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An Evaluation of the Possible Risks From Electric and Magnetic Fields (EMFs) From Power Lines, Internal Wiring, Electrical Occupations, and Appliances

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EXECUTIVE SUMMARY OF THE CALIFORNIA EMF RISK EVALUATION FOR POLICYMAKERS AND THE PUBLIC

WHY AND HOW THE EVALUATION WAS DONE:

On behalf of the California Public Utilities Commission (CPUC), three scientists who work for the California Department of Health Services (DHS) were asked to review the studies about possible health problems from electric and magnetic fields (EMFs) from power lines, wiring in buildings, some jobs, and appliances. The CPUC request for review did not include radio frequency EMFs from cell phones and radio towers. Reviewer 1, Vincent Delpizzo, Ph.D., is a physicist and epidemiologist; Reviewer 2, Raymond Richard Neutra, M.D., Dr.P.H., is a physician epidemiologist; and Reviewer 3, Geraldine Lee, Ph.D., is an epidemiologist with training in genetics. All three have published original research in the EMF area and have followed the field for many years. They were assisted in their reviews by DHS toxicologists, physicians, and epidemiologists.

THE CONCLUSIONS AFTER REVIEWING ALL THE EVIDENCE:

- *To one degree or another, all three of the DHS 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.*
- *They strongly believe that EMFs do not increase the risk of birth defects, or low birth weight.*
- *They strongly believe that EMFs are not universal carcinogens, since there are a number of cancer types that are not associated with EMF exposure.*
- *To 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. However,*
- *All three scientists had judgments that were "close to the dividing line between believing and not believing" that EMFs cause some degree of increased risk of suicide, or*
- *For adult leukemia, two of the scientists are "close to the dividing line between believing or not believing" and one was "prone to believe" that EMFs cause some degree of increased risk.*

HOW AND WHY THE CONCLUSIONS DIFFER FROM THOSE OF OTHER RECENT REVIEWS:

While there are important differences between the three DHS reviewers' conclusions, the DHS scientists are more inclined to believe that EMF exposure increased the risk of the above health problems than the majority of the members of scientific committees convened to evaluate the scientific literature by the National Institutes of Environmental Health Sciences Working Group (NIEHS) in 1998, the International Agency for Research on Cancer (IARC) in 2001, and the British National Radiological Protection Board (NRPB) in 2001. These other committees all assessed EMFs as a "possible" carcinogen for childhood leukemia. Thus, like the DHS panel, these other three panels were not much swayed by theoretical arguments of physicists that residential EMFs were so weak as to make any biological effect impossible. NIEHS additionally assessed EMFs as a possible carcinogen for adult lymphoid leukemia and NRPB assessed a possible link with Lou Gehrig's Disease. The three DHS scientists differed in that they had a somewhat higher degree of belief that EMF is linked with these three diseases and gave credence to evidence of a link to adult brain cancer and miscarriage that the other panels either didn't consider or characterized as "inadequate." There are several reasons for these differences. The three DHS scientists thought there were reasons why animal and test tube experiments might have failed to pick up a mechanism or a health problem; hence, the absence of much

support from such animal and test tube studies did not reduce their confidence much or lead them to strongly distrust epidemiological evidence from statistical studies in human populations. They therefore had more faith in the quality of the epidemiological studies in human populations and hence gave more credence to them.

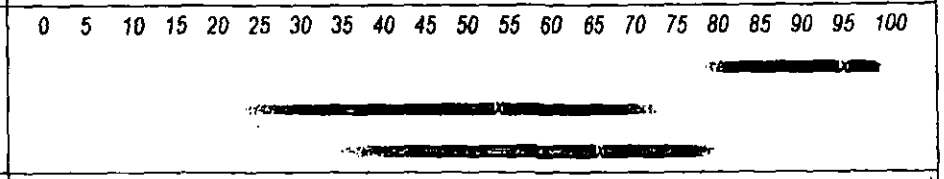
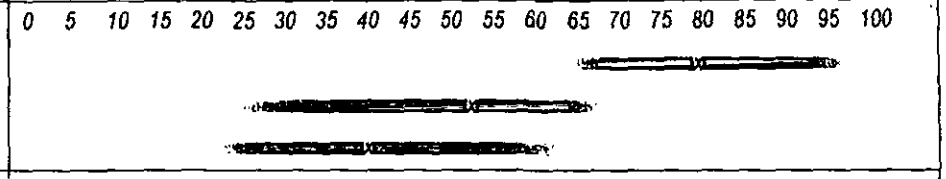
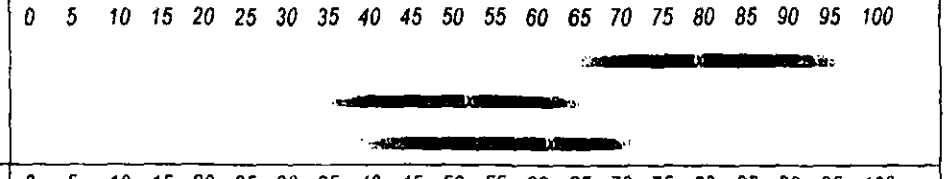
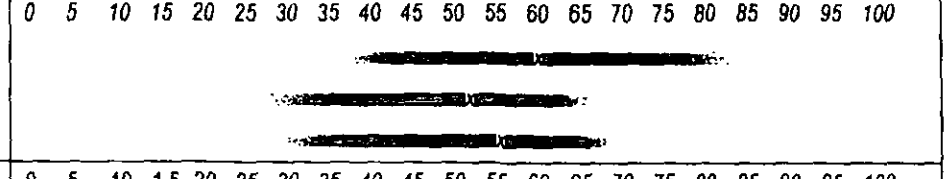
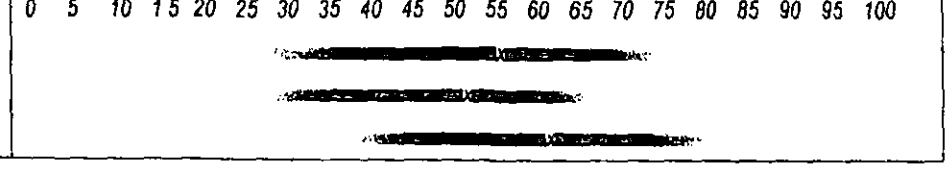
With the exception of miscarriage, which is common, the other diseases for which EMFs may be a contributing cause (childhood leukemia, adult brain cancer, Lou Gehrig's Disease) have low incidence, with rates between 1/100,000 and 1/10,000 a year. Even doubling such rates and accumulating them over a childhood or a lifetime leaves accumulated lifetime risks between 1/1,000 and 1%. Thus the vast majority (99%–99.9%) of highly exposed people would still not contract these diseases. Furthermore, calculations suggest that the fraction of all cases of the above-mentioned conditions that one could attribute to EMFs would be no more than a few percent of the total cases (if any). However, if EMFs do contribute to the cause of these conditions, even the low fractions of attributable cases and the size of accumulated lifetime risk of highly-exposed individuals could be of concern to regulators. Indeed, when deemed a real cause, estimated lifetime risks smaller than these (1/100,000) have triggered regulatory evaluation and, sometimes, actual regulation of chemical agents such as airborne benzene. The uncommon, accumulated high EMF exposures implicated by the evidence about these conditions come from unusual configurations of wiring in walls, grounded plumbing, nearby power lines, and exposure from some jobs in electrical occupations. There are ways to avoid these uncommon accumulated exposures by maintaining a distance from some appliances, changes in home wiring and plumbing, and power lines. However, to put things in perspective, individual decisions about things like buying a house or choosing a jogging route should involve the consideration of certain risks, such as those from traffic, fire, flood, and crime, as well as the uncertain comparable risks from EMFs.

While rodent and chicken egg studies provide little or no support for EMF effects, some studies on early-model higher emitting video display terminals (VDTs) and two new epidemiology studies in humans suggest that EMFs might cause a substantial proportion of miscarriages. Miscarriages are common in any case (about 10 per 100 clinically diagnosed pregnancies) and the theoretical added risk for an EMF-exposed pregnant woman might be an additional 10 per 100 pregnancies according to these two studies. If truly causal this could clearly be of concern to individuals and regulators. However, the type of EMF exposures implicated by these two new epidemiological studies (short, very high exposures) probably come from being within a few inches of appliances and unusual configurations of wiring in walls and grounded plumbing, and only rarely from power lines. Since the majority of people come into contact with non-obvious sources of these fields on a daily basis, it may not be possible to avoid the majority of such exposures in modern life, even if we avoided the obvious sources like some appliances.

Seventy-five percent of the women in the studies had at least one of these brief high exposures during a given day. Even one exposure a day, if experienced regularly during pregnancy, seemed to increase the risk of miscarriage. Nonetheless, the majority of pregnant women with such exposures did NOT miscarry.

FOR PURPOSES OF POLICY ANALYSIS, HOW DID THE THREE SCIENTISTS EXPRESS THEIR JUDGMENT THAT THE ABOVE DEGREES OF RISK MIGHT BE REAL?

The EMF Program's policy analysis required each of the three DHS scientists to express in numbers their individual professional judgments that the range of added personal risks suggested by the epidemiological studies were "real." They did this as a numerical "degree of certainty" on a scale of 0 to 100. For the conditions with the most suggestive evidence of EMF risk, the three scientists each came up with a graph that depicts their best judgments with a little "x" and the margin of uncertainty with a shaded bar. The differences in certainty between the three reviewers arises primarily from how sure they were that they could rule out study flaws or other explanatory agents and how much the evidence on one disease influenced certainty in the findings for other diseases.

CONDITION	REVIEWER	DEGREE OF CERTAINTY IN SOME AMOUNT OF ADDED PERSONAL RISK
CHILDHOOD LEUKEMIA (REVIEWED THE 19 EPIDEMIOLOGY STUDIES)	1 2 3	
ADULT LEUKEMIA (REVIEWED THE 43 EPIDEMIOLOGY STUDIES)	1 2 3	
ADULT BRAIN CANCER (REVIEWED THE 29 EPIDEMIOLOGY STUDIES)	1 2 3	
LOU GEHRIG'S DISEASE (ALS) (REVIEWED THE 7 EPIDEMIOLOGY STUDIES)	1 2 3	
MISCARRIAGE (REVIEWED THE 10 VDT, 3 ELECTRIC BLANKET, 2 PERSONAL EXPOSURE STUDIES)	1 2 3	

WHAT ASPECT OF THE "EMF MIXTURE" WOULD NEED TO BE MITIGATED (IF ANY)?

A variety of electrical phenomena are present in the vicinity of power lines, in-home wiring, plumbing, and appliances. These include EMFs with a variety of frequencies and orientations, stray currents from contact with grounded plumbing, and air pollution particles charged by electric fields. The epidemiological studies primarily implicate the magnetic fields or something closely correlated with them. Some researchers think that associated high- or low- frequency stray contact currents or charged air pollution particles are the true explanation rather than magnetic fields. The actions one would take to eliminate the fields are not always the same as one would take to eliminate the currents or the charged particles. There are some situations where different costly measures would be required to address the above-mentioned three possible explanations. There are other situations where one or more inexpensive avoidance actions will address all three. This additional uncertainty about what aspect of the mixture might need to be mitigated will thus provide a challenge for policymakers. The California EMF program funded policy projects to explore options that could be pursued in the face of these uncertainties (see www.dhs.ca.gov/ehib/emf). These are available to guide CPUC and other state agencies in policy formation. DHS is making no recommendations at this time.

WHAT RESEARCH GAPS EXIST?

Determining whether stray contact currents or charged air pollution particles are really common enough to explain the epidemiology would be highly policy relevant. Certain suggestive test tube and animal studies await replication. Epidemiology of common conditions which could be studied prospectively, like miscarriage and sudden cardiac death, would be policy relevant and could give a better understanding of what aspect of the EMF mixture might be biologically active.

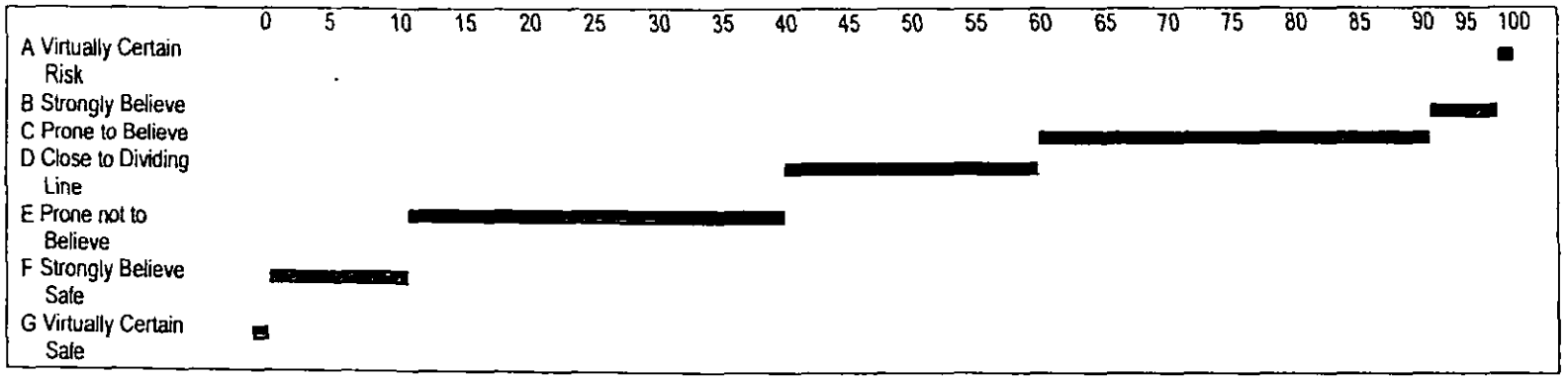
1 WHO DID THE EVALUATION AND WHAT FORM DID THE CONCLUSIONS TAKE?

On behalf of the California Public Utilities Commission (CPUC), three scientists who work for the California Department of Health Services (DHS) were asked to review the studies about possible health problems from electric and magnetic fields (EMFs) from power lines, wiring in buildings, some jobs, and appliances. The CPUC request for review did not include radio frequency EMFs from cell phones and radio towers. Reviewer 1, Vincent Delpizzo, Ph.D., is a physicist and epidemiologist; Reviewer 2, Raymond Richard Neutra, M.D., Dr.P.H., is a physician epidemiologist; and Reviewer 3, Geraldine Lee, Ph.D., is an epidemiologist with training in genetics. All three have published original research in the EMF area and have followed the field for many years. To integrate and extend their body of knowledge, the EMF Program contracted with specialists in biophysics, statistics, and animal experimentation to prepare a background in critical literature review in their respective fields and to make sure that the literature review was up to date through June 2000 (P. Gailey, Ph.D., G. Sherman, Ph.D., W. Rogers, Ph.D., and A. Martin, Ph.D.). The first three were involved with the writing of the 1998 National Institutes of Environmental Health Sciences (NIEHS) report. Furthermore, for each chapter of the review, another DHS epidemiologist or toxicologist was asked to read the original literature and consulted extensively with whichever of the three core reviewers was writing that chapter. This ensured that the writer based his/her evaluation on an understanding of the evidence that was as objective and consistent as possible. All three reviewers worked for the EMF program for at least five years and to some extent they influenced each other's thinking through their constant interaction and the review of each other's chapters. All three did their reviews according to the Risk Evaluation Guidelines (REG) that had been developed earlier and approved by the program's Science Advisory Panel (SAP). The Guidelines specified that the conclusions about any hazard should be done using two systems. The first was developed by the International Agency for Research on Cancer (IARC) and has been used by the NIEHS. It rates an agent as a Definite, Probable, Possible carcinogen or Not a carcinogen, or specifies that the evidence is "Inadequate" to rate the agent. In addition, the California Guidelines specified that in order to accommodate the probability-based computer models of the program's policy projects each of the DHS reviewers would individually assign a number between 0 and 100 to denote their degree of certainty that epidemiological associations between EMFs and certain diseases indicated that EMFs increased the risk of those diseases to some degree. They indicated their best judgement graphically with a little "x" and placed a shaded bar on either side of that "x" to indicate how uncertain they were. The best judgement and the uncertainty ranges could be used in quantitative policy analysis. The Guidelines, which were modified with advice from public comment and the SAP and the DHS reviewers, attached pre-agreed-upon English language phrases to various ranges of this degree of certainty. These are presented below in Table I.

If all three judges had best judgments above 50 out of 100, but that fell in different categories in Table I, judges were said to be "inclined to believe" that EMFs increased the risk of that disease to some degree.

TABLE I. EVERYDAY ENGLISH PHRASES TO DESCRIBE DEGREES OF CERTAINTY OF CAUSALITY (GRAPH ILLUSTRATES THE RANGE OF CERTAINTY NUMBERS TO WHICH THE PHRASES PERTAIN)

ARE THE HIGHEST EMFS AT HOME OR AT WORK SAFE, OR DO HIGH EMFS INCREASE THE RISK OF ..... TO A DEGREE DETECTABLE BY EPIDEMIOLOGY?	DEGREE OF CERTAINTY ON A SCALE OF 1 TO 100
Virtually certain that they increase the risk to some degree	>99.5
Strongly believe that they increase the risk to some degree	90 to 99.5
Prone to believe that they increase the risk to some degree	60 to 90
Close to the dividing line between believing or not believing that EMFs increase the risk to some degree	40 to 60
Prone to believe that they do not increase the risk to any degree	10 to 40
Strongly believe that they do not increase the risk to any degree	0.5 to 10
Virtually certain that they do not increase the risk to any degree	< 0.5



2 A Summary of What has Changed Since the California EMF Program Was First Proposed In the Early 1990s

Between the time CPUC mandated a targeted California research program in 1993 to the time of this writing, considerable information has accumulated. In addition, three expert panels, the NIEHS Working Group (Portier & Wolfe, 1998), the IARC (IARC, 2001), and the British National Radiological Protection Board (NRPB, 2001b) have indicated that EMFs are a possible cause of childhood leukemia.

Biophysics: Biophysical arguments based on physical principles and simplified biological models have produced lower and lower predictions as to what magnetic field intensities theoretically would be capable of producing biological effects. Nevertheless, theoretical modeling still would claim that most residential and occupational epidemiological results are "impossible" (Weaver et al., 1998). It would also claim that bioeffects from magnetic field experiments using intensities less than 100 mG* are "impossible" (Adair, 1999). A milliGauss (mG) is a commonly used measure of magnetic field strength. An average living room would have a 0.7 mG field. The standard international unit is a microTesla (μT). One μT equals 10 mG. Both units appear in this document. Those who adhere to these biophysical theories still discount the relevance of experimental results at higher intensities because of this "impossibility" threshold and would require robust bioeffect laboratory results from ambient levels of exposure. This is an unusual burden of proof since ambient levels of other pollutants often do not produce effects large enough to see in the laboratory. It should be noted that the majority of panelists at IARC, NIEHS, and NRPB who declared EMFs as "possible" carcinogens obviously did not accept some physicists arguments that bioeffects from high-end residential exposures were "impossible."

Mechanistic Research: EMFs, particularly those above 1000 mG, have been shown to have a number of physiological effects on cells (Portier & Wolfe, 1998), but the physical induction mechanisms of these effects are not clearly understood. No consensus has arisen on a mechanistic explanation of how the various epidemiological associations might have occurred. Repeated studies of the effects of pulsed and non-pulsed EMFs below 100 mG on chick embryos, in several laboratories, have continued to show "non-robust" effects (Martin, 1988), (Berman et al., 1990), (Martin, 1992), (Moses & Martin, 1992), (Moses & Martin, 1993), (Martin & Moses, 1995), (Litovitz et al., 1994), (Farrell et al., 1997a), (Farrell et al., 1997b), (Leal et al., 1989), (Chacon et al., 1990), (Ubeda et al., 1994), (Koch & Koch, 1991), (Singh & et al., 1991), (Espinar et al., 1997), (Blackman et al., 1988), (Yip et al., 1994a), (Yip et al., 1994b), (Coulton & Barker, 1991), (Youbicier-Simo et al., 1997), (Piera et al., 1992), (Pafkova & Jerabek, 1994), (Pafkova, Tejnorova & Jerabek, 1994), (Pafkova et al., 1996), (Veicsteinas et al., 1996). A statistically significant effect is said to be "non-robust" when its size is not greater than the differences between control groups in various experiments. Several independent researchers (Liburdy et al., 1993), (Blackman, Benane & House, 2001), and (Ishido, Nitta & Kabuto, 2001) have published studies on the effect of low intensity (12 mG, 60 Hertz) magnetic fields on the ability of melatonin to inhibit cancer cell proliferation in vitro. Thus, there are some studies that, while not universally accepted, purport to show biological effects at EMF intensities declared by biophysicists to be incapable of producing such effects.

