increased incidence of leukemia and brain cancer among adults, especially with respect to occupational EMF exposure. In earlier studies there was an implicit assumption that the relevant risk factor was exposure to electric fields. However, virtually all recent epidemiologic studies of cancer have focused on magnetic field exposures as the possible etiologic determinant.

Faced with growing public concern about whether EMF might be adverse to human health, Congress mandated the EMF-RAPID program in the 1992 Energy Policy Act. This five-year effort, jointly funded by federal and matching private funds, sought to explain any links between EMF exposures and human health and any special conditions under which cause-effect relationships might occur.

Energy Policy Act of 1992

In 1992, under the Energy Policy Act, the U.S. Congress instructed the NIEHS and the DOE to direct and manage a program of research and analysis aimed at providing scientific evidence to clarify the potential for health risks from exposure to extremely low frequency EMF. This resulted in formation of the EMF-RAPID program. The EMF-RAPID program had three basic components: 1) a research component focusing on health effects research primarily through mechanistic studies of EMF and engineering research targeting measurement, characterization and management of EMF; 2) information compilation and dissemination through brochures, public outreach and an EMF information line for communicating with the public; and 3) a health assessment including an analysis of the research data aimed at summarizing the strength of the evidence for evaluation of any hazard possibly arising from exposure to EMF. The NIEHS was directed to oversee the health effects research and evaluation and the DOE was given responsibility for engineering research aimed at characterizing and mitigating these fields. Under the Energy Policy Act, the Director of the NIEHS was mandated upon completion of the EMF-RAPID program to provide a report to the U.S. Congress outlining the possible human health risks associated with exposure to EMF.

The EMF-RAPID program was funded jointly by federal and matching private funds through fiscal year 1998. Authorized funding for this program was approximately $46 million. Administration of funding for the EMF-RAPID program was the responsibility of the DOE with funds for NIEHS-sponsored program activities transferred from the DOE to the NIEHS. The NIEHS received $30.1 million from this program for research, public outreach, administration and the health assessment evaluation of EMF. Of the funds received, the NIEHS spent the majority (89%) for research through grants and contracts. The remainder was used for public outreach/administration (2%) and the health risk evaluation (9%). In addition to EMF-RAPID program funds from the DOE, the NIEHS contributed $14.5 million for support of extramural grants and contracts and intramural research as well as long-term toxicity studies conducted by the National Toxicology Program.

The 1992 Energy Policy Act created two committees that provided guidance and direction to the EMF-RAPID program. One committee was the Interagency Committee (IAC) and was composed of representatives from NIEHS, DOE and the seven federal agencies (listed below) with responsibilities related to EMF:

- Department of Defense
- Department of Transportation
- Environmental Protection Agency

- Federal Energy Regulatory Commission
- National Institute of Standards and Technology
- Occupational Safety and Health Administration
- Rural Electrification Administration

The IAC, which was established by the president of the United States had responsibility for developing a strategic research agenda for the program, making recommendations for coordination of federal research activities and communication to the public and monitoring and evaluating the EMF-RAPID program.

The second committee was the National Electric and Magnetic Fields Advisory Committee (NEMFAC) that consisted of representatives from public interest groups, organized labor, state governments and industry. This group advised DOE and NIEHS on design and implementation of the EMF-RAPID program and provided input and recommendations to the IAC. The NEMFAC was involved in all aspects of the EMF-RAPID program, providing critical public review throughout the process of evaluating evidence for potential health effects.

The research initiative sponsored under the EMF-RAPID program's health effects research component relied on the accepted principles of hazard identification and risk assessment to establish priorities. All studies supported by the NIEHS and the DOE under this component were selected for their potential to provide solid, scientific data on whether EMF exposure represents a human health hazard, and if so, whether risks are increased under exposure conditions in the general population. Research efforts did not focus on epidemiologic studies (i.e. those in the human population) because of time constraints and the number of ongoing, well-conducted studies. The NIEHS health effects research focused on mechanistic, cellular and laboratory studies in the areas of neurophysiology, behavior, reproduction, development, cellular research, genetic research, cancer and melatonin. The DOE research initiatives focused on assessment of exposure and techniques of mitigation.