Animal Pathology: A large number of animal pathology studies have been carried out that tested a few aspects of the EMF mixture and, with some exceptions, did not show a carcinogenic, reproductive, or immunological effect (Portier & Wolfe, 1998). This has led some scientists to conclude that EMFs are probably safe.

Two laboratories in the former Soviet Union (Beniashvili, Bilanishvili & Menabde, 1991), (Anisimov et al., 1996) and one in Germany (Loscher et al., 1993), (Mevissen, Lerchl & Loscher, 1996a) reported co-promotional effects of magnetic fields on the occurrence of breast tumors in rats, though this result did not recur in two experiments in the United States (Anderson et al., 1999), (Boorman et al., 1999a) that partially replicated the conditions in the German experiments.

Epidemiology: Epidemiological studies on workers and children have tentatively implicated a wider range of diseases than the leukemia and brain cancer that dominated discussion in the early 1980s and 1990s (Portier & Wolfe, 1998). Published statistical summaries of the body of epidemiological evidence have suggested that chance is an unlikely explanation for the associations seen for childhood leukemia (Greenland et al., 2000), (Ahlbom et al., 2000), adult leukemia (Kheifets et al., 1997a), adult brain cancer (Kheifets, 2001), male breast cancer (Erren, 2001), and Amyotrophic Lateral Sclerosis (Ahlbom, 2001). This leaves bias, confounding, or EMF causality as alternative explanations. (See pp 21-22 below for definitions.) Parts of this evidence have convinced the NIEHS, the IARC, and the NRPB that EMFs are a **possible** carcinogen.

For childhood leukemia, the association now seems more consistent with measured 30-300 Hz magnetic fields than with proximity to power lines (Greenland et al.,

* A milligauss (mG) is a measure of magnetic field intensity. A typical living room measures about 0.7 mG. The average exposure during the day of a typical white-collar worker would be around 1 mG, a utility worker exposed to high fields during the day might average around 7 mG, while an electric train operator's exposure might average around 100 mG.

2000). Furthermore, alternative explanations of the associations, such as traffic and social class, seem much less likely (Reynolds et al., 2001), (Langholz, 2001). The study of Linet et al. on childhood leukemia (Linet et al., 1997) was originally and prominently interpreted as showing no effect. It has now been shown to contribute important support in pooled analyses that indicate that the association between the highest exposures to EMF and childhood leukemia are unlikely to be due to chance (Greenland et al., 2000).

An epidemiological literature is developing that associates magnetic fields with diseases and conditions that are more common than cancer, such as sudden cardiac death, dementia, suicide (NIEHS, Portier & Wolf, 1998), and spontaneous abortion (Li et al., 2002), (Lee et al., 2002). From a cost/benefit perspective, the confirmation of the associations with these more common diseases would have greater utilitarian policy implications (Florig, 2001) than the confirmation of EMF associations with rare diseases, such as childhood cancer or Lou Gehrig's Disease (amyotrophic lateral sclerosis).

Exposure: A number of epidemiological studies and exposure surveys have given a significantly better description of the range of exposures to some aspects of the EMF mixture, both in the occupational and in the general environment (Portier & Wolfe, 1998), (Li et al., 2002), (Lee et al., 2002), (Zaffanella & Kalton, 1998), (Zaffanella & Hooper, 2000). It has become clear that the 24-hour average of the minute-by-minute 50-60 Hz magnetic field exposures is primarily influenced by stray ground currents, internal wiring, and the power grid rather than by appliances. Maximum fields (the highest exposure during the day) are probably contributed by use of appliances, electrical transportation, or passing briefly by internal wires, current-bearing plumbing, or very close to above or below ground power lines.

Which Aspects of the "EMF Mixture" Might Be Bioactive?: As the decade of the 1990s began, a few childhood leukemia studies suggested that associations were stronger between leukemia and proximity to power lines than between the disease and measured fields (NAS et al., 1997). With more studies, this pattern has disappeared (Greenland et al., 2000). The earlier impression led to investigations of correlates with power lines and measured magnetic fields. Resonance between the static magnetic field of the earth and alternating 60 Hz fields was evaluated, as were transient changes in magnetic field, as potential explanations for the epidemiology. As indicated on page 32, the results do not strongly implicate these aspects of the EMF mixture (Kaune et al., 2002).

A new hypothesis has arisen (Kavet et al., 2000), (Dawson et al., 2001). It proposes that contact currents from low frequency voltages, and not exposure to magnetic fields, might explain some of the epidemiological associations. Others (Graham and Ludquist personal communication, 2001) suggest that the high frequency components of these currents are bioactive. In occupational settings, micro-shocks have been invoked to explain the persistent association between magnetic field exposure and ALS (NRPB, 2001b), (Ahlbom, 2001). These hypotheses have not yet been tested.

Scattered associations with electric fields have been reported (Coghill, Steward & Phillips, 1996), (Miller et al., 1996), but this association has not been consistent. A hypothesis and some evidence have developed with regard to electric fields near transmission lines and their effects on the charge and concentration of particulate air pollutants (Henshaw et al., 1996). If true, this would suggest that one should bury lines to block their electric fields and that rephasing would not be effective. However, this hypothesis has not been sufficiently supported by evidence.

Two recent studies of miscarriage and personal EMF exposure suggest that maximum fields or average change between consecutive exposures may convey risk (Li et al., 2002), (Lee et al., 2002). Studies of the effect of personal exposure on urinary melatonin metabolites in utility workers have suggested the possibility that the rate of change of the magnetic field may be bioactive (Burch et al., 1998). This, too, would have implications for any mitigation. One laboratory has reported that the super-imposition of random EMF noise in the laboratory can block the effects of orderly low-frequency magnetic fields (Litovitz et al., 1994). No replication of this study has been attempted yet.

Radio Frequency Research: Public concern and research on the question of radio frequency and low-frequency-modulated radio frequency have increased in the last decade. Although this area may turn out to be relevant to the low frequency literature reviewed here, exploration of it was beyond the resources, mandate, and expertise of the review team.

Funding: Funding for EMF research in the United States has dropped from the levels in the late 1980s. The Department of Energy research program of $10 million per year has been eliminated and the amount of resources devoted to EMF research by the utility industry and the Electric Power Research Institute has decreased from $10 million per year at its peak to $3.5 million in 2000. The National Institutes of Health have no special study section with EMF experts to review research proposals in this area, so proposals are judged by experts in other areas and compete for scarce research dollars.

3 How to Read This Document

This document is not just a summary of the facts from the vast literature on the possible health effects of extremely low frequency (ELF) electric and magnetic fields. Instead the bulk of the main document presents a much more detailed rationale for the conclusions drawn, and the evidence is summarized in graphical and tabular form.

In preparation for this evaluation, the California EMF Program held a two-day epidemiology workshop to discuss some of the most relevant epidemiological findings and methodological issues. The proceedings of that workshop, which were pivotal to some of the conclusions reported here, were published in a peer-reviewed Supplement (5) of the journal *Bioelectromagnetics* on January 22, 2001.

4 What is New in this Evaluation

New Evidence

There have been many adequate reviews, including some very recent ones (NAS et al., 1997), (Portier & Wolfe, 1998), (IARC, 2001). The NIEHS review, in particular, was regarded as the starting point for this evaluation. The NIEHS Working Group carried out their evaluation in June 1998. Several important studies have been published between the conclusion of the NIEHS Working Group review and this evaluation, including three major studies on childhood leukemia (Green, Miller & Agnew, 1999b), (Green et al., 1999a), (McBride et al., 1999), (UKCSS, 1999). The deadline for including studies in our evaluation was June 24, 2000. This is later than the deadline originally mentioned in the Risk Evaluation Guidelines (REGs). Since the DHS evaluation began later than initially envisaged, the reviewers felt that it was unwise to disregard recently published, and possibly important, studies simply to observe a previously set but otherwise arbitrary date. Only one large study (van Wijngaarden et al., 2000) that dealt with suicide emerged during this extended deadline period.

In addition, the reviewers considered studies sponsored by the California EMF Program (Li et al., 2002), (Lee et al., 2002) and in the Epidemiology Workshop satisfying the criteria for inclusion in this evaluation, as specified in the Guidelines. In this final draft, the DHS scientists also discuss articles that were brought to their attention during the public comment period.

The document has features that were not present in the NIEHS document. One of these—presenting a graded degree of certainty of causality—was described above. Also discussed are the aspects that make up the EMF mixture that characterizes the exposure of persons who come near the power grid, the internal wiring of houses, and common household appliances. These are described in Chapter 3. The reviewers stress the notion of "mixture" because different aspects of EMF exposure (e.g., 60-cycle magnetic fields and high-frequency transients) would require different actions for abatement. For each of the diseases considered, there are explicit discussions about whether the epidemiological associations observed, if real, would convey a risk from lifetime exposure that would be of regulatory interest. This is a parameter of interest to the social justice policy framework, which focuses on the individual risks of the most highly exposed. In Table IX, the baseline mortality for conditions considered possibly associated with EMFs are discussed. The reviewers ask if the attributable burden of mortality from even a very small fraction of that baseline would be of regulatory interest when compared to the mortality burden thought to be avoided by regulation of other agents. The attributable burdens of mortality or morbidity are parameters of interest to the utilitarian policy framework, which aims at the most good for the most people at the least cost. The document also attends to any evidence suggesting inequitable exposure or vulnerability to EMFs. This is relevant to the environmental justice policy framework, which is concerned with unfair distributions of risk.

Each health condition considered had at least two epidemiological studies in which there was a statistical association with some surrogate for EMF exposure. The list of conditions is similar to that discussed in the NIEHS document and includes

- Adult and childhood leukemia
- Adult and childhood brain cancer
- Male and female breast cancer
- EMF as a "broad spectrum" carcinogen for all cancers
- Miscarriage
- Other reproductive and developmental conditions
- Amyotrophic lateral sclerosis (Lou Gehrig's Disease)
- Alzheimer's disease
- Acute myocardial infarction

- Suicide
- Other adverse non-cancer health outcomes (depression, electrical sensitivity)

5 Qualitative Bayes or Degree of Certainty Approach to Evaluation

The DHS scientists found the usual process of describing the pattern of evidence in some detail and then expressing an opinion (without explaining the rationale for that opinion) to be insufficiently transparent. Accordingly, they supplement the usual IARC procedure with an additional form of presentation and an additional form of judging whether EMFs are a cause of disease. The following table shows the questions that were systematically addressed. For definitions of epidemiological terms in the table see pages 20-22 (Sections 12.1.1-12.1.3).

TABLE II. QUESTIONS RELEVANT TO DEVELOPING A DEGREE OF CERTAINTY ABOUT CAUSALITY

EXPLANATIONS OF A STATISTICAL ASSOCIATION OTHER THAN A CAUSAL ONE
Chance: How likely is it that the combined association from all the studies of EMF and disease is due to chance alone?
*Bias: How convinced are the reviewers that EMFs rather than a study flaw that can be **specified and demonstrated** caused this evidentiary pattern? If no specified and demonstrated bias explains it, how convinced are they that EMFs caused these associations rather than **unspecified** flaws?*
*Confounding: How convinced are the reviewers that these disease associations are due to EMFs rather than to another **specified and demonstrated** risk factor associated with EMF exposure? If not due to a specified risk factor, how convinced are they that they are due to EMFs rather than to **unspecified** risk factors?*
Combined effect: How convinced are the reviewers that these disease associations are due to EMFs rather than to a combined effect of chance and specified or unspecified sources of bias and confounders?
ATTRIBUTES SIMILAR TO HILL'S (HILL, 1965) THAT ARE SOMETIMES USED BY EPIDEMIOLOGISTS TO EVALUATE THE CREDIBILITY OF A HYPOTHESIS WHEN NO DIRECT EVIDENCE OF CONFOUNDING OR BIAS EXISTS
Strength of association: How likely is it that the meta-analytic association is strong enough to be causal rather than due to unspecified minor study flaws or confounders?
Consistency: Do most of the studies suggest some added risk from EMFs? How likely is it that the proportion of studies with risk ratios above or below 1.0 arose from chance alone?
Homogeneity: If a large proportion of the studies have risk ratios that are either above or below 1.0, is their magnitude similar (homogeneous) or is the size of the observed effect quite variable (heterogeneous)?
Dose response: How clear is it that disease risk increases steadily with dose? What would be expected under causality? Under chance, bias, or confounding?
Coherence/Visibility: How coherent is the story told by the pattern of associations within studies? If a surrogate measure shows an association, does a better measurement strengthen that association? Is the association stronger in groups where it is predicted? What would be expected under causality? Under chance, bias, or confounding? How convinced are the reviewers that the magnitude of epidemiological results is consistent with temporal or geographic trends?
Experimental evidence: How convincing are the experimental pathology studies supporting the epidemiological evidence? What would be expected under causality, bias, chance, or confounding?
Plausibility: How convincing is the mechanistic research on plausible biological mechanisms leading from exposure to this disease? What would be expected under causality, chance, bias, or confounding? How influential are other experimental studies (both in vivo and in vitro) that speak to the ability of EMFs to produce effects at low dose?
Analogy: How good an analogy can the reviewers find with similar agents that have been shown to lead to similar diseases? What would be expected under causality, chance, bias, or confounding?
Temporality: How convinced are the reviewers that EMF exposure precedes onset of disease and that disease status did not lead to a change in exposure?
Specificity and other disease associations: How predominantly are EMFs associated with one disease or subtypes of several diseases? What would the reviewers expect under causality, chance, bias, or confounding? How much is their confidence in EMF causality for disease X influenced by their confidence that EMFs cause disease Y?

As a heuristic device, and following Hutchinson and Lane (Hutchinson & Lane, 1980), the REGs suggested that these questions about the pattern of evidence be posed so that one could say the pattern is more likely under the hypothesis that EMFs contributed to the cause of that health condition or more likely under the hypothesis that chance, bias, or confounding produced the pattern. This allows the reviewers to provide the reader a rationale for the relative weight given mechanistic, animal pathology, and epidemiological evidence and to understand which parts of the evidence suggest causality and which speak against causality.

The DHS reviewers coined the term "Qualitative Bayes Approach" to characterize a form of verbally justifying judgments about hazard that paid attention to the insights of Thomas Bayes, an 18th-century mathematician. His insights would suggest starting with some initial degree of certainty that any given agent is capable of being harmful based on knowledge about agents in general. Evidence is then accumulated on this specific agent and this changes the degree of suspicion or certainty. Imagine a prehistoric hunter deciding whether to try out some jungle fruit he has never seen before. He has an initial degree of suspicion high enough that he does not partake right away. He takes some fruit home and feeds it successively to several types of captured birds. As each species seems to survive, it seems less and less likely that the fruit would be harmful to humans. But since the leaves of the tree bearing that fruit resemble those from a tree that bears a poisonous fruit (causing the initial suspicion to be very high) the hunter's specific experiments might still leave him fairly suspicious and lead him to cruelly feed the fruit to a captive from another tribe. Only if the captive survived would his initial suspicions be allayed. This example illustrates Thomas Bayes's two key insights. As evidence builds we update our degree of certainty of harm, but, at any point in time, that updated degree of certainty also depends on how suspicious we were initially. This idea is expressed mathematically by a simple formula. The first term of the Bayes formula is the "prior odds," that is, the odds that a given hypothesis is thought to merit *a priori*, before examining the evidence. In this document it is called the prior because it is not based on subsequent research.

The second term, the "likelihood ratio," is a multiplier, calculated (or, in this case, qualitatively discussed) after scientific evidence has been collected and evaluated. The term "likelihood ratio" is most properly restricted to the case where one compares the statistical likelihood of a result under one specific hypothesis relative to that under another hypothesis, usually the null. It expresses the likelihood of the observed pattern of evidence if EMFs do indeed cause disease, divided by the likelihood of that pattern if EMFs do not cause disease. The third term, the "posterior," is the product of the first two and represents the odds of the risk being true after the prior has been modified by our evaluation of the evidence.

Because of the difficulty of translating complex evidence into numbers, we only use the ideas behind the formula as a way of explaining how certain or uncertain we were to begin with and to explain the basis for the weights we gave a particular stream of evidence in order to update our degree of certainty. The Bayesian perspective used by the California reviewers recognizes that a reassuring pattern of evidence from a stream of evidence that often misses a harmful effect does not allay one's suspicion much, even though an alarming pattern of evidence from that same stream of evidence might increase suspicion a lot. Going back to the hunter-gatherer example: if birds sometimes survive eating fruits that are lethal to humans, then reassuring evidence from bird experiments would not allay suspicion as much as the death of the birds after eating the fruit would increase our suspicion. In the terminology of probability, the relative likelihood conveyed by a positive or negative result depends on the false-positive rate and false-negative rate characteristic of that stream of evidence. The mathematical basis for this insight is discussed in the REGs (www.dhs.ca.gov/ehib/emf). It resulted in realizing that any stream of evidence, judged by the extent to which it usually produced false-positive and/or false-negative results, could be classified into four possible types: 1) capable of strengthening OR weakening one's certainty, 2) predominantly capable of strengthening certainty (like the bird feeding example given above), 3) predominantly capable of weakening certainty and, 4) uninformative, neither capable of strengthening nor weakening one's confidence. While this structured discussion helped organize the reviewers' judgments, it did not involve a mathematical combination of weights as would be the case in a quantitative Bayes evaluation. It should be noted that the Hill's attributes are like the bird-feeding example. If they are present they strengthen confidence, but if they are absent, confidence falls only a little.

The DHS reviewers considered the following streams of evidence: biophysical evidence about the physical induction mechanism, research into physiological and pathophysiological mechanisms, research into animal pathology and epidemiological evidence. Clearly if all these streams of evidence were non-supportive, one's degree of certainty would fall, and if they were all supportive it would rise. If some streams of evidence are unsupportive and some are supportive, the DHS reviewers considered the inherent proclivity of each stream of evidence to give false positive or false negative results as a guide to what weight its results should be accorded. If apparently supportive evidence is shown clearly to be due to artifacts, this would lower the degree of certainty.

In the "Qualitative Bayes Approach" the DHS reviewers elicited their own expert judgment about the *a priori* (initial) probability of hazard after a special training session on how to avoid common errors of probabilistic estimation. It was important

to be explicit about the prior probability because some physicists were arguing on the basis of physical theory applied to simplified biological models of the cell, that any biological effect from residential EMFs was impossible and thus had a vanishingly small initial credibility. This meant that they would require extraordinarily strong specific evidence to change their initial impression. Previous risk assessments have not explicitly considered this issue.

The discussion then turns to the patterns of specific EMF evidence in biophysical, mechanistic, animal pathology, and epidemiological streams of evidence. Obviously, if all four streams of evidence pointed toward or away from an EMF effect, the reviewers' job would be easy. But what if some streams of evidence are supportive and some are not supportive? What weight should be given each stream of evidence? It was in the effort to address this problem that discussions of the inherent proclivity to give false positive and negative results came into play. This discussion was guided by a series of pre-agreed-upon questions described in the table above. The discussion included pro, con, and summary arguments. An example of such arguments are presented in the next table.

TABLE III. EXAMPLE OF PRO, CON, AND SUMMARY ARGUMENT

CHANCE		
AGAINST CAUSALITY	FOR CAUSALITY	COMMENT AND SUMMARY
(A1) Not all the associations (relative risks) are above 1.00 or statistically significant.	(F1) The narrow confidence limits in the meta-analytic summaries and the low likelihood of this pattern of evidence by chance leans away from chance as an explanation.	(C1) A non-chance explanation must be sought.

Considering this kind of structured discussion helped organize the reviewers' judgments, after he/she weighed all the information in the usual way, although it did not involve a mathematical combination of weights as would be the case in a quantitative Bayes evaluation. After consideration of this carefully structured discussion of the evidence (considering how much more—or less—likely the pattern of evidence would be if the risk hypothesis were true compared to the likelihood of that evidence if EMFs were safe), the reviewers expressed an expert judgment on the posterior probability of a causal relationship.

6 QUALITATIVE BAYES RISK EVALUATION COMPARED TO TRADITIONAL AND QUANTITATIVE BAYES RISK EVALUATIONS

The traditional risk assessment has a section in which a judgment is given as to whether the agent being evaluated is capable of causing cancer or some other adverse health effect. This is called the "hazard identification." The typical presentation is heavy in describing the relevant evidence and rather light in explaining the rationale for the conclusion. Often the weight, given mechanistic, animal pathology, and epidemiological streams of evidence, depends on a review panel's interpretation of adjectives which best describe the pattern of evidence. For example, is the pattern of evidence "sufficient" or should it be called "limited"? Can confounding and bias be "reasonably" discounted? Then there are pre-agreed-upon rules for combining the streams of evidence. Limited animal evidence plus limited epidemiological evidence results in one rank, sufficient animal evidence plus limited epidemiological evidence leads to another rank, and so forth. The combinatorial rules are straightforward, but the rationale for deciding that a stream of evidence is "limited" is not clearly defined and is subjective.

A completely quantitative Bayesian approach of the sort proposed by McColl et al. (McColl et al., 1996) or by Lindley (Lindley, 2000), would require assigning many quantitative parameters to a complex Bayesian Net model which would mathematically combine the subjectively assigned parameters to produce a posterior degree of certainty of causality. To the reviewers' knowledge, this kind of model has never been applied to any environmental agent. How experts such as physicians, combine streams of evidence to make judgements about causality has

been of great practical interest. As pointed out by Shortliffe (Shortliffe et al., 2001) there have been two general approaches. One is to infer statistically (Holman, Arnold-Reed & Klerk, 2001) or find by interview what rules experts usually employ. This assumes that the rules of thumb that experts use are optimal. As Holman (Holman et al., 2001) points out, however, this may not always be the case. The other approach is to use information to indicate what weights ought to be used. An example of this was de Dombal's (de Dombal et al., 1972) work using a Bayesian approach to diagnosing the acute abdomen on the basis of the prior probability of patients with certain diagnoses showing up in emergency rooms, and the relative likelihood of elements of medical history, physical signs, and laboratory test results in the several possible diagnoses. According to Shortliffe (Shortliffe et al., 2001), neither approach has so far been reduced to computer applications that render the combining of streams of evidence a cut and dried uncontroversial activity. It should be expected then, that the analogous task of risk evaluation will still rely on professional judgement and will not be free of controversy. For this reason, our stakeholders urged us to opt for transparency rather than computational elegance in our risk evaluation guidelines. In response to the third draft, the Electric Power Research Institute contracted with Professor Sander Greenland in late 2001 to prepare a quantitative Bayesian model based on the epidemiological evidence for childhood leukemia. Since his will be the only extant quantitative Bayesian epidemiological analysis, the reviewers contrast its proposed approach to their own. His model will provide a posterior dose-response curve based on a prior dose-response curve, the pooled epidemiological data, and prior estimates of selection bias and non-differential measurement bias. The all-important biophysical, mechanistic, and animal pathology streams of evidence will not be part of Greenland's model, although they could influence the prior dose-response curve in a subjective way. Calculations from Greenland's model would allow one to provide a probability that the posterior slope of the dose-response curve is not flat, that is, that there is some causal effect.

The following table compares the Qualitative Bayes evaluation to the traditional and to Greenland's Quantitative Bayes approach to risk evaluation as to a number of characteristics.

TABLE IV. COMPARISON OF USUAL RISK ASSESSMENT METHOD TO QUALITATIVE AND QUANTITATIVE BAYES METHODS

CHARACTERISTIC	USUAL METHOD	QUAL. BAYES	QUANT. BAYES
Evaluates all streams of evidence?	Sometimes	Yes	Focuses on epidemiology, other streams influence prior
Elicits prior probability?	No	Yes	Prior dose-response curve
Compares likelihood of each element of the evidence under the hazard and non-hazard hypotheses?	No	Qualitatively	Quantitatively with many of the parameters subjectively elicited
Pro, con, and summary arguments to make rationale transparent?	No, most risk assessments are skimpy in justifying hazard categories assigned	Yes	Not unless a supplementary document were to accompany the model
Combines relative likelihoods mathematically to derive posterior?	No	No	Yes, but in some versions non-epidemiol. evidence is folded into the prior subjectively
Elicits an expert posterior probability after considering all	No	Yes	No

CHARACTERISTIC	USUAL METHOD	QUAL. BAYES	QUANT. BAYES
elements of the evidence?			
Displays judgments of various judges separately?	Usually strives for semblance of consensus	Yes	Technically possible for different experts to elicit their own parameters
Frames intermediate degrees of certainty as "not a proven hazard?"	Often	No, reveals posterior probability	No, reveals posterior probability

Both the Qualitative Bayes and the Quantitative Bayes evaluations can provide a posterior degree of certainty that the epidemiological associations are causal, which, if in the range from 10 to 90 out of 100, will not seem trivial to the general public and will stimulate policy discussions. The statements, "possible," "there is no proven hazard," or "there is no consistent evidence," often used for this range of degrees of confidence, will not stimulate such discussions. Thus, both the Qualitative Bayes and Quantitative Bayes methods pose risk communication "problems" for those who believe that society should not begin policy discussions until most scientists are virtually certain that a hazard exists. The traditional hazard identifications would pose the same "problem" if they routinely used more nuanced categories of hazard assessment that distinguished between, say, a certainty level of 11/100 and one of 89/100. As now framed they pose a risk communication "problem" for those who believe that policy discussions should begin even before a hazard is firmly established.

Compared to traditional qualitative evaluations, the Qualitative Bayesian approach makes the evaluation more transparent, but it still accommodates different opinions. The DHS reviewers have no doubt that critics of their conclusions could use the Qualitative Bayes format to make their points. Some of the physicists who believe that they have a theory to prove that no residential EMF effect is possible would use priors so low that their posterior degrees of certainty would be low as well; the toxicologists who believe reassuring animal tests prove that EMFs are safe would make a case that the animal study results pull down their degree of certainty of a hazard to a level below their initial degree of certainty. In a contentious area such as EMFs, the reviewers doubt very much that any of the three styles of risk evaluation discussed in the table would force a consensus among subject matter experts who weigh and interpret the several streams of evidence differently. Even in the Quantitative Bayes model experts will use different priors and will elicit different subjective relative likelihood parameters for items like bias and confounding, for which there is no direct evidence. In the traditional method, experts will disagree on whether a stream of evidence warrants the adjective "limited" or "sufficient," and in the Qualitative Bayes approach experts will disagree on "how much more likely" the pattern of evidence is under the causal and non-causal hypotheses. But the reasons for these different judgments will be more transparent in the Qualitative Bayes style of risk evaluation and we believe that this is desirable in controversial areas.

7 How Credible Was the EMF Hypothesis to Begin With?

The three reviewers first considered the initial credibility of the hypothesis (before any targeted research had been done) that everyday residential and electrical occupational EMF exposures could influence the risk of disease. Like the majority of reviewers at IARC and NIEHS, the DHS reviewers were swayed only a little by theoretical biophysical arguments that such influences were impossible, since these arguments depend on assumptions about biological systems that may or may not be sophisticated enough to reflect reality and rule out an effect. The reviewers acknowledged, though, that this was probably the only agent they had encountered where these kinds of "impossibility" arguments had been made. However, a better understanding of biology (and not any change in physics theory) could conceivably explain how an organism could detect and be affected by the spatially and temporally coherent EMFs or other aspects of the EMF mixture emanating from power lines and appliances.

The reviewers considered the proportion of chemical agents that had tested positively for carcinogenicity at high doses (about 20%) as one benchmark (Fung et al., 1993). They also considered the fluctuation of disease rates starting in the late 19th century when electricity began to spread gradually from wealthy urban areas to other parts of the world. Any changes could put *a priori* bounds on the size and direction of any EMF effect. Milham (Milham & Ossiander, 2001) drew attention to

something that Court Brown and Doll (Brown & Doll, 1961) had pointed out more than 40 years ago, that an increased risk of leukemia mortality for 2- to 4-year-old children first appeared in the 1920s and increased in intensity in the 1940s. Thus some factor(s) (perhaps electricity, perhaps accuracy in diagnosis), in those modernized locations caused the registration of toddler leukemia deaths to increase threefold. The evidence from Court Brown, Doll, and others that childhood leukemia mortality registration had indeed increased during the early 20th century increased the prior probability of a moderately large EMF effect, at least for childhood leukemia. Since similar trends were not reported for other conditions, it was considered that modest protective or harmful effects from rare high exposures were compatible with the data.

The three DHS reviewers underwent special training in probability elicitation. They then judged that EMF effects were about as probable or a little less probable to influence the risk of disease as any man-made environmental pollutant taken at random. The three reviewers gave probabilities ranging from 5% to 12% *a priori*, that EMFs at or above the 95th percentile of typical residential US exposures would produce effects detectable by epidemiologists when compared to the 1st percentile of residential exposure or below.

8 The Weight Accorded Biophysical Arguments that Bioeffects from Residential and Most Occupational Fields were Impossible or that No Physical Induction Mechanism had Been Elucidated

While the reviewers do not doubt established physical theory, they believe that its application to simplified biological models is not sufficiently convincing to prove the impossibility of epidemiological or laboratory observations. However, the argument that environmental fields have very little energy lowered the prior probability that EMFs might have biological or pathological effects. The fact that there was no mechanistic explanation for how residential-level electric or magnetic fields might cause chemical or cellular changes, that there was no recognized molecule or organ capable of reacting or detecting residential magnetic fields, and the fact that recognized physiological effects of pulsed and very high magnetic fields did not have a well-understood physical induction mechanism did not decrease the updated degree of confidence much. This is because many known physiological and pathological effects go for a long time without a full mechanistic understanding.

9 The Weight Accorded Experimental Evidence On Any Pathophysiological Mechanisms by Which EMF Might Work

It has long been known that EMFs can affect biological processes, if their intensity is strong enough. In fact, safe exposure limits have been set to prevent these effects. A good review can be found in the book *Electromagnetic Fields (300 Hz to 300 GHz), Environmental Health Criteria 137*, published under the joint sponsorship of the United Nations Environment Program, the International Radiation Protection Association, and the World Health Organization (Geneva, 1993). In almost all cases, these levels are exceeded only in very rare occupational environments. Since they are almost never exceeded in the general environment, such levels are not a public health concern. A much more complex debate centers on whether these are the only possible effects or whether the temporal and spatial coherence of the man-made fields associated with electric power can be somehow discriminated from the incoherent endogenous currents and interact with biological processes at levels much lower than those for which exposure limits exist. The reviewers agreed that, as was also the case initially for many disease-causing agents, there is not a well-documented mechanism that explains how the EMF "mixture" at residential or occupational levels could initiate a biological response or, having initiated that response, how a chain of events could lead to damage or disease of various types. There are biological effects from aspects of the EMF mixture, particularly at exposure doses far above residential and occupational levels. At this time they do not provide a clear mechanistic understanding of how the EMF mixture could cause disease. The absence of a clear mechanistic chain of effects and the failure of many experiments with aspects of the EMF mixture to produce any mechanistic effects did not lower the reviewers certainty of causality much below what it was initially. The evidence that there are some mechanistic effects of some aspects of the EMF mixture at doses (thousands of mG) far higher than usually encountered in the environment did not boost the confidence of causality very much beyond the initial probability because the biophysical arguments suggest that they might not be relevant to effects at lower levels. The DHS reviewers accepted the unusually strict requirement that mechanistic results in the laboratory must be demonstrable at ambient levels of exposure.

It should be noted that the assumption of many of the mechanistic experiments is that the effects of magnetic or electric fields (like those of many chemicals and ionizing radiation) occur at a level of organization demonstrable in a chemical mixture, a mixture of cellular components, or a mixture of cells and does not depend on the presence of an intact multicellular organism. There are some well-recognized effects that violate these assumptions. For example, the intact shark, through a

special organ with an array of connected detectors, can detect tiny electrical fields emitted by distant prey. The exact biophysical mechanisms by which the individual detectors work cannot be documented using individual receptors at the ambient levels detected by the intact shark (Kalmijn, 1971), (Wissing, Braun & Schafer, 1988).

The lack of mechanistic understanding, which was initially the case for many harmful agents, is not as strong an argument against causality as the presence of such an understanding would be in favor of causality. Therefore the mechanistic line of evidence did not contribute much to the reviewers' judgments.

10 The Weight Accorded to Experimental Evidence not Clearly Connected With Particular Endpoints but Relevant to the Ability of Low-Level EMFs to Be Bioactive

A number of studies, both in vivo and in vitro, report bioeffects which, while they do not shed light on physical induction or pathophysiological mechanisms, do suggest that there are effects other than those mediated by well-understood mechanisms, such as induced currents. For example, the initial observations by Liburdy of inhibition of the melatonin antiproliferative action by 12 mG 60 Hz fields in 1993 (Liburdy et al., 1993) has been confirmed and extended by two other laboratories (Blackman et al., 2001), (Ishido et al., 2001). The series of studies using pulsed magnetic fields that showed non-robust effects on chicken embryos at intensities below 100 mG (Martin, 1988), (Berman et al., 1990), (Martin, 1992), (Moses & Martin, 1992), (Moses & Martin, 1993), (Martin & Moses, 1995), (Litovitz et al., 1994), (Farrell et al., 1997a), (Farrell et al., 1997b), (Leal et al., 1989), (Chacon et al., 1990), (Ubeda et al., 1994), (Koch & Koch, 1991), (Koch et al., 1993), (Singh & et al., 1991), (Espinar et al., 1997), (Blackman et al., 1988), (Yip et al., 1994a), (Yip et al., 1994b), (Coulton & Barker, 1991), (Youbicier-Simo et al., 1997), (Piera et al., 1992), (Pafkova & Jerabek, 1994), (Pafkova et al., 1996), (Pafkova et al., 1994), (Veicsteinas et al., 1996) also provide some evidence of bioeffects that would be considered "impossible" according to biophysical theory. These two areas of research have been greeted with suspicion. For example, Weaver (Weaver, Vaughan & Martin, 1999) dismisses in vitro effects as being artifactual, due to an insufficiently rigorous lack of temperature control, because biophysical theory suggests that tiny fluctuations in temperature would produce more effects than magnetic fields below 100 mG. The DHS reviewers were not convinced by this argument. These studies were no less rigorously conducted than most in vitro studies in other fields of research. There is no direct evidence that inducing magnetic fields also heats the tissues. If experimental controls beyond the current technological limits are required, then ALL in vitro and in vivo research should be called into question.

The reviewers had differing opinions on the extent to which this evidence should change the belief in the hypothesis from what it was when this issue was first raised. One could argue that any experiment that shows an effect where none is expected ought to increase the credibility that EMF can indeed interact with biological systems at energy levels that biophysical theory considers too low to be effective. These studies thus provide some grounds for mistrusting the prediction of simplified biophysical models that no effect is possible below 100 microTesla (μT). Reviewer 1 was compelled by the evidence as it stands, while the other two reviewers would require further experimentation to gain general acceptance of the results before putting a lot of weight on them. All three reviewers agreed that confirming or explaining away the results from these two groups of experiments would be important for those who put great weight on biophysical "impossibility" arguments.

11 The Weight Accorded to Animal Pathology Experiments

The reviewers agreed that, with few exceptions, animal pathology studies based on high exposures to certain aspects of the EMF mixture showed no effects. There were three reasons why the reviewers believed that animal bioassays of single ingredients of the EMF mixture might be prone to missing a true effect:

a) Finding the right animal species to test: While the reviewers recognized that most agents found to cause cancer in humans also cause cancer in some (but not all) animal species, they were also cognizant that there are known human carcinogens, such as cigarette smoke, alcoholic beverages, benzene, and arsenic, for which no animal model existed for many decades.

b) Testing one ingredient of a mixture: The reviewers all questioned whether the bioassay of one element of a mixture could be sensitive enough to detect problems in the entire mixture. For example, many reassuring assays on the carcinogenicity of caffeine would not reassure us about the carcinogenicity of coffee. The animal pathology studies to date have been on pure steady 60 Hz fields not on the mixture of ingredients found near power lines or appliances.

c) Assuming that high intensities of magnetic fields produce larger effects than moderate fields do: The reviewers also questioned the sensitivity of a bioassay involving a small number of animals and assuming a monotonically increasing risk from low to high-dose, when the epidemiological studies that prompted the bioassays did not suggest an ever-increasing response.

The epidemiology suggests that the effect, if any, at 100s of mG (Tynes, Reitan & Andersen, 1994b), (Floderus, Tornqvist & Stenlund, 1994), (Alfredsson, Hammar & Karlehagen, 1996), (Minder & Pfluger, 2001) is no greater than that of children at 3 mG (Greenland et al., 2000), or of highly exposed utility workers with 24 hr time weighted averages (TWAs) around 7 mG (Kheifets, London & Peters, 1997b), (Kheifets, 2001). One would not expect rodents at 1000 mG to demonstrate a large enough effect to be detected in a conventionally sized laboratory experiment with a few hundred animals.

Accordingly, the lack of response in most animal pathology studies did not lower the degree of certainty by much. Reviewer 1 and 3 had their degree of confidence increased somewhat by repeated, but unreplicated, results from one German laboratory (Mevissen et al., 1996b) and isolated results from two laboratories in the former Soviet Republics (Anisimov et al., 1996), (Beniashvili et al., 1991), which showed co-promotional effects on breast tumors. None of the reviewers were much influenced by the statistically significant increase in thyroid cancers in one of the bioassays (Boorman, McCormick & Findlay, 1999b), even though it had not appeared in control series of previous bioassays and was thus a very unlikely occurrence. This effect showed up in only one sex of rats and not in mice and thus did not pass conventional toxicological criteria for animal carcinogenicity.

12 The Weight Accorded to Epidemiology Combined with Other Streams of Evidence

In the reviewers' judgement, it was epidemiological evidence that produced the most change in the degree of certainty from what it was *a priori*. Epidemiological studies are non-experimental statistical studies of human populations that compare rates of disease in groups with different levels of exposure or compare the proportion of exposed subjects in groups of healthy and diseased persons. The weakness of epidemiological evidence is that one cannot rule out the effect of factors associated with EMFs ("confounders") or completely avoid the limitations of collecting evidence in the real world instead of a controlled laboratory environment. These limitations may introduce errors ("bias") in the results. On the other hand, the strength of epidemiology is that it deals with the species of interest (humans) and the mixture and dose of interest (the EMF mixture as experienced by humans).

The individual studies, most of which were described in the NIEHS report, have been summarized in tables and graphs in this report. A structured evaluation of the epidemiological evidence was carried out for each of the 13 endpoints and summarized with the classification used by IARC and also by a statement of the degree of certainty that the observed epidemiological associations were causal in nature. In evaluating the credibility of epidemiological evidence, it is common to consider whether the risk being studied is "biologically plausible" and if "experimental evidence" exists to support the epidemiology. The three reviewers followed this practice considering the impact on the epidemiological findings of mechanistic evidence and evidence about bioactivity at near ambient levels under the heading of "plausibility" and of the animal pathology under the heading of "experimental evidence." However, these non-epidemiological studies were discussed in detail in separate chapters.