The EMF-RAPID program, in a collaborative effort between the DOE and NIEHS, established four regional EMF exposure facilities where state-of-the-art magnetic field exposures could be conducted. Two facilities were located in DOE laboratories (Pacific Northwest Laboratories, Richland, Washington, and Oak Ridge National Laboratories, Oak Ridge, Tennessee) while NIEHS oversaw EMF exposure facilities at the Food and Drug Administration (FDA, Rockville, Maryland) and at the National Institute for Occupational Safety and Health (NIOSH, Cincinnati, Ohio). During the course of the EMF-RAPID program, these facilities focused on in-house mechanistic studies, and advances were made in conducting studies that have minimal bias. These centers also served as sites for investigators who wanted to conduct preliminary

investigations without the expense of having to build their own exposure facilities.

The EMF-RAPID program ended December 31, 1998. At the end of the program, three reports were prepared in response to the Energy Policy Act:

- NIEHS Working Group report entitled "Assessment of Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields", published in August 1998

- NIEHS report entitled "Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields", submitted to the U.S. Congress in May 1999

- National Research Council report entitled "Research on Power Frequency Fields Completed Under the Energy Policy Act 1992" published in 1999

Summary of EMF-RAPID Program Reports

NIEHS Working Group Report

The NIEHS working group produced an extensive, updated review of the entire scientific literature related to all aspects of research on the health effects of EMF. The working group's evaluation and conclusion are as follows:

Carcinogenicity in Humans

The final evaluation of the carcinogenicity of extremely low frequency electric and magnetic fields was made following the working procedures and evaluation method of the IARC with some modifications. The final evaluations for non-cancer end-points were made by a similar procedure, with consideration of other data relevant to the evaluation of carcinogenicity and its mechanisms. The predominant evaluations of the various health end-points considered by the working group are *limited evidence* and *inadequate evidence.*[1]

Limited evidence is the degree generally provided by studies for which there is credible evidence of an association and for which a causal linkage cannot be established with a high degree of certainty. This does not mean the effect is weak, nor does it mean there is clearly an effect, although these issues enter into the evaluation. In most cases, this degree of evidence is associated with one or more of the following problems:

- questionable identification of the exposure factor(s) associated with the disease outcome (either a dose surrogate was used or individuals were missclassified as to their exposure category),
- bias may have played a small role in the finding,
- confounders were not ruled out to the satisfaction of the original investigator and/or the working group,

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1 IARC defines evidence of carcinogenicity as *sufficient* when the working group considers that a causal relationship has been established between exposure to the agent and human cancer in studies in which chance, bias, and confounding could be ruled out with reasonable confidence. IARC defines evidence as *suggesting lack of carcinogenicity* when there are several adequate studies covering the full range of levels of exposure that human beings are known to encounter, which are mutually consistent in not showing a positive association between exposure to the agent and any studied cancer at any observed level of exposure. A conclusion of evidence suggesting lack of carcinogenicity is inevitably limited to the cancer sites, conditions and levels of exposure, and length of observation covered by the available studies.

- the observed effect was small, making clear detection of an effect difficult, and
- there is little information on dose-response in the study report.

Inadequate evidence can imply one of four possibilities:

- there are insufficient data for making a judgment of any kind (e.g. poor study design, making interpretation impossible),
- the data suggest a positive effect, but, due to limitations in design or very weak findings, cannot be interpreted as suggesting a causal linkage,
- the data suggest a negative effect, but, due to limitations in design or very few findings, cannot be interpreted as suggesting no effect,
- or the data are contradictory and no clear pattern is discernible.

Based on the studies researching the relationship between EMF and human cancer, the working group determined that EMF are possibly carcinogenic to humans (IARC, Group 2B).[2] Studies were reviewed after being divided into categories that considered type of cancer, mode of exposure, and age of human subjects.