12.1 Issues Relevant to the Evaluation of the Epidemiological Evidence

Epidemiological results, because of the limitations of the data collected in a "real world" environment, need to be evaluated with particular care. The three major concerns are the effects of chance, bias, and confounding.

12.1.1 Chance

Epidemiological studies are expensive. Moreover, in the case of EMF and cancer, it may be virtually impossible to find sufficient subjects with both a rare disease and the rare high exposures. The very well-conducted studies carried out in some Scandinavian countries are based on so few subjects that a single additional case of cancer would change their findings. It is possible to reduce the effect of chance findings by combining results from a number of studies in a meta-analysis or even to merge the data collected for different studies in one large data set (pooled analysis). For health endpoints such as childhood leukemia (Greenland et al., 2000), adult leukemia (Kheifets et al., 1997a), adult brain cancer (Kheifets, 2001), amyotrophic lateral sclerosis (Ahlbom, 2001), male breast cancer (Erren, 2001), and miscarriage (Lee et al., 2002), (Li et al., 2002), pooled or meta-analytic analyses achieve conventional "statistical significance." This could be interpreted as follows: If these were randomized experiments without the possibility of bias or confounding, the statistical associations found would not be expected to occur by chance in 5 or fewer experiments out of 100 replications, if there really was no effect. Of course, epidemiological studies are not experiments, and it would be unethical and impractical to experimentally subject large numbers of humans to potentially harmful agents. This leads to the consideration of bias and confounding.

12.1.2 Bias

Any source of error in collecting the data may introduce a bias, which is a reason why the apparent result might not be the truth. A very common bias results from errors in assessing the true exposure of the subjects to the agent of interest, in this

case EMFs. Provided exposure of cancer cases and healthy controls is not assessed differently, this bias on average results in an underestimate of the risk, if one exists. When comparing the health risk of subjects exposed above one value to that of subjects below that value, non-differential misclassification of exposure* would not, on average, show an association if one does not truly exist. However, it may inflate the risk of intermediate exposure subjects and thus frustrate attempts to estimate a dose-response function. In most of the EMF studies, measurements were not taken for a long enough duration during the induction period of the disease to avoid this kind of misclassification. And there is even some argument about whether the right aspect of the EMF mixture has been measured. The three reviewers concluded that all of this may have led to an underestimate of any true effect of high versus low exposures and may have frustrated the ability to develop an appropriate dose-response curve.

Of the many errors that can creep into epidemiological studies, one in particular has been a source of argument with regard to a subset of the EMF epidemiological studies. We are referring to "selection bias" in some of the case control studies. A case control study is analyzed by comparing a series of cases with a disease to a series of healthy subjects as to their EMF exposure. If the cases display a higher proportion of high EMF exposure than the controls, this suggests a causal effect of EMFs. If, however, the probability of being selected for study is influenced both by whether one has the disease AND whether one had a high EMF exposure, then an apparent difference will appear between the cases and the healthy controls, which is the result of this biased selection and the result does not reflect any true effect of EMFs on the disease. One way to recruit healthy subjects is random telephone contact. This method excludes subjects of lower socio-economic status (SES), who may not have a telephone. Experience has shown that healthy controls of lower SES are sometimes less likely to participate in epidemiological studies than upper class subjects. In some studies, lower class subjects are more likely to live in neighborhoods with nearby power lines (Bracken et al., 1998). Since cancer patients of all social classes are easier to recruit (through a cancer registry) and more likely to be interested in participating, the effects of non-representative control selection may distort the comparisons between cases and controls and, therefore, the study results. In the case of EMF, it is claimed that the fact that there are more subjects living close to power lines among the cancer patients than among the healthy controls could be due to the fact that low SES subjects are more likely to live close to power lines and they are underrepresented in the control group. This issue of possible selection bias in case control studies is a particular issue for the North American case control studies on childhood leukemia. Hatch (Hatch et al., 2000) indicate that the association between childhood acute lymphoblastic leukemia (ALL) and front door magnetic fields greater than 3 mG was 1.9 (1.1-3.27) among full participants in their study but fell to 1.6 (0.98-2.61) when 147 partial participants were included. Although this difference was well within sampling variability, she suggested that it might be evidence of the presence of a selection bias which might be even more extreme if non-participants had their front doors measured and had been included in the analysis. Hatch (Hatch et al., 2000) concluded that "while confounding alone is unlikely to be an important source of bias....selection bias may be more of a concern...in case-control studies." The Scandinavian studies relied on cancer registries and lists of citizens and did not require permission of the subjects so that selection bias was not a problem. Ahlbom (2001) has shown that the results of the two groups of studies are not much different. The pooled analysis of all the studies he dealt with showed a relative risk for exposures above 4 mG as 2.0 (1.3-3.1), while the results after excluding the US studies was 1.7 (1.0-2.8). That is, the confidence interval of the two risk estimates overlap, indicating that there may or may not be some overestimate of the effect of living near power lines in the American studies, but that even if these are excluded, the association remains statistically significant. In the pooled analysis by Greenland et al. (2001), there was an effect of power line proximity ("wire code"), as well as an effect of measured magnetic fields. This might indicate some selection bias for power line proximity. Nonetheless, magnetic fields come only partially from power lines. Internal wiring and currents on plumbing form an important source (Zaffanella & Kalton, 1998). The only evidence we know of that examines personal EMF exposure from all sources and its relation to social class (Lee GM & Li D-K, personal communication) does not suggest differences in personal EMF exposure in different social classes. The evidence linking EMFs and adult leukemia, adult brain cancer, Lou Gehrig's disease, and Li's prospective miscarriage study come largely from study designs where selection bias is not possible (studies where rosters of healthy workers or subjects of high and low exposure are followed until death or health outcomes are determined from available records without requiring subject cooperation). Thus, although selection bias may have distorted the associations between EMF and childhood leukemia in some of the studies, the three reviewers did not believe that it totally explained the childhood leukemia findings and selection bias was not even an issue in the bulk of the studies related to adult leukemia, adult brain cancer, ALS, or in one of the two recent studies on EMF and miscarriage.

* "non-differential misclassification of exposure" is said to occur when errors of measurement occur equally in cases of disease and in healthy controls.

12.1.3 Confounding

The term "confounding" is derived from the Latin "confundere," to melt together. Epidemiologists use the term when the impact of two risk factors "melt together" and must be disentangled. If heavy alcohol consumption and smoking are both known to cause esophageal cancer, and people who drink also tend to smoke, then the effect of drinking will confound the effect of smoking and vice versa. Therefore one must correct for this confounding in the way the data are analyzed. Sometimes the non-effect of a factor which conveys no risk at all is confounded with the true effect of another factor. For example, it has been suggested that people who live near power lines also live on busy streets with lots of traffic and air pollution. This argument suggests that the effect of air pollution on childhood leukemia was confounded with the non-effect of the power lines, and the power lines were falsely implicated instead of the air pollution. Two conditions must pertain for an agent to be a strong confounder of the EMF effect on the various diseases discussed in this report. That agent must be strongly correlated with EMF exposure and it must have an effect on the studied disease that is even stronger than the apparent effect of EMF. If it is weakly correlated with EMF exposure it must have an effect on disease that is very strong indeed if it is to make EMF falsely appear to have an effect. Langholz (Langholz, 2001) has examined the candidate confounders for childhood leukemia and their association with power line proximity wire code. He concluded that while something connected with the age of home was a possibility, factors like traffic density, ethnicity, and smoking were not likely confounders. Indeed, not all studies of traffic and childhood leukemia suggest it as a risk factor (Reynolds et al., 2001), but a recent study of traffic and power line proximity and childhood leukemia (Pearson, Wachtel & Ebi, 2000) did suggest that there might be a joint effect. Hatch (Hatch et al., 2000) examined a variety of socioeconomic, and other confounders, and concluded that together, or alone, measured confounders would distort the association with ALL by less than 15%. Hatch also found no association between residential mobility, magnetic fields, or leukemia unlike Jones (Jones et al., 1993).

Electric shocks have been invoked to explain the relation between high-exposure jobs in the utility industry and ALS (Ahlbom, 2001), (NRPB, 2001a). If this were confirmed, they might also be invoked to explain the adult leukemia and brain cancer associations on the as yet unproven assumption that shocks could somehow cause cancer. However, the literature linking shock to ALS, unlike much of the literature linking high-EMF exposure jobs to ALS, depends on subjects remembering shocks. They are thus more vulnerable to recall bias than the EMF studies. Some of the studies suggest a protective, not a harmful, effect (Cruz et al., 1999); (Kondo & Tsubaki, 1981), (Gunnarson et al., 1992) and the size of the harmful effects of shock are less than the high EMF job effect (Deapen & Henderson, 1986), (Savettieri et al., 1991). No published study has demonstrated a correlation between shocks and high-EMF exposure jobs. Studies are underway to see if grounding currents are associated with measured magnetic fields and power line proximity. The three reviewers felt that the evidence for the confounders that had been proposed for EMF exposure did not have strong support and therefore their degree of confidence was not decreased by the pattern of evidence.

12.1.4 Combined Effect of Chance, Bias, and Confounding

Although each of these possibilities by itself is unlikely to explain the association between EMF and cancer, is it possible that a combination of the three may be responsible for an artifactual finding? The DHS reviewers considered this possibility and concluded that this is not a credible explanation when many studies of different design have reported similar results. It is not impossible that individual studies may have their result completely explained by an extraordinary coincidence in which independent unlikely events occur simultaneously. However, for many diseases considered here the general pattern of results is not critically dependent on accepting each individual study as reliable. For example, in the case of childhood leukemia, it has been repeatedly shown that, even if a few studies are excluded, the results of meta-analyses, pooled analyses, or sign tests are not significantly altered.

In conclusion, the DHS reviewers, to different degrees, concluded that chance, bias, and confounding are not probable explanations for the reported associations when they have been reported repeatedly by independent investigators. In addition, the DHS reviewers considered other criteria, notably the Hill's criteria for causality, keeping in mind that these are not to be considered as strict rules to follow. Apart from consistency, which, as noted above made them doubt the non-causal explanation for a few endpoints, none of the Hill's attributes, when applied to the pattern of evidence, influenced their degree of certainty by much.

The DHS reviewers recognize the size of the associations between EMF exposure and the various diseases studied are not so far above the resolution power of the studies that confounding and bias could be definitively ruled out as explanations. They recognized that there was rarely an orderly progression of increased risk within studies and that the effects reported for groups with dramatically high exposures like electric train operators did not display dramatically high risks when compared to those with low or moderate exposures. There are also examples where the statistical results are not completely coherent. However, these evidentiary tests are prone to giving false negative results due to non-differential measurement error and sample size problems. Also, EMFs may have societally important effects that

are nonetheless truly close to the detection of epidemiology. Finally, an agent may act in an "on/off" fashion and would not produce a steadily increased effect. These patterns of evidence therefore lowered confidence some, but not a lot.

13 Conclusions

Having examined and discussed each of the health endpoints mentioned above in a separate chapter in the main document, the three DHS reviewers each assigned their best judgment IARC classification and degree of certainty (as a number between 0 and 100). These determinations are summarized in Table V. Column 1 displays the condition considered. Column 2 identifies the reviewer. Column 3 shows the IARC classification in which the number "1" denotes a definite hazard: "2A" a probable hazard, "2B" a possible hazard, and "3" evidence "inadequate" to make a classification. Column 4 displays the pre-agreed-upon phrases for describing zones of certainty. Column 5 shows the ratio of the reviewers imputed posterior odds to the reviewers imputed prior odds (more about this below). In column 6, the reviewers graphed their best-judgment degree of certainty as an "x" and indicated their uncertainty with a shaded bar on either side of that best judgment.

To provide an illustration, this method has been applied to two non-EMF examples in the first two rows. In row 1, Reviewer 2 has indicated that air pollution is a definite causal trigger of asthma attacks and that he is virtually certain of this. In row 2 he shows that he strongly believes that particulate air pollution causes excess deaths. There is relatively little uncertainty around either of these determinations.

Row 3 displays the prior degree of certainty that there would be epidemiologically detectable effects when comparing disease rates among persons exposed to EMFs at or above the 95th percentile of US residential levels to rates at or below the 1st percentile residential exposure. These prior degrees of certainty range from 5 to 12 on a scale from 0 to 100.

Column 5 is labeled "IRL" for "imputed relative likelihood." If the degree of certainty is converted to a probability scale (0–1.0) and, in turn, if one converted the probability to odds (probability/(1–probability)) the imputed prior odds can be compared to analogously calculated imputed posterior odds. One would base these on the "best judgment" posterior degrees of certainty graphed in Table V. The resulting "imputed relative likelihoods" provide some indication of how much the overall pattern of evidence in biophysics, mechanistic, animal pathology, and epidemiological streams of evidence have combined to move the reviewers from their respective starting degrees of certainty. For example, with regard to air pollution triggering asthma attacks, the existing evidence has caused Reviewer 2 to move 900-fold from his prior, while the childhood leukemia evidence has moved him 22-fold*. Royall (Royall, 1997) has suggested anchoring the interpretation of such relative likelihood numbers on the relative likelihoods derived by probability theory from the following hypothetical experiment: Suppose that a reviewer has two urns, one that contains only white balls, the other that contains half white balls and half black balls. He takes one of the two urns at random. To determine which urn he has ended up with, he begins repeatedly withdrawing a ball and then replacing it in the urn (after noting down its color) and mixing up the balls before pulling out yet another ball. If on only one draw he were to find a black ball, he would know that he was dealing with the urn containing 50% black balls. But what is the relative likelihood conveyed by drawing one or more consecutive white balls? Royall demonstrates that drawing 5 white balls in a row conveys a relative likelihood of 32, while drawing 10 consecutive balls conveys a relative likelihood of 1,024. Reviewer 2 views the asthma/air pollution data as being almost as strong as the evidence conveyed by drawing 10 consecutive white balls during the urn experiment, while the childhood leukemia evidence is equivalent to drawing just shy of 5 consecutive white balls.

* Reviewer 2 had a prior of 5 and a posterior for childhood leukemia of 54. The prior odds are 5/95 = 0.0526. The posterior odds are 54/46 = 1.174. The imputed relative likelihood is 1.174/0.0526 = 22.3.

TABLE V. PRIOR AND POSTERIOR DEGREES OF CERTAINTY AND DHS REVIEWERS' APPLICATION OF IARC CLASSIFICATION

CONDITION	REVIE-WER	IARC CLASS	CERTAINTY PHRASE	IRL	DEGREE OF CERTAINTY FOR POLICY ANALYSIS THAT AN AGENT (EMFs) INCREASES DISEASE RISK TO SOME DEGREE
Air Pollution Triggered Asthma Attacks (Example: Not EMF-Related)	2	Human Risk	Virtually Certain	931	0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Particulate Air Pollution Triggered Deaths (Example: Not EMF-Related)	2	Prob. Risk	Strongly believe	171	0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Prior Confidence that EMFs Could Cause Epidemiologically Detectable Disease	1	N.A.	Prone not to believe	1	0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	2		Strongly believe not	1	
	3		Strongly believe not	1	
Childhood Leukemia	1	1	Strongly believe	140	0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	2	2B	Close to dividing line	22	
	3	2A	Prone to believe	17	
Adult Leukemia	1	1	Prone to believe	29	0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	2	2B	Close to dividing line	21	
	3	2B	Close to dividing line	6	
Adult Brain Cancer	1	2B	Prone to believe	29	0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	2	2B	Close to dividing line	20	
	3	2B	Close to dividing line	13	

CONDITION	REVIE-WER	IARC CLASS	CERTAINTY PHRASE	IRL	DEGREE OF CERTAINTY FOR POLICY ANALYSIS THAT AN AGENT (EMFs) INCREASES DISEASE RISK TO SOME DEGREE
Childhood Brain Cancer					0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	1	3	Close to dividing line	7	
	2	3	Prone not to believe	2	
	3	3	Prone not to believe	3	
Breast Cancer, Female					0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	1	3	Close to dividing line	7	
	2	3	Prone not to believe	3	
	3	3	Prone not to believe	2	
Breast Cancer, Male					0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	1	3	Close to dividing line	6	
	2	3	Prone not to believe	12	
	3	3	Prone not to believe	2	
EMF Universal Carcinogen?					0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	1	3	Strongly believe not	0.4	
	2	3	Strongly believe not	0.5	
	3	3	Strongly believe not	0.2	
Miscarriage					0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	1	2B	Close to dividing line	9	
	2	2B	Close to dividing line	20	
	3	2B	Close to dividing line	11	
Other Reproductive					0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	1	3	Strongly believe not	0.4	
	2	3	Strongly believe not	0.8	
	3	3	Strongly believe not	0.2	

CONDITION	REVIE-WER	IARC CLASS	CERTAINTY PHRASE	IRL	DEGREE OF CERTAINTY FOR POLICY ANALYSIS THAT AN AGENT (EMFs) INCREASES DISEASE RISK TO SOME DEGREE
ALS (*Lou Gehrig's* Disease)					0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	1	2B	Close to dividing line	9	
	2	2B	Close to dividing line	21	
	3	2B	Close to dividing line	11	
Alzheimer's					0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	1	3	Close to dividing line	5	
	2	3	Prone not to believe	4	
	3	3	Prone not to believe	2	
Suicide					0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	1	3	Close to dividing line	6	
	2	3	Close to dividing line	15	
	3	3	Close to dividing line	7	
Heart					0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	1	3	Close to dividing line	6	
	2	3	Prone not to believe	8	
	3	3	Prone not to believe	3	

14 How different is this evaluation from the NIEHS, NRPB, and IARC findings?

As outlined in Table VI below, there are both common points and significant differences between the EMF Program's evaluation and those carried out at about the same time by the NIEHS (for the Federal EMF-RAPID Program), the NRPB (NRPB, 2001a), (NRPB, 2001b), and the IARC (Note: The NRPB did not use the IARC classification system but expressed their conclusion using common language expressions).

The following table compares these evaluations:

Table VI. A Comparison of DHS Reviewers' Degree of Certainty with That of Other Agencies

HEALTH OUTCOME	NIEHS WORKING GROUP	IARC	NRPB	DHS
Childhood Leukemia	2B*	2B	Possible	2B to 1
Adult Leukemia	2B* (lymphocytic)	Inadequate	Inadequate	2B to 1
Adult Brain Cancer	Inadequate	Inadequate	Inadequate	2B
Miscarriage	Inadequate	Not considered	Not considered	2B
ALS	Inadequate	Not considered	Possible but perhaps due to shocks	2B
Childhood Brain Cancer, Breast Cancers, Other Reproductive, Alzheimer's, Suicide, Sudden Cardiac Death, Sensitivity	Inadequate	Inadequate or not considered	No for Parkinson's Disease, Inadequate for Alzheimer's, Other endpoints not yet considered	Inadequate

It is clear from Table VI that, when applying the IARC guidelines, the DHS reviewers agreed with IARC and NIEHS reviewers that in many cases (e.g., childhood brain cancer and male and female breast cancer) the evidence would be classified by IARC as inadequate to reach a conclusion. One of the DHS reviewers agreed with the IARC and NIEHS on childhood leukemia. Two of the reviewers agree with NIEHS, but not with IARC, on adult leukemia. All three reviewers agreed with NRPB that EMF was a "possible" cause of ALS. Otherwise, the DHS reviewers regard the EMFs association more likely to be causal than NRPB, IARC, or NIEHS did.

It should be noted that all of the review panels thought that the childhood leukemia epidemiology warranted the classification of EMF as a "possible" carcinogen and thus did not agree with the biophysical arguments that EMF physiological effects (and therefore pathological effects) were "impossible."

There is a wide range of opinions in the scientific community as to the probability that EMFs cause health problems. The DHS reviewers provided numerical values for their degrees of confidence that risk of various diseases could be increased to some degree by EMF exposure. Other researchers have rarely packaged their judgments in this way, so it is hard to make comparisons. Judging by one such exercise that the DHS reviewers conducted (Neutra, 2001), reasonable scientists can have different ways of interpreting the data resulting in different degrees of certainty.

* Although the majority of scientists assembled to prepare the NIEHS Working Group Report voted for a "possible 2B" classification for these cancers, the lay person's summary submitted by the Director of NIEHS to Congress stated: "ELF-EMF exposure cannot be recognized as entirely safe because of weak scientific evidence that exposure may pose a leukemia hazard." (Final Report NIH Publication 99-4493, May 1999)

The three DHS reviewers have been active in the EMF field for more than a decade and are familiar with the opinions and arguments used by the scientists in scientific meetings. Since Reviewer 1 was part of the IARC-EMF review panel and all three reviewers had some participation in the earlier parts of the NIEHS process, they also have some understanding of the process by which selected panels of these individuals arrived at a group determination about EMFs. The reviewers think there are at least two relevant differences between their process and the usual procedures followed by the other groups.

First, the DHS Guidelines require that they consider the inherent tendency of the several streams of evidence to either miss a true effect, or falsely "indict" a putative causal agent. The weight given to those streams of evidence was influenced by this consideration. The standard guidelines involve discussions of whether the adjectives "limited" or "sufficient" best fit the pattern observed in a stream of evidence, and depending on the decision one makes, simple guidelines of how combinations of "limited" and "sufficient" streams of evidence influence whether a "possible," "probable," or "definite" causal status is assigned. While the DHS Guidelines allow null results of animal pathology studies using one ingredient of a mixture to get little weight, the IARC rules involve a simple combination of binary judgments about the animal and epidemiological evidence. The way the DHS reviewers used the Guidelines meant that they did not let the primarily null results from the mechanistic and animal pathology streams of evidence decrease their certainty as much as seems to be the case for reviewers in other panels. The reasons for this have been explained above. Having been less deterred by the null mechanistic and animal pathology, they were also less prone to invoke unspecified confounders and bias as an explanation for the persistent, if not homogeneous, epidemiological findings for certain health endpoints.

The other reason for the discrepancies in the DHS reviewers' IARC classification choices can be traced to differences in the procedures for combining the scientists' judgments. They found several striking differences between the IARC and this evaluation processes:

- The Panel's Composition. The EMF Program's review was carried out by the EMF Program's scientific staff and not by a large panel of experts outside the agency. An outside panel, however, evaluated the document. One could criticize the DHS panel as being too small and not diverse enough, but this is standard procedure for California government agencies. The IARC followed its usual practice of convening outside experts to write drafts, discuss the drafts, and turn them over to staff to finalize. Given the spread of the scientific opinions on the EMF issue, it is safe to say that the outcome of any review is a strong function of the working group members' belief before the review takes place. (The DHS reviewers have striven to make this transparent through the elicitation of the prior beliefs and the "pro and con" discussion.) Two unbiased ways to assemble a working group would be by random selection out of a pool of "qualified" individuals or through a conscious effort to include balanced numbers of individuals known to have opposite points of view. In the first case, the definition of "qualified" could influence the verdict of any sample, and sampling variability could yield a mix of opinions that would vary from sample to sample so that different working groups could reach different conclusions. The second procedure could be an excellent solution, if the evaluation were carried out through extensive debates and discussions, with a shared desire to come to a consensus opinion irrespective of its potential social and economic consequences. This was the original approach used by IARC (Tomatis, private communication). However, the pressure to conclude the evaluation within a short period of time led to abandoning the discussion format in favor of the voting system. This leads to the next important difference.
- The Time Element: The meeting to draft the IARC-EMF monograph (June, 2001) lasted five and a half days. The vast majority of the plenary session time was dedicated to reviewing the draft chapters prepared ahead of time by designated committee members with maybe 10% of the time allowed for discussion of the rationale for reaching conclusions. Whenever a paragraph precipitated a controversial discussion, a common way out was to propose the deletion of the offending paragraph, a proposal that the time-pressured working group members were usually glad to adopt. In contrast to this process, the DHS reviewers spent innumerable hours and days, over a period of years and in consultation with independent consultants, to explain their inferences and resolve or clarify their differences.
- The Format of the Conclusion: IARC aims for a consensus conclusion. Members with more extreme views are strongly encouraged to converge on a middle of the road conclusion. In the California evaluation, if consensus could not be reached (as was the case for some endpoints), each member was allowed to express his or her personal belief. Although two of the DHS reviewers were subordinate to the third, substantial differences remained for some endpoints and are openly revealed in this evaluation.
- IARC's Voting System: The members of the working group were asked to vote separately on animal and human evidence. Although a sizable

minority of the working group believed that there was limited animal evidence indicating a possible cancer risk, their opinion was not carried past that point of the process. Since the majority regarded the animal evidence as "inadequate," when the final vote on the overall evaluation was taken, the option posed to the working group's members were the majority positions, that is, that animal evidence was inadequate and epidemiological evidence for childhood leukemia was limited. According to the guidelines, these two majority positions resulted automatically in a Group 2B classification and Class 2A or Class 1 were not even considered as options to vote on, even if individual reviewers, such as Reviewer 1, might have so voted. The published monograph does not document that the minority view had in fact a higher degree of certainty of the EMF risk than the majority view.

Somewhat similar considerations apply to the NIEHS evaluation. Although the whole process lasted eighteen months, the decision was reached over the course of a week-long meeting, followed by a vote. This meeting was preceded by a series of workshops including discussions and presentations, but not all members of the working group participated in the workshops, and most of the workshop participants were not members of the working group. Therefore, the final conclusion was still the result of a few days intensive meeting, during which much of the time was devoted to revising and finalizing the wording of the final report rather than to writing about points of controversy. The working group report did document the vote count.

Apart from procedural differences, there are also philosophical differences between the various review panels. For example, with regard to adult leukemia, the IARC's evaluation differs from the NIEHS and the California evaluation because of the way epidemiological evidence was considered. Almost all the evidence on adult leukemia comes from occupational studies. The Epidemiology subgroup at the IARC meeting regarded most of these studies as being of poor quality, with within- and between-study inconsistencies. Most of the evaluation centered on the most recent large studies (Sahl, Kelsh & Greenland, 1993), (Savitz & Loomis, 1995), and (Theriault et al., 1994), which contradicted each other. The DHS reviewers' evaluation considered the whole body of studies, residential and occupational. While they acknowledge that many of the studies have limitations, neither they, nor the IARC reviewers, have identified fatal flaws. For example, there is no evidence to suggest that the use of crude exposure assessment surrogates, while virtually certain to influence the quantitative estimate of risk and to frustrate any attempt to explore the dose-response relationship, introduced an upward bias in the reported association. On the contrary, the limitations of the studies may well be responsible for the inconsistencies between them. And while these inconsistencies do exist, they are not as common as the IARC evaluation may suggest. The Kheifets (1997) meta-analysis concludes that the body of epidemiological evidence shows a slight but statistically significant increase in risk. From a binary outcome standpoint, the studies with a relative risk estimate >1 are more than twice as numerous as those with a RR ≤ 1.

Nonetheless, where the DHS and other reviewer panels agreed to assign a "possible" carcinogen label to an EMF/disease association, it is not easy to infer if there would be agreement on a degree of certainty. According to Dr. Rice, Chief of IARC's Carcinogen Identification and Evaluation Unit (personal communication to Vincent DelPizzo), "If IARC were to say that an exposure is in Group 2A, probably carcinogenic to humans, that would mean that the evidence is just a little short of certainty that the exposure in question has actually caused human cancer. . . Group 2B is the lowest level of identifiable carcinogenic hazard in the IARC system."

Finally, it must be remembered that in DHS's EMF Program, policy recommendations were addressed separately from the risk evaluation. In some other cases, evaluations are part and parcel of a policy recommendation (they may include regulatory recommendations in the conclusion). This may make them more conservative, as it seems to be the case with IARC: "....the IARC Monographs system of carcinogenic hazard evaluations is deliberately a very conservative one. There are many carcinogenic hazards in the human environment that are very real indeed, and control of exposures to those hazards is extremely important for public health. To accomplish this, it is necessary that carcinogenic hazards be correctly identified. We must avoid misdirecting public attention to any exposure of any kind that may be perceived as a hazard, but in fact is a misplaced concern." (Dr. Jerry Rice in a letter to Vincent DelPizzo, Aug. 10, 2001). The cover letter to the NIEHS report to congress concluded with a recommendation for only "passive regulatory action" (NIEHS, 1999). The DHS's three reviewers have packaged their differing degrees of confidence about causality in a way that can be used in the decision analytic models prepared for the program. DHS has pointed out that the policy implications of this range of confidences depends on the policy framework of the decision maker: non-interventionist, utilitarian, virtual-certainty-required, or social justice. The public regulatory process will determine which one or which mixture of these frameworks will apply to govern policy. Thus the DHS risk evaluation is packaged to facilitate decision making but separates risk assessment from risk management. The fact that a reviewer may feel very certain that EMF is a risk factor for a particular disease does not imply that he or she advocates exposure mitigation.

In summary, the differences between the DHS reviewers' judgments and those of other reviewers are partly due to differences in procedure and terminology and partly due to the way those three reviewers weighed the several streams of evidence.

15 Differences Between DHS Reviewers

As noted above, the three DHS reviewers were not able to reach a consensus on all health endpoints. In this section, they explain the reasons behind their respective judgments.

15.1 Reviewer 1 (DelPizzo)

In almost all cases, Reviewer 1's posterior degree of confidence is higher than that of the other two reviewers. There are several reasons for this difference.

a) Different priors—the reviewer is generally more suspicious of man-made environmental pollutants, which have no place in the evolution process.

b) Reliance on the sign test—this reviewer has put much weight in the sign test, a simple, dichotomous test, which measures the probability of several studies erroneously reporting the existence of a risk while no risk truly exists. In many cases the test finds that this probability is extremely small, that is, the results are unlikely to be erroneous. In the reviewer's opinion, this test is particularly suitable to answer the simple question, is there a risk or not? rather than asking what the relative risk is. The results of this test are not changed if the outcome of one or more studies are partly due to bias. Some worst-case scenarios, assuming extraordinary coincidences of chance and bias acting simultaneously in the same direction, do weaken the evidence, but when a condition has been studied by many different investigators, these scenarios do not reduce Reviewer 1's belief by much.

c) Weight given to empirical results—Reviewer 1's prior was limited by the intuitive belief that the energy associated with environmental EMFs is so small that, even if these fields are potentially disruptive, the amount of disruption is insufficient to cause a biological effect. Once Reviewer 1 examined the results of in vivo and in vitro research on EMF exposure, however, he became convinced that biological EFFECTS (as distinct from PATHOLOGY) can result from exposure to levels below those which conventional knowledge considers necessary. That is, if one equates "energy" to "dose," exposure to environmental fields may be regarded as a non-negligible dose. Thus, the argument that kept Reviewer 1's prior low disappears and the possibility of a hazard, when repeatedly reported by independent epidemiological studies, becomes more credible.

15.2 Reviewer 2 (Neutra)

The fact that EMFs are the only agent that this reviewer has encountered for which there are theoretical arguments that no physiological, much less pathological, effect could be possible, did decrease Reviewer 2's prior somewhat. But physics applied to simplified models of biology were not convincing enough to make this prior credibility vanishingly small. This reviewer noted biological effects in mechanistic experiments in the thousands of mG but accepted the arguments that these were probably not relevant to effects below 100 mG. The few experiments that claimed to show an effect below 100 mG (the chick embryo studies and the confirmatory studies of Liburdy's melatonin studies) were considered highly worthy of further study, but not robust enough or free enough of alternative explanations at this point to cancel out the modest initial doubts about the energetic feasibility of residential EMFs to produce biological effects. The animal pathology studies have convinced Reviewer 2 that very-high-intensity pure 60 Hz or 50 Hz sinusoidal magnetic fields do not have a strong enough effect to produce consistent pathological effects in small numbers of the species and strains of animals selected for study. If these species of animals were to respond as humans are described to have done in the epidemiology, this was a predictable result even if pure sinusoidal 60 Hz fields were the active ingredient of the EMF mixture. Humans exposed to hundreds of mG, like electric train engineers, when compared to persons with 24-hour average exposures around 1 mG do not show relative risks consistently above 1.00 much less very high relative risks. Why would animals be expected to do so? Moreover, pure sinusoidal fields may not be a bioactive ingredient of the mixture, and the animal species chosen may not be appropriate models for humans. Reviewer 2 believes that the animal bioassay stream of evidence in this case is thus triply vulnerable to missing a true effect, and the null results do not reduce his confidence in an EMF effect much. The fact that there are epidemiological associations with several different cancer types and with other diseases that have different known risk factors does increase confidence somewhat but, without mechanistic reasons, not a great deal. Any changes from the prior were due to epidemiological evidence. Large studies likely to be free of selection bias carried a lot of weight. Many studies of different design and in different locations showing similar results also carried substantial weight, although Reviewer 2 only interpreted the sign test to indicate whether a meta-analytic or pooled association came from just a few large studies, or from a rather consistent pattern of result from many studies. Reviewer 2 did not think that any of the specific

candidate confounders or biases that had been proposed to date for explaining away the epidemiology had convincing evidence to support it. The fact that most of the associations are not much above the resolving power of epidemiological studies left open the possibility of unspecified combinations of bias, confounding, and chance having produced these associations. This kept Reviewer 2 from having an updated degree of confidence above the certainty zone of "close to the dividing line between believing and not believing" that EMFs increase the risk to some degree.

15.3 Reviewer 3 (Lee)

Reviewer 3 mainly used the human epidemiological evidence to form a posterior degree of confidence. The large number of studies showing consistent results across different study designs, study populations, and exposure assessments, as well as large, well-conducted studies with adequate power to address confounding, bias, dose response, and effects among subgroups contributed strongly in updating the prior degree of confidence. The association of EMF with several types of disease and experimental and animal evidence were minor contributions to the updating process. Specificity, visibility, analogy, and, in general, temporality did not contribute much to the posterior degree of confidence.

16 How The Degrees of Confidence and Range of Uncertainty Could be Used in Policy Analyses

Community and stakeholder policy decisions usually are made from one or more of the following ethical perspectives: "non-interference," which emphasizes individual choice and rights free from the infringement of others and of government; "social justice," which emphasizes the protection of the weak, and rights and duties; "virtual-certainty-required," where protective action is only taken when the vast majority of scientists are virtually certain that there is a problem; and the "utilitarian perspective," which emphasizes results and the most good for the most people at the least cost. Each perspective would have somewhat different requirements for the degree of confidence of causality before initiating action.

The "non-interference" perspective seeks to avoid regulatory impingement and taxes and tends to favor "right to know" warnings and voluntary solutions to problems, regardless of the degree of confidence. The "virtual-certainty-required" framework would tend to require a high degree of confidence with narrow uncertainty bounds on the part of most scientists and a high probability of harm from exposure before acting on an environmental hazard. Indeed, this perspective would favor risk-assessment methods having few false positives, even at the cost of false negatives.

The "social justice" perspective seeks to avoid even the possibility of risk, particularly if the risk and the benefit are imposed on different parties. This perspective would tend to advocate protective action at lower degrees of confidence, wider uncertainties, and lower absolute probabilities of harm given exposure. It would favor risk-assessment approaches with few false negatives, even in the face of false positives. It would focus on the added lifetime risk to the most highly exposed.

The "utilitarian cost/benefit" perspective would evaluate the policy implications of the best estimate of the degree of confidence but would explore the consequences of the lower and upper bounds of the confidence that a hazard exists. It would focus on the burden of societal disease that could be avoided by EMF mitigation. Depending on the relative prevalence of stakeholders who suffer, respectively, from false positives and false negatives, the utilitarian perspective would develop a preference for risk-assessment methodologies. The reviewers would propose that the policy integration document discuss the implications for policy arising from the range of best estimates among the three reviewers and the range of uncertainties expressed. It should also discuss where the three DHS reviewers' degrees of confidence lie in the spectrum of scientific opinion.

17 Evidence of Risk Relevant for Policymakers Mindful of Environmental Justice Issues

It is sometimes alleged that lower SES subjects are more likely to live in areas with stronger environmental EMFs. Salzberg et al. (Salzberg, Farish & DelPizzo, 1992) first explored this hypothesis and found only weak support for it. Bracken et al. (Bracken et al., 1998) reported a strong correlation between some SES indicators (women's occupations, house values) and the very high-current configuration (VHCC) wire code configuration. Hatch (Hatch et al., 2000) found no such association. Two very large data sets collected in the San Francisco Bay Area as part of the study by Lee et al. (Lee et al., 2002) found no evidence of an association between family income and measured EMF exposure. However, there was a weak association between low SES and wire code (Hristova et al., 1997). In a geographic information system (GIS) study as part of the power grid policy project, English et al. (http://www.dhs.ca.gov/ehib/ emf/ pdf/ AppendixG-GIS.PDF) examined the ethnic and income characteristics of census blocks within 500 feet of transmission lines. The proportion of black and Hispanic residents in these corridors was lower than the state average proportion. Zaffanella and Hooper (Zaffanella & Hooper, 2000) found somewhat higher magnetic fields in schools with students of lower socioeconomic status. In summary, the evidence to support the contention that the EMF exposure,

if real, disproportionately affects low SES subjects is not very strong, but there is some suggestive data that decision makers may consider when evaluating policy options.

18 The EMF Mixture

A careful assessment of the electricity-related exposures from power lines, appliances, and occupations would reveal what amounts to a complex mixture including electrical and magnetic fields with their respective frequency, polarization, etc. The reviewers will call these the "aspects" of the mixture.

Each aspect varies from instant to instant to form a time-series of intensities, which can be summarized as a single number by various summary "exposure metrics," which may be more or less biologically active. For example, the exposure metric of ionizing radiation that best predicts biological effects is the simple integral of the exposure-time series. The exposure metric that best predicts the effect of an antibiotic might be the integral of blood levels above some threshold. Other electricity-related correlates of proximity to power lines, internal wiring, and appliances are not part of the fields at all, but might be correlated with them. These include electrically charged and "sticky" air pollution particles; contact currents from stray currents, from plumbing and in the earth, and intermittent shocks. The reviewers will call these the "ingredients" of the mixture.

What aspects, ingredients, or exposure metrics, if any, should we be considering in this risk evaluation?

For a number of years, some researchers believed that if the risk increase were truly due to some component of the EMF mixture then this component must be something captured by the exposure-assessment surrogate known as "wire coding," consisting of classifying residences based on their proximity to visible power lines and on the type of these power lines. Recent new data and reanalysis of old data (Linet et al., 1997), (Greenland et al., 2000) appear to have disposed of this hypothesis convincingly. They have shown that risk is more consistently correlated to measured or calculated TWA magnetic field than to wire coding classification.

This does not mean that the TWA—measured by surrogates such as point-in-time or "spot" measurements, calculations using engineering models and historical line current loads and job exposure matrices—is necessarily the true causal agent. The units, mG or μT, that measure the magnetic field's TWA do not describe the magnetic field (and much less the electric field associated with it) any more than the units marked on the volume dial on a stereo system fully describe the sound coming out of the speakers.