Using the definitions above, the working group determined that:

- There is limited evidence that residential exposure to EMF is carcinogenic to children based on the results of studies of childhood leukemia.
- There is limited evidence that occupational exposure to EMF is carcinogenic to humans on the basis of results of studies of chronic lymphocytic leukemia.
- There is inadequate evidence for an association between occupational exposure to EMF and the risk for other cancers. The other cancer studies which were considered

2 IARC evaluations categorize exposures as Group 1 (the agent is carcinogenic to humans) when there is *sufficient evidence* of carcinogenicity in humans, or when there is *less than sufficient* evidence in humans but there is *sufficient evidence* of carcinogenicity in experimental animals and a strong evidence in exposed humans that the exposure acts through a relevant mechanism of carcinogenicity; Group 2 when the degree of evidence of carcinogenicity in humans is *almost sufficient*, or when there are no human data, but there is evidence of carcinogenicity in experimental animals; Group 2A (probably carcinogenic to humans) when there is *limited evidence* of carcinogenicity in humans and *sufficient evidence* of carcinogenicity in experimental animals; Group 2B (possibly carcinogenic to humans) when there is *limited evidence* of carcinogenicity in humans and *less than sufficient* evidence of carcinogenicity in experimental animals or when there is *inadequate evidence* of carcinogenicity in humans, but *sufficient evidence* of carcinogenicity in experimental animals; Group 3 (the agent is not classifiable as to its carcinogenicity to humans) when the evidence for carcinogenicity is *inadequate* in humans and *inadequate* or *limited* in experimental animals; or Group 4 (probably not carcinogenic to humans) when there is *evidence suggesting lack of carcinogenicity* in humans and in experimental animals.

by the working group included acute myelogenous leukemia, brain cancer, male breast cancer, and female breast cancer. The designation of inadequate evidence is due to limitations in study design, inconsistency in findings across studies, and/or a lack of association.

- There is inadequate evidence that residential exposure to EMF is carcinogenic to adults. The cancers considered were leukemias, breast cancer, and cancers of the nervous system.

- There is inadequate evidence that exposure to EMF is associated with childhood nervous system tumors.

- There is inadequate evidence that exposure to EMF is associated with childhood lymphoma.

Overall, the evidence in support of the decision to classify EMF as possibly carcinogenic (Group 2B) is driven by the results of studies on childhood leukemia in residential environments and on chronic lymphocytic leukemia in adults in occupational settings. The fact that limited evidence was seen for chronic lymphocytic leukemia in adults should not be construed as providing support for the finding with regard to leukemia in children, however. Childhood leukemia and adult chronic lymphocytic leukemia are very different diseases with different etiologies. Also, the inadequacy of the evidence for an effect on the risk for chronic lymphocytic leukemia in adults in the studies of residential exposure neither supports nor refutes the findings in the studies of occupational exposure. The *in-vitro* and mechanistic data provide, at best, marginal support for the conclusion that EMF are possibly carcinogenic to humans. While magnetic fields at high intensities provide moderate support for effects *in vitro*, there was little evidence of effects at low intensities which cover most of the range of exposure in the studies of residential childhood exposure and adult occupational exposure. Relatively few of the studies of occupational exposure addressed exposure to electric fields.

Carcinogenicity in Experimental Animals

The overall conclusion of the working group was that most of the studies in experimental animals suggest a lack of carcinogenicity, and the few that gave results of borderline positivity are inadequate to conclude that exposure to magnetic fields at the magnitude and configurations at which they were investigated increases the incidence of cancer in rodents.

Non-cancer Health Effects

None of the findings for adverse health effects seen after exposure to EMF achieved a degree of evidence beyond inadequate. The end-points evaluated in humans were adverse birth outcomes after maternal exposure, adverse reproductive effects after paternal exposure, Alzheimer's disease, amyotrophic lateral sclerosis and other motor neuron diseases, suicide and depression, and cardiovascular disease. There is inadequate evidence that any of these conditions are caused by occupational exposure to EMF. Additionally, there is inadequate evidence that environmental exposure to EMF has adverse effects on pregnancy outcome or is associated with depression.

There appears to be substantial, accumulating evidence that complex clinical exposures to pulsed EMF have a significant beneficial effect on the primary bone healing processes. The studies of both osteotomy and spinal fusion show a robust effect. While no effect on secondary bone healing was observed, there was significant inhibition of bone resorption and evidence of new bone formation. Magnetic therapy appears incapable of enhancing the healing of osteotomies, ingrowth of bone into a defect, bone elongation, or graft healing.