Nevertheless, although the reviewers cannot definitely "rule in" the component(s) of interest, they can rule out some aspects of the fields that are not correlated with TWA field strength. A detailed discussion of this issue can be found in Neutra and DelPizzo (2001). Here, the reviewers include Table VII adapted from that paper, pointing out which of the more commonly proposed metrics are indeed correlated with TWA (indicated by a "• ") and those which are not (indicated by "No"):

TABLE VII. CORRELATION OR ABSENCE OF CORRELATION BETWEEN EXPOSURE METRICS AND EXPOSURE-ASSESSMENT SURROGATES

EXPOSURE METRIC TO 30-300 HZ MAGNETIC FIELDS	HIGH WIRE CODE	HIGH MEASURED FIELD	HEALTH ENDPOINT	REFERENCE
(1) TWA	•	•	•	many
(2) Length of time with constant field above a threshold	•	•		
(3) Repeated periods of elevated exposure	•	•	•	(Feychting, Forssen & Floderus, 1997), (Feychting, Pedersen & Svedberg, 1998b). (Lee & McLoed, 1998)
(4) Third harmonic	•	?	?	(Kaune, 1994b)
(5) Resonance with static field	No	No	?	(Kaune, 1994b), (Bowman, 1995)
(6) Time above a threshold	•	•	?	(von Winterfeldt & et. al., 2001)
(7) Polarization	?	?	?	(Burch et al., 2000)
(8) Transients	No	No		(Preece et al., 1999)
(9) Maximum daily exposure	•	•	•	(Li et al., 2002), (Lee et al., 2002)
(10) Average change between measurements	•	•	•	(Lee et al., 2002)
(11) Electric field	Not inside home	Not inside home	?	(Miller et al., 1996), (Coghill et al., 1996)

This table allows the reviewers, at least, to cast doubt on two metrics that are supported by mechanistic arguments, but not (or at least not consistently) by empirical data. These are 1) magnetic field transient, which can induce strong, if brief, electrical currents in the body, and 2) resonance conditions, which may facilitate energy transfer from the field to the living organism.

The table also emphasizes the difficulty of testing the hypothesis of an EMF risk by conducting experimental studies. Studies using an exposure apparatus that delivers an appropriate TWA (but not an appropriate exposure to a hypothetical aspect, ingredient, or exposure metric found in residential or occupational environments) are liable to produce false-negative results. Or they may produce positive results suggesting dose-response relationships different from those that may result from environmental fields.

Reducing TWA exposure will reduce exposure to several other metrics and reduce any risk from TWA or the exposure metrics that are changed with it. However, this is a sufficient but not necessary condition: if TWA is not by itself the causal factor and if we could identify and remove from the EMF mixture the component directly causally associated with the health endpoint, a subject could still be exposed to high TWA and not be at risk. Also, because the correlation coefficient between TWA and these other components of the field are modest to moderate, reducing TWA exposure would not reduce the risk proportionally to the decrease in the average field strength.

The following table compares the values of the magnetic field strength, measured by direct personal measurement or by environmental monitoring (spot or 24-hour measurements). Note that these are not data collected on the same sample, but general information gleaned from the literature (Zaffanella & Kalton, 1998), (Lee et al., 2002) and mathematical modeling.

TABLE VIII COMPARISON OF THE VALUES OF THE MAGNETIC FIELD (MG) STRENGTH MEASURED BY DIRECT PERSONAL MEASUREMENT WITH ENVIRONMENTAL MEASUREMENTS

PERCENTILE POINT OF EACH TYPE OF MEASUREMENT	TWA PERSONAL FIELD	AVERAGE SPOT HOME MEASUREMENT	MEDIAN SPOT HOME MEASUREMENT	MEDIAN 24-HOUR HOME FIELD
99	5.5	6.6	5.8	5.5
95	3.2	3	2.6	2.6
90	2.4	2.1	1.7	1.8
75	1.5	1.1	1	1
50	0.9	0.6	0.5	0.5

The personal TWA is generally higher than the environmental levels, reflecting the contribution that occasional close proximity to localized sources (appliances, wall wires, buried cables) makes to the average personal exposure. However, at the upper end of the distribution, this difference is minimal or non-existent, reflecting the fact that exposure to localized sources is common to all subjects. These localized sources contribute a few tenths of a mG to the personal 24-hour average (TWA).

What determines the "exposed" status of a subject in epidemiological studies (generally defined as a TWA above 2–4 mG) is usually the background environmental exposure, and that is contributed largely by home exposure (where people spend the most time). Certain occupations are an exception to this generalization because work-time exposure is so much higher than home exposure. According to Zaffanella's "1000 homes study" (Zaffanella, 1998), these background fields are due, with almost equal frequency, to proximate power lines and to grounding system fields.

Of course, this conclusion about background fields will change drastically if future research confirms the hypothesis-generating data by Lee (Lee et al., 2002) and Li (Li et al., 2002), indicating that, at least for spontaneous abortion (SAB), the true risk factor is the maximum daily exposure above 14 mG or the average field change between measurements. If maximum exposure, or one very strongly correlated to it, is the appropriate metric, then sources of localized fields (appliances, home wiring) become more important than power lines and ground currents because the latter seldom produce fields of the intensity implicated by the Lee and Li studies.

An additional difficulty that arises in this case is that personal measurements taken at the hip, as is common practice, may introduce errors that are large compared to the instrument error. This is because the field produced by a localized source shows significant variation based on which anatomical site is measured (DelPizzo, 1993),

even though some sources like power lines outside the house may produce a field at locations like the eye and the hip that are virtually identical. We also have no clear evidence by which to determine if the EMFs interact with biological systems at specific target organs. For example, there is some evidence that birds perceive geographic variations of the earth's magnetic field by means of their eyes (Graves, 1981). On the other hand, EMFs might act directly on cells in the marrow or in the uterus. Personal measurements taken at the hip might miss some exposures to the eye, but not exposures to the uterus.

It must be stressed that, although the Li (2002) and Lee (2002) studies are recent, good-quality studies with similar results, they have not yet been replicated. While meriting attention, they do not negate the wealth of data associating 24-hour average field to risk of other diseases.

19 Potential Annual numbers of Deaths Attributable to EMFs

Two recent review articles calculated the proportion of all childhood leukemia cases that might be attributed to the rare highest residential EMF exposures. This was estimated to be around 3%. With about *100 childhood leukemia* deaths per year, this would translate to about 3 deaths in California per year attributable to EMFs. The evidence does not permit similar direct calculations for the other reviewed conditions. However, suppose that only 1% of the conditions that were considered in this evaluation (minus those that the three reviewers "strongly believed" were not caused by EMFs) could be attributed to EMF exposure. The numbers of attributable cases could still be in the hundreds per year and comparable to the theoretical burden of ill health that has motivated other environmental regulation (di Bartolomeis, 1994). The annual California deaths from each of these conditions are shown in Table IX. The reader can apply 1% to these numbers to verify the assertion in the previous sentence.

Table IX. 1998 Yearly California Deaths (some fraction of which might be affected by EMFs) *

AGE GROUP	CHILD LEUK.	ADULT LEUK.	CHILD BRAIN	ADULT BRAIN	MALE BREAST	FEMALE BREAST	SPONT. ABORT.*	ALS	ALZ-HEIMER	SUICIDE	ACUTE M.I.
0-19	99	0	79	0	0	0	11,000	0	0	171	2
29 Plus	0	1888	0	1294	30	4095	49,000	434	320	3044	17,236

* From http://www.ehdp.com/vn/ro/av/cau1/eg1/index.htm

+ Note: many would not consider spontaneous abortion as serious as the death of a child or adult.

20 Potential Added Lifetime Risk from High Exposure

Since epidemiology is a blunt research instrument, the theoretical lifetime individual risk that derives from any agent that has an epidemiologically detectable effect will be automatically greater than the lifetime risk of 1/100,000 that triggers many regulatory processes. This means most of the epidemiological associations examined in this document could clearly be of regulatory concern if real.

That being said, with the exception of miscarriage, the theoretical lifetime risks from the highest EMF exposures are such that, depending on the disease and assuming relative risks ranging from 1.2 to 2.0, 93% to 99.9% of even highly exposed individuals would escape contracting the non-miscarriage health conditions studied.

These insights are illustrated in Table X below.

TABLE X. ADDED LIFETIME RISK IMPLIED BY RELATIVE RISKS OF 1.2 OR 2.0 FOR RARE AND COMMON DISEASES

ANNUAL INCIDENCE	DISEASES IN CATEGORY	ADDED ANNUAL RISK FROM: RR =1.2; RR= 2.0	ADDED LIFETIME RISK FROM: RR = 1.2, RR = 2.0	LIFETIME CHANCE OF ESCAPING DISEASE AFTER EXPOSURE
1/100,000	ALS, Male Breast Cancer	0.2/100,000 ; 1/100,000	1.4/10,000; 7/10,000	99.99%; 99.93%
5/100,000	Child Leukemia	1/100,000; 5/100,000	2/10,000; 10/10,000	99.98%; 99.9%
10/100,000	Suicide, Adult Brain, & Leuk.	2/100,000; 10/100,000	14/10,000; 70/10,000	99.9%; 98.3%
100/100,000	Acute Myocardial Infarction	20/100,000; 100/100,000	1.4%; 6.8%	98.6%; 93.2%
1%	Alzheimer's	0.2%; 1%	NA (late onset)	NA
10%	Miscarriage	2%; 10%	NA (occurs during pregnancy)	NA

Note: RR = risk ratio; NA = not applicable

Two new epidemiology studies (Li et al., 2002), (Lee et al., 2002) suggest that a substantial proportion of miscarriages might be caused by EMFs. Miscarriages are common in any case (about 10 out of 100 pregnancies) and the theoretical added risk for an EMF-exposed pregnant woman may be an additional 10 out of 100 pregnancies according to these two studies. If true, this could clearly be of personal and regulatory concern. However, the type of EMF exposure implicated by the new epidemiological studies (short, very high exposures) probably come primarily from being very close to appliances and indoor wiring, and only rarely from power lines. Seventy-five percent of the women in the studies had at least one of these exposures during a day, and even one exposure a day, if typically experienced during pregnancy, seemed to increase the risk of miscarriage. Nonetheless, the vast majority of pregnant women with such exposures did NOT miscarry.

21 POLICY-RELEVANT AREAS FOR FURTHER RESEARCH

One of the major impediments to evaluating the potential bioactivity of a complex mixture is identifying the bioactive components of that mixture. This usually requires finding some kind of bioassay with which to assess the mixture and then successive fractions of it. While some epidemiologists have attempted to evaluate the effects of different aspects of the EMF mixture and some exposure analysts have attempted to characterize the occurrence and intercorrelation of its aspects, important policy-relevant questions still remain.

Experimentalists have rarely used the mixture as it occurs in real life and have focused instead on one or the other aspect of the mixture, usually pure sinusoidal 60 Hz fields at intensities far above those found in residential or blue collar occupational environments. Deeply ingrained experimental research styles and an orientation to explaining mechanisms rather than describing phenomena has meant that investigator-initiated research and even programs that attempted to guide research have rarely been characterized by progressively refined descriptions of dose-response relationships to produce stronger bioeffects.

This has been compounded by the expectation of a quick resolution of the question *by those who fund research, as was the case with the New York State program of* the mid-1980s, the current California Program, and the recent five year federal EMF–RAPID program. As was discovered after President Nixon's "War on Cancer" in the early 1970s, research progresses slowly and in successive multi-year research cycles, with the results of each cycle governing the direction of the next. It would not be surprising if it took four more five-year research cycles to clarify the EMF issue.

This means that if one were serious about clarifying this issue there would need to be a long-term commitment to steady research funding and funding for intermittent assessments of the state of the science and research directions. Most research peer review groups would favor research where a clear bioeffect was present and credible alternative mechanisms were being explored. Those situations tend to have

a high yield of early definitive results, and such results lead to continued research funding, publications, and research career advancement. The EMF area does not fit this description and from this perspective would receive a low priority for funding from the usual peer review study sections. Indeed, prominent researchers who doubt that there are any bioeffects, much less epidemiological effects, from the residential and occupational EMF mixture, feel there is nothing to find and have recommended that no more funding for this area be provided (Park, 1992).

Clearly the three DHS reviewers disagree with the assessment of the evidence to date and see a number of research areas which are worth pursuing that could influence and focus exposure avoidance strategies, if any. The cost effectiveness of further research has been a topic of the program's policy analysis and will be discussed at greater length in our policy integration document. The cost/benefit analysis of EMF research suggests that there is so much at stake in choosing between "expensive," "inexpensive," and "no mitigation" that more research funding can be easily justified. (http://www.dhs.ca.gov/ehib/emf/pdf/Chapter09-ValueofInformation.pdf)

The highest initial priorities for the reviewers would be to carry out exposure studies in residential settings and the workplace to see if purported aspects of the EMF mixture that would require different mitigation strategies are correlated with magnetic field exposure and could therefore explain their apparent effect. Such aspects include sudden exposures to the 60 Hz fields, such as micro-shocks, stray ground currents, and charged air pollutants. Such exposure studies would make it possible to reanalyze some of the existing worker cohorts to determine if these aspects are associated with diseases.

Rather than further pursuing new studies of rare diseases with long incubation periods, further studies of the more common conditions in which EMFs might have shorter induction periods, such as spontaneous abortion, acute myocardial infarction, and suicide should be given priority. These would be more relevant to a utilitarian policymaker.

On the experimental front, the reviewers suggest giving priority to finding reliable bioeffects below 100 mG and to carefully exploring dose-response relationships and then mechanisms. The balance between investigator-initiated and programmed research, as well as the guidelines that will be used for interpreting results, need to be carefully considered.

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Review

Childhood Leukemia and EMF: Review of the Epidemiologic Evidence

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All populations are exposed to varying degrees of electromagnetic fields (EMF); in this study we consider only extremely low frequency (ELF) and radio frequency (RF) fields. After the first study of ELF and childhood leukemia in 1979, intensive epidemiologic investigation has sought to shed light on the potential relation between EMF and childhood leukemia. Consistent associations from epidemiologic studies and two pooled analyses have been the basis for the classification of ELF as a possible carcinogen by the International Agency for Research on Cancer (IARC). The study of RF is still in its infancy and little is known about residential RF exposure or its potential effects on childhood leukemia. The purpose of this study, presented at the WHO Workshop on Sensitivity of Children to EMF in Istanbul, Turkey in June 2004, is to review and critically assess the epidemiologic evidence on EMF and childhood leukemia. Bioelectromagnetics Supplement 7:S51–S59, 2005. © 2005 Wiley-Liss, Inc.

Key words: epidemiology; extremely low frequency EMF; radio frequency; cancer; review

INTRODUCTION

Childhood leukemia has remained a focal point of extensive etiologic, diagnostic, and therapeutic research since its recognition as a clinical entity over a century ago [Pinkel, 1993]. It is one of the most common cancers in children, comprising more than a third of all childhood cancers [Greenberg and Shuster, 1985]. The age standardized rate of leukemia for children younger than 15 years has been estimated to be 3.5 per 100 000 per year for females and 4.2 per 100 000 per year for males in the developed world, 2.2 per 100 000 per year for females, and 2.9 per 100 000 per year for males in the developing world [IARC, 2000].

Leukemia results from chromosomal alterations and mutations that disrupt the normal process by which lymphoid or myeloid progenitor cells differentiate. The underlying triggers for molecular damage may be inherited at conception, may occur during fetal development or during infancy (see T. Lightfoot in this issue for details). Most likely there is an accumulation of a series of detrimental genetic changes over time. Though there have been significant advances in diagnostic techniques and improvements in treatment, most of the etiology of leukemia in children is unknown.

A wide variety of factors have been hypothesized to be involved in the etiology of childhood leukemia. Among environmental exposures possibly associated with childhood leukemia, ionizing radiation is a generally accepted risk factor [Bhatia et al., 1999]. The list of chemical agents for which some evidence points to a link with leukemogenesis includes solvents, pesticides, tobacco smoke, and certain dietary agents. The possible role of viral or other infectious agents in triggering leukemia development has also been hypothesized [Mezei and Kheifets, 2002]. Generally accepted associations, however, explain only 10% of childhood leukemia incidence [Ichimaru et al., 1978], leaving the majority with unexplained etiology.

Consistent epidemiologic evidence demonstrates a small risk of extremely low frequency (ELF) electromagnetic fields (EMF) on childhood leukemia, thus leading to an International Agency for Research on Cancer (IARC) classification of ELF as a "possible" or 2B carcinogen in 2002. As compared to the ELF literature, research on the potential health effects of radio-frequency (RF) EMF is still in its infancy and studies to date have been uninformative. The purpose of this study is to present the epidemiologic literature on EMF and childhood leukemia, and to discuss possible

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explanations for the observed ELF and childhood leukemia association.

EPIDEMIOLOGIC STUDIES OF ELF AND CHILDHOOD LEUKEMIA

The study by Wertheimer and Leeper [1979] was the first epidemiologic study to examine the relation between EMF and childhood leukemia. They developed a metric called wire codes as a proxy for exposure to EMF; it considers the likely current load carried by electrical power lines outside homes as indicated by the thickness of the wires and different wiring configurations, for example the location of transformers and the proximity of the lines to the home. In their analysis of childhood leukemia and wire codes, there were more reported cases of childhood leukemia in homes with high-current configurations than in those with low-current configurations. Since this first study, there have been over 20 studies examining this association. Epidemiologic studies of ELF and childhood leukemia are difficult to design, conduct and interpret for a number of methodologic reasons. EMF are imperceptible, ubiquitous, have multiple sources, and can vary greatly over time and short distances [Bracken et al., 1993]. Also, the small number of leukemia cases available in any given population necessitates retrospective design, making exposure assessment even more difficult.

After the development of EMF measurement instruments, a small number of studies used spot measurements under varying household power use conditions. Later, studies included both 24–48 h measurements in the child's bedroom as well as shorter measurements in other areas inside and outside the home (see Table 1): [Tomenius, 1986; Savitz et al., 1988; London et al., 1991; Coghill et al., 1996; Linet et al., 1997; Michaelis et al., 1997; Dockerty et al., 1999; Green et al., 1999a; McBride et al., 1999; UK Childhood Cancer Study Investigators, 1999; Ahlbom et al., 2000; Schuz et al., 2001; Kabuto et al., 2005]. Some studies have used calculated fields, based on a number of variables that often include distance of home to a transmission line and current phases and loads (see Table 1): [Myers et al., 1990; Feychting and Ahlbom, 1993; Olsen et al., 1993; Verkasalo et al., 1993; Tynes and Haldorsen, 1997; Bianchi et al., 2000]. While ELF exposure assessment can be deemed one of the most important tasks in epidemiologic studies, it remains one of the biggest challenges. The assessment of exposure to magnetic fields has improved over time, yet our ability to predict exposure remains severely limited. It has been suggested that EMF exposure assessment might be more accurate for children than for adults since children spend more time at home and do not have occupational exposures [Forssen et al., 2002].

Inadequate sample size is another methodological challenge: there are few people at or above exposure levels at which most associations between EMF and childhood leukemia are observed, that is above 0.3 or 0.4 μT, that obtaining statistically stable estimates of effect is virtually impossible. Although many studies have attempted to include large sample sizes, any study is only as big as its smallest cell, which is most often the cell containing the highly exposed leukemia cases. For instance, in the UK study that involved 1094 cases and 1096 controls, only 5 cases and 3 controls were observed at levels greater than 0.4 μT [UK Childhood Cancer Study Investigators, 1999]. Some studies have had cases but no controls in the highest exposure categories, suggesting elevated risk in these categories, but making odds ratios (ORs) inestimable [Coghill et al., 1996; Dockerty et al., 1999]. One study, however, had no cases but several controls in the highest group [Tynes and Haldorsen, 1997].

Although many epidemiologic studies have observed ORs of above 1.5 (some around 4) for the exposure categories above 0.3 or 0.4 μT as compared to the lowest exposure category of <0.1 μT, most are not statistically significant. The only two studies with OR estimates below one have serious methodologic limitations and/or are based on small numbers [Fulton et al., 1980; Myers et al., 1990]. Small effect estimates are notoriously hard to evaluate because it is difficult to achieve enough precision to distinguish a small risk from no risk, and small effect estimates are more likely to result from misclassification, unmeasured, confounding, and selection bias, all of which often go undetected and unmeasured.

Given the small-observed associations, a limited understanding of causal risk factors for childhood leukemia, and methodological difficulties such as exposure assessment, a conclusive interpretation of these studies remains a challenge. Two pooled analyses represent the most powerful attempt so far to provide a cohesive assessment of the epidemiologic data [Ahlbom et al., 2000; Greenland et al., 2000]. These analyses, while focusing on a largely overlapping but distinct set of studies, come to similar conclusions (see Table 1 for details on the studies included in each pooled analysis).

In the pooled analysis by Greenland et al. [2000], 12 studies using measured or calculated fields were identified. For this analysis, the metric of choice was the time-weighted average; and it included a total of 2656 cases and 7084 controls. The estimated OR for childhood leukemia was 1.68 (95% CI 1.23, 2.31) for

TABLE 1. *Epidemiologic Studies on the Association Between EMF and Childhood Leukemia*

Reference	Measurement	>0.3 μT[a] Cases/controls	>0.3 μT[a] OR (95% CI)	≥0.4 μT[b] Cases/controls	≥0.4 μT[b] OR (95% CI)
Tomenius [1986]	Spot measurement: max. uniaxial value outside front door	3/9	1.5 (0.4–5.7)		
Savitz et al. [1988]	Spot measurements: arithmetic mean of low-power measurement in three locations (child's bedroom, parent's bedroom, other room occupied by child >1 h/day, front door)	3/5	3.5 (0.8–15.4)		
Myers et al. [1990][c]	Calculated fields				
London et al. [1991]	24 h child bedroom measurement	17/10	1.6 (0.7–3.5)		
Feychting and Ahlbom [1993]	Calculated fields	6/22	4.5 (1.7–12.0)	5/20	3.7 (1.2–11.4)
Olsen et al. [1993]	Calculated fields	3/3	2.0 (0.4–10.0)	2/0	N/A
Verkasalo et al. [1993]	Calculated fields	1/5	2.0 (0.2–18.0)	1/1	6.2 (0.7–56.9)
Coghill et al. [1996]	Night-time child bedroom measurement	1/0	N/A		
Linet et al. [1997]	24 hr bedroom measurement, weighted by spot measurements in other rooms	42/28	1.5 (0.9–2.4)	17/5	3.4 (1.2–9.6)
Tynes and Haldorsen [1997]	Calculated fields	0/31	N/A	0/10	N/A
Michaelis et al. [1997]	24 h child bedroom measurement	6/6	2.4 (0.8–7.6)	2/2	2.0 (0.3–15.2)
Dockerty et al. [1999]	24 h child bedroom measurement	3/0	N/A	0/0	N/A
Green et al. [1999a][c]	48 h personal measurement				
McBride et al. [1999]	24 h bedroom	14/11	1.4 (0.6–3.2)	13/10	1.6 (0.7–3.7)
UK Childhood Cancer Study Investigators [1999]	Two phase measurement, 48 h home measurement if shorter measurement or other indication showed high EMF	5/3	1.7 (0.4–7.0)	5/3	1.0 (0.3–3.4)
Bianchi et al. [2000][c]	Calculated fields				
Schuz et al. [2001]	24 h child bedroom measurement			3/3	15.9 (0.8–44.1)
Kabuto et al. [2005]	1 week child bedroom measurement	11/13	1.7 (0.7, 3.8)	Not reported	2.6 (0.8–8.9)

[a]Estimates from Greenland et al. [2000] shaded in light gray; UK Childhood Cancer Study Investigators [1999] and Kabuto et al. [2005] have been added to pooled analysis in Greenland [2005]; Reference category <0.1 μT.
[b]*Estimates from Ahlbom et al. [2000] shaded in dark gray; Reference category <0.1 μT.*
[c]Estimates that do not use >0.3 μT or ≥0.4 μT categories. Myers et al. [1990]: for ≥0.1 μT (1 case/4 controls) compared to <0.01 μT, OR = 0.4 (0.04–4.33). Green et al. [1999a]: for ≥0.14 μT (29 cases/33 controls) compared to <0.03 μT, OR = 4.5 (1.3, 15.9). Bianchi et al. [2000]: for >0.1 μT (3 cases/3 controls) compared to <0.001 μT, OR = 4.5 (0.9, 23.2).

exposures greater than 0.3 μT as compared to exposures less than 0.1 μT, controlling for age, sex, and study.

Using more stringent inclusion criteria, Ahlbom et al. [2000] included nine studies using measured and calculated fields. There were a total of 3203 cases and 10338 controls in the pooled sample. In this analysis, using the geometric mean as the metric of choice the estimated OR for childhood leukemia was 2.00 (1.27, 3.13) for exposures greater than or equal to 0.4 μT as compared to exposures less than 0.1 μT, controlling for age, sex, *socioeconomic status (SES) (in measurement* studies only), and East/West (in German study only).

POSSIBLE EXPLANATIONS

The observed associations between childhood leukemia and magnetic field exposure above 0.3–0.4 μT can be due to chance, selection bias, misclassification, or other factors which confound the observed association between exposure and disease. Below we will discuss each of these interpretations in turn.

Chance

Both pooled analyses were based on large numbers and hence resulted in tight confidence intervals. When compared, they demonstrate consistency in the size of their effect estimates and range of confidence intervals. It appears unlikely that random variability (or chance) played a role in the observed effect estimates of both *pooled analyses; in his analysis of biases and random* error, Greenland [2005] estimates that the probability of random error explaining the observed association is 0.0001.

Selection Bias

In studies of ELF and childhood leukemia, selection bias has been proposed as an explanation for the observed association or at least accounting for part of it

[IARC, 2002]. Selection bias occurs when the probability of being included relates to both exposure and disease, that is, there is differential participation by cases and controls and when exposure status impacts participation. Case-control studies that rely on in-home measurements are especially vulnerable to this bias because selection might operate both at the point of initial enrollment and again when measurements are made. While some studies do in fact report response rates, accurate response rates are not available for all studies. Participation rates often depend on the type of study, with reported rates of 94%–100% in registry based studies, 37%–68% among eligible participants interviewed, and 9%–31% with measurements in matched analysis [Mezei and Kheifets, in preparation]. Hence, the potential for bias is low in registry-based studies and high in studies using measurements.

It is hypothesized that selection bias occurs through SES or mobility, either because participation is higher for high SES controls than for low SES controls because high SES children are less likely to be highly exposed than are low SES children, or because high mobility controls are both less likely to be included and more likely to have high exposure than low mobility controls, leaving a group of controls included in the study with lower exposure levels than would be in a representative group of children without leukemia. Under these scenarios, selection bias upwardly biases the effect estimate. However, most of the available information on SES and mobility is either based on ecological studies or studies of wire code, for example, a study on the association between family income and wire codes [Gurney et al., 1995] and a study reported that people who changed addresses more frequently were more likely to live at addresses with higher wire codes [Jones et al., 1993]. Little is known to what extent measured fields are correlated with either SES or mobility; both German and US studies showed that lower income tended to be associated with higher magnetic field exposure.

The strongest evidence for selection bias comes from a US study in which exclusion of partial participants from analyses tended to increase the risk estimates for childhood leukemia [Hatch et al., 2000]. The strongest evidence against the selection bias comes from Ahlbom et al. [2000] pooled analysis. The studies conducted in the Nordic countries, not requiring subject participation due to the use of calculated magnetic fields measurements, are not subject to selection bias. Taking advantage of this fact, investigators compared risk estimates in Nordic studies to the rest of the world and found similar estimates (OR = 2.1, 0.9–4.9 and OR = 1.9, 1.1–3.2, respectively). Another argument against selection bias is that there is an apparent lack of a consistent association in studies of childhood brain tumors and residential magnetic fields. Many of the leukemia studies included in the pooled analysis examined brain tumors as well and there is no reason to think that selection bias would affect one outcome and not the other. However, this conclusion is tentative since there are fewer and smaller brain tumor studies, and a pooled analysis of brain tumor studies is yet to be conducted [Kheifets, 2001].

Understanding the impact of selection bias on effect estimates from case-control studies remains a high priority, not only for clarifying the association between magnetic field exposure and leukemia, but also because of its general importance to the field of epidemiology.

Misclassification Bias

All of the difficulties with ELF exposure assessment are likely to have led to substantial exposure misclassification, which, in turn, is likely to interfere with detection of an association between exposure and disease. Almost certainly, measurement errors in both measured and calculated fields are not only present in all studies but also vary considerably from study to study. Target exposure, often described as the average exposure during the period prior to disease diagnosis, is not measured consistently among studies. Furthermore, measured exposure probably does not reflect the biologically relevant exposure, which remains unknown.

It is generally assumed that misclassification in ELF and leukemia studies is non-differential [IARC, 2002] that exposure misclassification does not differ by disease status. Non-differential misclassification translates into a bias of the effect estimate towards the null in most situations, although misclassification in middle categories can lead to the distortion of the dose-response curve.

Pooled analyses points to the occurrence of an effect of ELF on leukemia at high levels of exposure, described as greater than 0.3 or 0.4 μT. In the pooled analysis by Ahlbom et al. [2000] estimated relative risks for childhood leukemia with mean residential magnetic field exposure were: OR = 1.08 (95% CI = 0.89–1.31) for 0.1–0.2 μT, OR = 1.11 (0.89–1.47) for 0.2–0.4 μT, OR = 2.00 (1.27–3.13) for above 0.4 μT, all relative to exposure below 0.1 μT. In the pooled analysis by Greenland et al. [2000], the OR was 1.01 (0.84–1.21) for 0.1–0.2 μT and 1.06 (0.78–1.44) for 0.2–0.3 μT, while for exposures greater than 0.3 μT the OR was 1.68 (1.24–2.31), all compared to exposure less than 0.1 μT.

Since there is no established gold standard for the biologically relevant exposure, neither sensitivity (ability to correctly identify exposed individuals in a

population) nor specificity (ability to correctly identify unexposed individuals in a population) of the measurement tool used to characterize exposure can be determined. We do know, however, that the specificity is particularly important for rare exposures; even a small decrease in specificity (less than 5%) can reduce a risk ratio estimate of five to an observed risk of less than two (J. Schuz, personal communication, 2004). A similar reduction in sensitivity has only a small effect on the risk estimate. For magnetic fields, identifying the unexposed as such is difficult.

According to Greenland [2005], while misclassification is likely to be ever-present, it is unlikely to solely provide an explanation for the observed association; it does, however, introduce a great deal of uncertainty into the potential dose-response.

Confounding

Since the early days of EMF research, investigators have searched for possible confounding factors that can explain the observed associations. The hypothesized confounders of the relation between ELF and childhood leukemia include socio-economic status, residential mobility, residence type, viral contacts, environmental tobacco smoke, dietary agents, and traffic density [Savitz et al., 1988; London et al., 1991; Linet et al., 1997; Michaelis et al., 1997; Green et al., 1999a,b; McBride et al., 1999; UK Childhood Cancer Study Investigators, 1999, 2000; Schuz et al., 2001]. None of these variables have been found to confound the association, although some have been identified as potential risk factors. For a factor to be a confounder it has to exert an effect considerably larger than the observed association and be strongly correlated with exposure. A confounder can obscure or distort the statistical association between exposure and disease. Owing to limited knowledge of the etiology of childhood leukemia and an absence of strong risk factors, it is not surprising that substantial confounding has not been identified. The same observation, however, makes it difficult to exclude the possibility of a yet-to-be-identified confounder or some combination of confounding factors. Nevertheless, substantial confounding of the observed association seems unlikely.

Multiple-Bias Modeling

The observed ELF and childhood leukemia associations from epidemiologic studies are clearly difficult to interpret due to the high degree of uncertainty regarding the influence of potential biases. With such small relative risks, it is possible that one or a combination of the biases can explain the observed associations. In pooled analyses, where random error is not the only source of uncertainty, uncertainty from biases can be modeled using multiple-bias modeling [Greenland, 2005]. Multiple-bias modeling is used to systematically integrate the major sources of uncertainty into the results to provide a more unbiased estimate of effect and can be used as a tool to better understand the impact of the different types of biases on the effect estimate.

Greenland [2005] performed multiple-bias modeling using the data from Greenland et al. [2000] pooled analysis, updated with data from two studies [UK Childhood Cancer Study Investigators, 1999; Kabuto et al., 2005]. He concludes that while selection bias is present, it is unlikely to explain the association; that confounding is probably less important than selection bias; and that allowing for misclassification tends to increase the point estimate of risk, but also increases the standard deviation, resulting in less certainty that there is a positive association, but a higher certainty that the effect estimate is large. In other words, misclassification greatly increases uncertainty, making both no association and a strong association more plausible. Greenland [2005] estimates the probability that the combination of misclassification, selection bias, confounding, and random error, or the net impact, explains the observed association of 2%–4%. Other plausible assumptions would yield different results. The point of this analysis, however, is that the studies completed through 2003 are not decisive because of their design limitations and further studies of similar design would add little information.

Other Hypotheses

The absence of a clearly elucidated, robust, and reproducible mechanism of interaction of low-level magnetic fields with biological systems deprives epidemiologic studies of focus in their study designs and hinders the interpretation of the results. Based on known physical principles and a simplistic biological model, it has been argued that average magnetic fields of 0.3–0.4 μT are orders of magnitude below levels that could interact with cells or tissues and that such interactions are thus biophysically implausible [NRC, 1997; Portier and Wolfe, 1998; NRPB, 2001, 2003; Neutra et al., 2002]. Kavet and Zaffanella [2002] argue that exposure to contact currents are capable of overcoming this "implausibility" argument; (see R. Kavet in this issue for details): an open-circuit voltage (V_{OC}) may exist on the surfaces of appliances or plumbing, and if a person comes in contact with such a surface a minute amount of current can flow into the body. This hypothesis is based on theoretical calculations that show a high correlation between residential magnetic fields and V_{OC}. A dosimetry model suggests that very

small currents can produce a dose in the bone marrow of a child that is much higher than the dose produced by high average residential magnetic field exposure. Furthermore, this predicted dose is higher than the dose at which biological effects relevant to carcinogenesis have been observed.

Another hypothesized biological mechanism is the potential link between ELF and serum melatonin level and, in turn, its postulated association with leukemia risk [Schuz et al., 2001] (see Henshaw et al. in this issue for details). This hypothesis is based on the observation that, in some studies in adults, chronic exposure to ELF reduces and/or disrupts the nocturnal production of melatonin. A stronger association between night-time exposure (as compared to 24 h) and childhood leukemia has been observed. Melatonin has been proposed to be a radical scavenger and antioxidant, and to be protective of oxidative damage to the human hematopoietic system. Hence, serum melatonin levels have been suggested to be biologically relevant to the development of leukemia.

Lastly, research has also focused on identifying children genetically susceptible to leukemia and understanding the interaction between genetic susceptibility and environmental exposure on leukemia risk. Chromosomal translocations have been shown to initiate leukemia in utero [Greaves, 2002]. A "second-hit" is hypothesized as needed to complete disease progression and cause leukemia (see T. Lightfoot in this issue for more details). Magnetic fields might be one of the exposures involved in the later stages of leukemogenesis.

All of these hypotheses remain speculative and are motivated by a need to explain the observed association between magnetic field and childhood leukemia.

Causality

Epidemiologic studies of magnetic fields have consistently found an association between ELF and childhood leukemia, but lack of a known mechanism at such low energy levels and negative animal data detract from a conclusion that the ELF and childhood leukemia association is causal [IARC, 2002].

In vitro studies on the possible carcinogenicity of electric and magnetic fields have investigated a variety of processes in a number of cell lines and tissue cultures, under a wide range of exposure conditions. Since ELF do not appear to initiate cancer, researchers have hypothesized that they may act as a cancer promoter or progressor. In vitro research on the carcinogenicity of ELF has been plagued by a lack of consistency and reproducibility. Of the approaches to evaluating ELF as a potential health hazard, toxicologic experiments provide the most consistently negative data [Portier and Wolfe, 1998]. In particular, data on leukemia in experimental animals is negative [IARC, 2002].

However, even consistent negative toxicologic data cannot completely overcome consistent epidemiologic studies. First, a good animal model for childhood leukemia has been lacking. Second, particularly for ELF, the complex exposures that humans encounter on a daily basis and a lack of understanding of the biologically relevant exposure calls into question the relevance of exposures applied in toxicology. Another limitation of toxicologic studies is that animals cannot be exposed to fields that are orders of magnitude more powerful than those encountered by humans, decreasing their power to detect small risks.

It is worth mentioning that epidemiologic data appears to be not only consistent, but also specific. For cancer, the observed association seems to be limited to leukemia, and even more specifically to childhood leukemia. Several explanations can be advanced to explain the lack of an association with adult leukemia. One possibility is that, as mentioned above, exposure assessment methods used are much better in capturing exposure of children than that of adults. Of more interest to the WHO Workshop on Sensitivity of Children to EMF is the possibility that children are more vulnerable to magnetic fields due to, for example, the timing of exposure relevant to their development or predisposition due to an initiating event that occurred in utero.

The classification of ELF as a "possible human carcinogen" by IARC was based on consistent epidemiological evidence of an association between exposure to these fields and childhood leukemia and laboratory studies in animals and cells, which were not supportive of exposure to ELF causing cancer [IARC, 2002]. Although the body of evidence is always considered as a whole, based on the weight of evidence approach and incorporating different lines of scientific enquiry, epidemiologic evidence, as most relevant, is given the greatest weight.

EPIDEMIOLOGIC STUDIES OF RF AND CHILDHOOD LEUKEMIA

RF fields are produced by radio and TV broadcast towers, mobile phone base stations, and other communications infrastructure. Several ecological studies or cluster investigations have examined cancer risk, including risk of childhood leukemia, among populations in proximity to radio and television broadcast towers [See Table 2: Selvin et al., 1992; Maskarinec et al., 1994; Hocking et al., 1996; Dolk et al., 1997; McKenzie et al., 1998; Cooper et al., 2001]. A recent study looked at mortality from cancers in areas of close

TABLE 2. Epidemiologic *Studies on the Association Between RF and Childhood Leukemia**

Reference	Exposure	No. cases	OR (95% CI)
Selvin et al. [1992]	Microwave antenna, internal comparison	52	N/A; analysis of spatial data
Maskarinec et al. [1994]	Low-frequency radio, <2.6 miles	12	2.0 (0.1–8.3)
Hocking et al. [1996]	TV antenna, inner/outer	—	1.6 (1.1–2.3)
Dolk et al. [1997]	TV and FM radio, <2 km	10	1.1 (0.6–2.0)
McKenzie et al. [1998]	TV antennas, continuous ($\mu W/cm^2$)	—	0.9 (0.6–1.4)
Cooper et al. [2001]	TV and FM radio, <2 km	1	1.1 (0.0–6.3)
Michelozzi et al. [2002]	Radio station, <6 km	8	2.2 (1.0–4.1)

*Adapted from Ahlbom et al. [2004].

proximity to radio broadcasting towers [Park et al., 2004]. These analyses are mostly based on distance from the source and include small number of cases. Hence, such studies have been largely uninformative: the results are inconsistent and most studies are limited by small sample size, lack of any information on exposures, short follow up periods, and the limited ability to deal with potential confounders. There may be substantial biases in study design, since much of the epidemiologic research has been conducted in response to concerns, either based solely on the exposure source or on a perceived cancer cluster among persons living in the vicinity.

Due to the recent development of technologies using radio frequencies, there is an emerging interest in RF and childhood leukemia. There are unique methodological challenges to its study, because RF fields are harder to characterize than ELF fields; and RF signals from new wireless technologies involve increasingly complex frequency and modulation patterns. Exposure assessment methodology for RF fields, including the development of an RF meter, is still in its infancy. Rapid changes in technology and exponential increase in its use make exposure assessment both more difficult and more urgent.

FURTHER RESEARCH

The ELF and leukemia association has been studied extensively and further studies of similar design are unlikely to provide new insights; only studies that can substantially improve exposure assessment and/or identify highly exposed persons or susceptible subgroups can be informative. The question of selection bias should be further investigated, particularly the relationship between magnetic fields, SES, mobility, and participation. Ultimately, selection bias can only be resolved with large well-conducted cohort studies or with case-control studies in which exposure information can be collected independently. However, the rarity of both childhood leukemia and exposure (magnetic fields above 0.3–0.4 μT) will require either a prohibitively expensive study or an innovative study design.