There is weak evidence that short term exposure to EMF causes changes in heart-rate variability, changes in sleep disturbance, or suppression of melatonin.

There is no evidence that short term exposure to EMF has other effects on the biological end-points studied in the laboratory.

NIEHS Report to the U.S. Congress

The Director of NIEHS submitted the NIEHS report to the U.S. Congress in May 1999. The summary and conclusion of this report are as follows:

> The scientific evidence suggesting that EMF exposures pose any health risk is weak. The strongest evidence for health effects comes from associations observed in human populations with two forms of cancer: childhood leukemia and chronic lymphocytic leukemia in occupationally exposed adults. While the support from individual studies is weak, the epidemiologic 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. In contrast, the mechanistic studies and the animal toxicology literature fail to demonstrate any consistent pattern across studies although sporadic findings of biological effects (including increased cancers in animals) have been

reported. No indication of increased leukemias in experimental animals has been observed.

The lack of connection between the human data and the experimental data (animal and mechanistic) severely complicates the interpretation of these results. The human data are in the "right" species, are tied to "real-life" exposures and show some consistency that is difficult to ignore. This assessment is tempered by the observation that given 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 EMF has been identified. Epidemiologic studies have serious limitations in their ability to demonstrate a cause and effect relationship, whereas laboratory studies, by design, can clearly show that cause and effect are possible. Virtually all of the laboratory evidence in animals and humans and most of the mechanistic work done in cells fail to support a causal relationship between exposure to EMF at environmental levels and changes in biological function or disease status. 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 epidemiologic findings.

The NIEHS concludes that EMF exposure cannot be recognized as 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. However, because virtually everyone in the United States uses electricity and therefore is routinely exposed to EMF, passive regulatory action is warranted, such as a continued emphasis on educating both the public and the regulated community on means aimed at reducing exposures. The NIEHS does not believe that other cancers or non-cancer health outcomes provide sufficient evidence of a risk to warrant concern currently.

The ultimate goal of any risk assessment is to estimate the probability of disease in an exposed population. In general, this involves the combination of three basic pieces of information: the probability that the agent causes the disease, the response as a function of exposure given that the exposure does cause disease, and the distribution of exposures in the population being studied. The NIEHS believes that the probability that EMF exposure is truly a health hazard is currently small. The weak epidemiologic 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.

The risk of getting leukemia prior to age 15 in the United States is about 0.05% (5/10,000 people). Assuming the risk of childhood leukemia is real, the lifetime risk of childhood leukemia attributable to EMF would be between 2.5 to 7.5 per 100,000 people. On a yearly basis, this conditional risk is approximately 15 times less than the lifetime risk or 2 to 6 additional cases per million children per year.

National Research Council Report

In response to a request from the DOE, following the directives of the Energy Policy Act of 1992, the NRC established a committee of scientists and engineers to review the activities conducted under the EMF-RAPID program. The NRC committee issued its report in 1999. The conclusions of the committee are as follows:

> The NIEHS working group produced an extensive, updated review of the entire literature related to all aspects of research on the effects, if any, of magnetic fields — a useful accomplishment that unfortunately was overshadowed by the use of the IARC method to review the status of magnetic fields as a potential human carcinogen. Labeling power frequency magnetic fields a group 2B human carcinogen (possible human carcinogen) conveys to the public a conclusion that the committee believes is not supported by the underlying research. The results of the EMF-RAPID program do not support the contention that the use of electricity poses a major unrecognized public health danger. The new, largely unpublished contributions of the EMF-RAPID program are consistent with the 1997 NRC assessment of the available body of information on biological effects of power frequency magnetic fields 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 exposure to residential electric and magnetic fields produces cancer, adverse neurobehavioral effects, or reproductive and developmental effects." The committee agreed that no finding from the EMF-RAPID program alters this conclusion. In view of the negative outcomes of EMF-RAPID replication studies, it now appears less likely that magnetic fields in the normal domestic or occupational environment produce important health effects, including cancer.

Conclusion

Based on the review and analysis of the exhaustive literature review and other research projects completed under the EMF-RAPID program, the Virginia Department of Health is of the opinion that there is no conclusive and convincing evidence that exposure to extremely low frequency EMF emanated from nearby high voltage transmission lines is causally associated with an increased incidence of cancer or other detrimental health effects in humans. Even if it is assumed that there is an increased risk of cancer as implied in some epidemiologic studies, the empirical relative risk appears to be fairly small in magnitude and the observed association appears to be tenuous. The studies published in the literature lack clear demonstration of a cause and effect relationship as well as a definitive dose-response gradient. A two- to three-fold increase in relative risk of certain cancers observed in some studies is within the range where experimental bias or confounding factors cannot be completely ruled out.

Evidence from the laboratory studies has thus far failed to confirm that exposure to EMF causes cancer in experimental animals. Laboratory experiments have also failed to show how EMF could initiate or promote the growth of cancer. The results of both *in vivo* and *in vitro* experimental studies conducted so far do not lend support to an association between exposure to EMF and cancer.

Furthermore, scientific proof of a causal association is established using multiple criteria, only one of which is epidemiologic association. Other important criteria in confirming causality (including strength of association, consistency and specificity of observations, appropriate temporal relationship, dose-response relationship, biological plausibility, and experimental verification) have not been satisfied for the implicit adverse effects of power-line frequency EMF.

Bibliography

1. NIEHS (National Institute of Environmental Health Sciences). 1998. Assessment of health effects from exposure to power-line frequency electric and magnetic fields. NIEHS Working Group Report. NIH Publication No. 98-3981. NIEHS. Research Triangle Park, NC.

2. NIEHS (National Institute of Environmental Health Sciences). 1999. NIEHS Report on health effects from exposure to power-line frequency electric and magnetic fields. Prepared in response to the 1992 Energy Policy Act (PL 102-486, Section 2118). Submitted to the U.S. Congress May 1999. NIH Publication No. 99-4493. NIEHS. Research Triangle Park, NC.

3. NRC (National Research Council). 1999. Research on power frequency fields completed under the Energy Policy Act of 1992. National Academy Press. Washington, D.C.

Appendix A

Senate Joint Resolution No. 126

Requesting the State Corporation Commission and the Department of Health to monitor ongoing research on the health and safety effects of high voltage transmission lines.

Agreed to by the Senate, January 30, 1985
Agreed to by the House of Delegates, February 14, 1985

WHEREAS, in recent years there has been a significant increase in the concern over the health and safety aspects of high voltage transmission lines; and

WHEREAS, a joint subcommittee established pursuant to Senate Joint Resolution No. 26 of the 1984 Session of the General Assembly carefully studied the health and safety aspects and heard from a number of experts who were not in agreement over whether harmful effects exist; and

WHEREAS, currently there are a large number of studies on the health and safety of such lines, the result of which the joint subcommittee feels should be continuously monitored so that if any causal relationships develop the General Assembly will be informed and will be able to take appropriate action to protect the citizens of Virginia; and

WHEREAS, it is the sense of the joint subcommittee that this monitoring could best be done by the State Corporation Commission, which by statute has oversight over the construction of transmission lines, and the Department of Health; now, therefore, be it

RESOLVED by the Senate, the House of Delegates concurring, That the State Corporation Commission and the Department of Health are requested to monitor the ongoing research on the health and safety effects of high voltage transmission lines; and, be it

RESOLVED FURTHER, That the Department of Health, after consultation with the State Corporation Commission, is requested to report its findings annually to the General Assembly.

Appendix B

Senate Joint Resolution No. 278

Requesting the State Corporation Commission and the Department of Health to include studies pursuant to the Energy Policy Act of 1992 in their monitoring of research to determine whether electric and magnetic fields affect human health.

Agreed to by the Senate, February 9, 1993
Agreed to by the House of Delegates, February 17, 1993

WHEREAS, Senate Joint Resolution No. 126 (1985) requested the State Corporation Commission (SCC) and the Department of Health (DOH) to monitor ongoing health and safety research relating to high-voltage electric transmission lines and requested DOH, after consultation with the SCC, to report its findings annually to the General Assembly; and

WHEREAS, the General Assembly has received six such annual reports reviewing the extensive research related to the subject; and

WHEREAS, public interest in this subject has continued; and

WHEREAS, the Federal Energy Policy Act of 1992 requires the Secretary of Energy to undertake a comprehensive five-year study to determine whether electric and magnetic fields produced by the generation, transmission and use of electric energy affect human health and authorizes an appropriation of $65 million, to be supplemented by nonfederal sources, for that purpose during the years 1993-1997 so that action, if any, to be taken by the federal government can be based upon scientifically valid research; and

WHEREAS, the Department of Energy, the National Institute of Environmental Health Sciences, the Environmental Protection Agency, the Department of Defense, the Occupational Safety and Health Administration, the National Institute of Standards and Technology, the Department of Transportation, the Rural Electrification Administration and the Federal Energy Regulatory Commission will participate in the study, and the National Academy of Sciences will periodically evaluate the progress of the study; and

WHEREAS, that Act provides for the establishment of the National Electric and Magnetic Fields Advisory Committee to advise the Secretary of Energy with respect to the design and implementation of the study; the committee shall be composed of ten members including representatives of state health agencies and state regulatory agencies as well as other experts in the field; and

WHEREAS, the results of the study, as well as information compiled during the course of the study, may be useful to the General Assembly; now, therefore, be it

RESOLVED by the Senate, the House of Delegates concurring, That the SCC and DOH, with assistance from the Medical College of Virginia, be requested to continue to monitor relevant on-going research as described in SJR 126 and to submit annual reports thereon; and, be it

RESOLVED FURTHER, That as part of the foregoing activity, the SCC and DOH be requested to monitor and, if feasible, participate in the study of electric and magnetic fields pursuant to the Energy Policy Act of 1992.

Appendix C

Senate Bill No. 379

VIRGINIA ACTS OF ASSEMBLY -- 1998 SESSION

CHAPTER 764

An Act to rescind and terminate the annual monitoring and reporting requirements initiated by Senate Joint Resolution No. 126 (1985) and continued by Senate Joint Resolution No. 278 (1993).

Approved April 16, 1998

Whereas, the General Assembly passed Senate Joint Resolution No. 126 in 1985 requesting the Department of Health (DOH), in consultation with the State Corporation Commission (SCC), to monitor ongoing research on the health and safety effects of high voltage electric transmission lines and report annually its findings; and

Whereas, in 1993 the General Assembly, recognizing the continued public interest in this subject, passed Senate Joint Resolution No. 278 requesting the DOH and the SCC to continue their annual reporting and monitoring activities; and

Whereas, after 13 years of monitoring and reporting, there no longer exists the need for such an ongoing project; now, therefore,

Be it enacted by the General Assembly of Virginia:

1. *§ 1. That the monitoring and annual reporting requirements embodied in Senate Joint Resolution No. 126 (1985) and continued by Senate Joint Resolution No. 278 (1993) are no longer required and are terminated by the passage of this act.*

2. That a report will be submitted by the Virginia Department of Health to the General Assembly that summarizes the results of the studies conducted by the National EMF Research and Public Information Dissemination Program created by the Energy Policy Act of 1992, and which are expected to be reported to Congress by the end of 1998.

Appendix D

Previous Reports in the Series

1. Health Effects of High Voltage Transmission Lines, August 15, 1984.

2. Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines, September 25, 1985.

3. Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines (Second Annual Report), November 13, 1986.

4. Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines (Third Annual Report), October 23, 1987.

5. Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines (Fourth Annual Report), December 5, 1988.

6. Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines (Fifth Annual Report), March 15, 1990.

7. Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines (Sixth Annual Report), January 10, 1991.

8. Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines (Seventh Annual Report), March 10, 1992.

9. Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines (Eighth Annual Report), March 24, 1993.

10. Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines (Ninth Annual Report), April 20, 1994.

11. Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines (Tenth Annual Report), March 14, 1995.

12. Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines (Eleventh Annual Report), February 26, 1996.

13. Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines (Twelfth Annual Report), March 20, 1997.

14. Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines (Thirteenth Annual Report), January 5, 1998.