Pooled analyses for childhood leukemia have been extremely informative and should be extended to include new childhood leukemia studies. Although new studies are unlikely to fundamentally change results of the previous pooled analyses, recent [Schuz et al., 2001; Kabuto et al., 2005] and ongoing studies, such as those currently underway in Italy and the United Kingdom, will add information from more countries and add to the number of highly exposed cases, allowing further investigation. For example, it might be possible to further explore the high end of the dose-response curve and risk modifiers such as age. Similarly, a pooled analysis of brain cancer studies can provide insight into existing data.

Current exposure assessment is particularly weak for base stations, and TV and radio towers. Improved exposure assessment and the development of RF exposure meters are critical steps to better capture exposure from these sources and to determine the feasibility of epidemiologic studies of leukemia in children living in the vicinity of these sources. In addition, it has been suggested that mobile phones are an important source of EMF exposure, particularly to bone marrow in the hands of children. If indeed there is a high potential for exposure to the hand, an epidemiologic study of childhood leukemia among young mobile phone users should be considered.

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Paper

Childhood cancer in relation to distance from high voltage power lines in England and Wales: a case-control study

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Abstract

Objective To determine whether there is an association between distance of home address at birth from high voltage power lines and the incidence of leukaemia and other cancers in children in England and Wales.

Design Case-control study.

Setting Cancer registry and National Grid records.

Subjects Records of 29 081 children with cancer, including 9700 with leukaemia. Children were aged 0-14 years and born in England and Wales, 1962-95. Controls were individually matched for sex, approximate date of birth, and birth registration district. No active participation was required.

Main outcome measures Distance from home address at birth to the nearest high voltage overhead power line in existence at the time.

Results Compared with those who lived > 600 m from a line at birth, children who lived within 200 m had a relative risk of leukaemia of 1.69 (95% confidence interval 1.13 to 2.53); those born between 200 and 600 m had a relative risk of 1.23 (1.02 to 1.49). There was a significant ($P < 0.01$) trend in risk in relation to the reciprocal of distance from the line. No excess risk in relation to proximity to lines was found for other childhood cancers.

Conclusions There is an association between childhood leukaemia and proximity of home address at birth to high voltage power lines, and the apparent risk extends to a greater distance than would have been expected from previous studies. About 4% of children in England and Wales live within 600 m of high voltage lines at birth. If the association is causal, about 1% of childhood leukaemia in England and Wales would be attributable to these lines, though this estimate has considerable statistical uncertainty. There is no accepted biological mechanism to explain the epidemiological results; indeed, the relation may be due to chance or confounding.

Introduction

The electric power system produces extremely low frequency electric and magnetic fields. Since 1979 there has been concern that these fields may be associated with cancer.[1] Concern has concentrated on magnetic rather than electric

fields and on childhood leukaemia in particular. A pooled analysis of nine studies that met specified quality criteria found that children living in homes with 24 hour average fields of ≥ 0.4 μT have twice the risk of leukaemia.[2] In 2001 the International Agency for Research on Cancer classified extremely low frequency magnetic fields as "possibly carcinogenic" on the basis of "limited" epidemiological evidence and "inadequate" evidence from animals.

Magnetic fields in homes arise mainly from low voltage distribution wiring, house wiring, and domestic appliances. Only a small fraction of homes are close to high voltage overhead power lines (transmission lines), but in these homes the power line is likely to be the main source of magnetic field.

We investigated whether proximity of home address at birth to transmission lines in England and Wales is associated with increased risks of childhood cancer. It is not known which period of life, if any, is relevant to induction of cancer by magnetic fields. Previous research has considered address at diagnosis or throughout some specified period. Over half (55%) of cases of childhood leukaemia and 43% of other cancers in childhood occur by the age of 5 years.

Methods

Cases and controls

Children aged 0-14 years with cancer (malignant neoplasms and tumours of the central nervous system and brain) in England, Scotland, and Wales, ascertained through several sources including the National Cancer Registration System and the UK Children's Cancer Study Group, are included in the National Registry of Childhood Tumours at the Childhood Cancer Research Group.

We identified nearly 33 000 cases of childhood cancer in children born in England and Wales, 1962-95, and diagnosed in England, Wales, or Scotland over the same period. We obtained birth information for just over 31 000 cases, 1700 having been excluded because the child was adopted or the birth record could not be traced. For each case we selected from birth registers a control matched for sex, date of birth (within six months), and birth registration district. Registration districts vary greatly in size and are frequently redefined; there are currently about 400. We attempted to find the postcode and approximate grid reference of the address at birth for all cases and controls, but this was not always possible. The final dataset comprised 29 081 matched case-control pairs (9700 for leukaemia) that we could map with respect to transmission lines.

Calculation of distance from power lines

We looked at overhead power lines forming the National Grid in England and Wales—that is, all 275 and 400 kV overhead lines (the highest voltages used) plus a small fraction of 132 kV lines, about 7000 km altogether. We obtained the grid references of all 21 800 pylons concerned from the records of National Grid Transco. Using the postcode at birth we identified subjects living within 1 km of a transmission line. For 93% of these addresses we obtained, from the Ordnance Survey product AddressPoint, a 0.1 m grid reference and hence calculated the shortest distance to any of the transmission lines that had existed in the year of birth, re-creating previous locations of lines when necessary and possible. For calculated distances less than 50 m, we took the average of the nearest and furthest points of the building from the line, using large scale maps. We aimed to obtain a complete set of accurate distances for all subjects within 600 m of a line, a distance chosen to be well beyond that at which the magnetic field from the line is thought to be important.

Statistical analysis

We used conditional logistic regression on the matched case-control pairs to calculate relative risks and χ^2 values.

Results

Table 1 shows the distribution of distances from the nearest line for cases, subdivided into leukaemia, central nervous system/brain, and "other," and for matched controls. Most (97%) of these distances were ≥ 600 m. The relative risk is an estimate of the incidence compared with that at distances ≥ 600 m. For leukaemia, at each distance category < 600 m the relative risks are greater than 1.0; there is some evidence that the risk varies according to distance from the line, though there is no smooth trend. For the other diagnoses, our data suggest no increased risk.

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Table 1 Distance of address at birth from nearest National Grid line for cases and controls in each diagnostic group, and estimated relative (RR)

In general, emanations from a line source are expected to reduce in strength as the reciprocal of distance, but the magnetic field from a power line generally falls as the inverse square of distance, or sometimes the inverse cube.[3] For each diagnostic group, we tested whether the risk is some function of distance (d) from the nearest line (table 2), using three models: that the risk depends on the rank of the distance band, the reciprocal of the distance ($1/d$), or the inverse square ($1/d^2$). There were no significant results for central nervous system/brain tumours or for "other tumours." For leukaemia, the results of two of the trend analyses were significant ($P < 0.01$); these analyses suggest the risk might depend either on the rank of the distance category or on the reciprocal of distance. The latter seems more plausible. We therefore retabulated the results for leukaemia at intervals corresponding to roughly equal intervals of $1/d$ (table 3). This change in the grouping of the data does not change the pattern of relative risk estimates shown in table 1 or the significance of the test for trend with $1/d$. For simplicity we also analysed risk of leukaemia in bands 0-199 m and 200-599 m. The risks relative to $\geq$ 600 m were 1.69 and 1.23; the trend with $1/d$ was significant ($P < 0.01$).

View this table: [in this window] [in a new window] **Table 2** Tests of hypotheses relating trends in relative risks to alternative measures of proximity to nearest line (based on the eight distance categories* in table 1). Figures are χ^2 for trend (with 1 df) and P value

View this table: [in this window] [in a new window] **Table 3** Relative risk (RR) estimates for leukaemia using revised distance categories (see text)

We examined the possibility that the relation between distance and risk of leukaemia is a consequence of a relation between distance and socioeconomic status. We used the Carstairs deprivation index to allocate a measure of socioeconomic status to the census ward in which each child was living at birth.[4] The results in table 4 confirm the previously reported association between affluence and risk of childhood leukaemia (P for trend < 0.01).[5] Adjustment for socioeconomic status had no effect on the relative risks for distance (table 3).

View this table: [in this window] [in a new window] **Table 4** Relative risks for categories of socioeconomic status

Power lines produce small air ions through a process known as "corona." Fews et al suggest that this could lead to health effects when winds blow the ions away from the line.[6] We have made an initial test of this hypothesis using a simple model suggested by Preece et al (personal communication), assuming the prevailing wind is from the south west. The case-control ratio was no greater downwind than upwind of power lines, so, using this admittedly oversimplified approach, we have no evidence to support this hypothesis.

Discussion

To date this is the largest study of childhood cancer and power lines, with roughly twice the number of children living close to power lines than in the next largest study.[7] We found that the relative risk of leukaemia was 1.69 (95% confidence interval 1.13 to 2.53) for children whose home address at birth was within 200 m of a high voltage power line compared with those more than 600 m from the nearest line. For 200-600 m the relative risk was 1.23 (1.02 to 1.49). The finding that the increased leukaemia risk apparently extends so far from the line is surprising in view of the very low level of magnetic

field that could be produced by power lines at these distances.

Possible explanations for findings

There is no obvious source of bias in the choice of cases or controls. The study is based on records of childhood cancer in England and Wales over most of the period that the National Grid has existed. Registration for childhood cancer is nearly complete, and it seems improbable that the likelihood of registration is related to proximity of birth address to transmission lines. Controls were selected from registers compiled through the legally required process of birth registration. No participation by cases or controls was required. We calculated distances without knowing case-control status, and we were able to include 88% of the eligible cases, each with a matched control.

Populations near power lines may have different characteristics from the rest of the population. In our control data there is a slight tendency in urban areas for greater affluence (measured by the Carstairs index) closer to lines, though in rural areas there is no clear trend. There is known to be a positive association between affluence and rates of childhood leukaemia. However, adjustment for socioeconomic status of the census ward of birth address did not explain our finding. Population mixing has been associated with childhood leukaemia,[8] but in our cases individual mobility, measured by changes of postcode between birth and diagnosis, was no more common for those whose home at birth was closer to the lines. Other characteristics of the population (for instance parity, which has sometimes been found to be associated with childhood leukaemia[9]) may vary with proximity to power lines, but we do not have the data to determine whether these explain our result.

The results are highly significant but could nevertheless be due to chance—for example, if the leukaemia controls are not sufficiently representative of the relevant population. Some support for this explanation can be derived from the different distance distributions observed for the leukaemia and non-leukaemia controls in table 1. Comparison of the leukaemia cases with the latter still suggests that there is an increased risk for leukaemia but it is much lower than that found using the matched controls. We emphasise, however, that the use of the matched controls is the most appropriate approach.

Six of the studies included in the pooled analysis referred to above[2] contain, or have been extended to include, analyses of proximity to power lines.[7 10-14] Of these, one, a previous UK study,[10] with 1582 cases of leukaemia diagnosed during 1992-6 (most of which will be contained within our 9700), found a relative risk of 1.42 (0.85 to 2.37) for acute lymphocytic leukaemia within 400 m for 275 and 400 kV lines; this supports our results. Studies in Canada[11] and Sweden[7] also found increased risks for childhood leukaemia (Canada: relative risk 1.8 (0.7 to 4.7) for residence within 100 m of transmission lines of 50 kV or more, and 1.3 within 50 m; Sweden: 2.9 (1.0 to 7.3) for residence £ 50 m versus 101-300 m from 220 and 400 kV power lines, with no increase for other childhood cancers). Studies from Denmark,[12] Norway,[13] and the United States[14] found relative risks below 1.0 but were based on smaller numbers. None of these estimates relates to distances as great as ours; some used a reference category that is within the distance where we found an increased risk.

Our study concerned home address at birth, whereas much previous magnetic field epidemiology has concerned address at other times. Half of the children with leukaemia in this study had the same address at diagnosis as at birth; we have no corresponding information for the control group.

The most obvious explanation of the association with distance from a line is that it is indeed a consequence of exposure to magnetic fields. For magnetic fields in the home the pooled analysis by Ahlbom et al found a relative risk of 2.00 (1.27 to 3.13) for exposures $\geq$ 0.4 μT versus < 0.1 μT; the risks for fields < 0.4 μT were near the no effect level.[2] Another pooled analysis, including additional studies, found a similar result with a threshold of 0.3 μT.[15] For the power lines we investigated, the magnetic field falls to 0.4 μT at an average of about 60 m from the line (based on calculations using one year of recorded loads for a sample of 42 lines). Our increased risk seems to extend to at least 200 m, and at that distance typical calculated fields from power lines are < 0.1 μT, and often < 0.01 μT—that is, less than the average fields in homes from other sources. Thus our results do not seem to be compatible with the existing data on the relation between magnetic fields and risk. The estimated relative risk was more closely related to the reciprocal of the distance from the line than to the square of the reciprocal of the distance.

Conclusions

While few children in England and Wales live close to high voltage power lines at birth, there is a slight tendency for the birth addresses of children with leukaemia to be closer to these lines than those of matched controls. An association between childhood leukaemia and power lines has been reported in several studies, but it is nevertheless surprising to find the effect extending so far from the lines. We have no satisfactory explanation for our results in terms of causation by magnetic fields or association with other factors. Neither the association reported here nor previous findings relating to

level of exposure to magnetic fields are supported by convincing laboratory data or any accepted biological mechanism.

Assuming that the higher risk in the vicinity of high voltage lines is indeed a consequence of proximity to the lines we can estimate the attributable annual number of cases of childhood leukaemia in England and Wales. The annual incidence of childhood leukaemia in England and Wales is about 42 per million; the excess relative risks at distances of 0-199 m and 200-599 m are about 0.69 and 0.23, respectively, giving excess rates of 28 and 10 per million. (These two estimates allow for the fact that the incidence for England and Wales is itself partly based on cases occurring in the vicinity of power lines.) We estimate that of the 9.7 million children in the population (2003 estimate), at birth about 80 000 would have lived within 199 m of a line and 320 000 between 200 and 599 m. Thus, of the 400-420 cases of childhood leukaemia occurring annually, about five would be associated with high voltage power lines, though this estimate is imprecise. We emphasise again the uncertainty about whether this statistical association represents a causal relation.

What is already known on this topic

Power frequency magnetic fields, produced by the electric power system, are "possibly carcinogenic"

A pooled analysis of case-control studies found that children living in homes with high magnetic fields (> 0.4 μT) had twice the risk of childhood leukaemia

High voltage power lines are one source of these fields

What this study adds

A UK study of 29 000 cases of childhood cancer, including 9700 cases of leukaemia, found a raised risk of childhood leukaemia in children who lived within 200 m of high voltage lines at birth compared with those who lived beyond 600m (relative risk 1.7)

There was also a slightly increased risk for those living 200-600 m from the lines at birth (relative risk 1.2, P for trend < 0.01); as this is further than can readily be explained by magnetic fields it may be due to other aetiological factors associated with power lines

We are grateful to colleagues at the Childhood Cancer Research Group and at National Grid Transco for help with this study and to cancer registries and the United Kingdom Children's Cancer Study Group for notifications of cases of childhood cancer.

Contributors: GD was responsible for overall direction of the study and publication. GD and JS had the initial idea and designed the study. TV and MEK collected information on cases and controls and carried out the statistical analysis. JS assessed exposures. GD and JS are guarantors

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Competing interests: JS is employed by National Grid Transco and worked on this project with their permission. A written contract exists between the Childhood Cancer Research Group and National Grid Transco specifying that the Childhood Cancer Research Group has complete control over the conduct, interpretation, and publication of this study; this paper has not been approved by anyone in National Grid Transco other than JS in his capacity as author and does not necessarily represent National Grid Transco's views.

Ethical approval: The Childhood Cancer Research Group has local ethics committee approval and, through membership of the UK Association of Cancer Registries, has approval from the Patient Information Advisory Group with respect to cancer registration function.

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BEFORE THE
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IN RE: APPLICATION OF TRANS-ALLEGHENY INTERSTATE LINE COMPANY FOR (I) A CERTIFICATE OF PUBLIC CONVENIENCE TO OFFER, RENDER, FURNISH AND/OR SUPPLY TRANSMISSION SERVICE IN THE COMMONWEALTH OF PENNSYLVANIA; (II) AUTHORIZATION AND CERTIFICATION TO LOCATE, CONSTRUCT, OPERATE AND MAINTAIN CERTAIN HIGH VOLTAGE ELECTRIC TRANSMISSION LINES AND RELATED ELECTRIC SUBSTATION FACILITIES; (III) AUTHORITY TO EXERCISE THE POWER OF EMINENT DOMAIN FOR THE CONSTRUCTION AND INSTALLATION OF AERIAL ELECTRIC TRANSMISSION FACILITIES ALONG THE PROPOSED TRANSMISSION LINE ROUTES IN PENNSYLVANIA; (IV) APPROVAL OF AN EXEMPTION FROM MUNICIPAL ZONING REGULATION WITH RESPECT TO THE CONSTRUCTION OF BUILDINGS; AND (V) APPROVAL OF CERTAIN RELATED AFFILIATED INTEREST ARRANGEMENTS	:	Docket Nos. A-110172 A-110172F0002 A-110172F0003 A-110172F0004 G-00071229

DIRECT TESTIMONY OF WILLIAM H. BAILEY, Ph.D.

Re: Current Status of Health-Related Research Of Electric and Magnetic Fields

April 13, 2007

Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.

A. My name is William H. Bailey. My business address is Exponent, 420 Lexington Avenue, Suite 1740, New York, NY 10170.

Q. WHAT IS YOUR POSITION AT EXPONENT, INC.?

A. I am a Principal Scientist in the Health Sciences practice and Director of Exponent, Inc.'s New York office.

Q. PLEASE DESCRIBE YOUR CURRENT RESPONSIBILITIES AND PROFESSIONAL EXPERIENCE.

A. Exponent, Inc. ("Exponent") is a research and consulting firm engaged in a broad spectrum of activities in science and technology. My practice specializes broadly in the health sciences and, more specifically, in human exposure assessment. My work involves reviewing, analyzing, and conducting research. One of the areas in which I have done a great deal of work over the past 25 years relates to potential biological and health effects of electrical facilities, such as transmission lines, substations, and electrified railroad lines.

EDUCATION AND EXPERIENCE

Q. PLEASE SUMMARIZE YOUR EDUCATION AND YOUR ACADEMIC AND RESEARCH EXPERIENCE.

A. I earned a Ph.D. in neuropsychology from the City University of New York. My education includes a B.A. from Dartmouth College in 1966, and an MBA from University of Chicago, awarded in 1969. Since 1986, I have been a visiting research scientist at the Cornell University Medical College. I also have been a

visiting lecturer at Rutgers University, the University of Texas (San Antonio), and the Harvard School of Public Health. From 1983 to 1987, I was head of the Laboratory of Neuropharmacology and Environmental Toxicology at the New York State Institute for Basic Research. For the nine previous years, I was an Assistant Professor and Postdoctoral Fellow in Neurochemistry at The Rockefeller University.

Q. PLEASE OUTLINE YOUR SCIENTIFIC RESEARCH EXPERIENCE CONCERNING ELECTRIC AND MAGNETIC FIELDS.

A. I have studied and conducted research on electric and magnetic fields ("EMF") for 25 years. My research has included laboratory, exposure assessment, and epidemiological studies concerning alternating current ("AC") electric and magnetic fields and studies on direct current ("DC") electric fields and air ions.

Q. HAVE YOU SERVED AS A REVIEWER AND SCIENTIFIC ADVISOR ON HEALTH-RELATED ISSUES FOR STATE AND FEDERAL AGENCIES OR SCIENTIFIC ORGANIZATIONS?

A. Yes. I have reviewed research for the National Institutes of Health, the National Science Foundation, and other government agencies. Concerning transmission lines in particular, I served on a Scientific Advisory Panel convened by the Minnesota Environmental Quality Board to review health aspects of a high-voltage transmission line. In addition, I served as a consultant on transmission line health and safety issues to the Vermont Department of Public Service, the New York State Department of Environmental Conservation, and the staffs of the

Maryland Public Service Commission and the Maryland Department of Natural Resources.

I also have worked with the National Institute of Occupational Health and Safety, the Oak Ridge National Laboratories, the U.S. Department of Energy, and the Federal Railroad Administration to review and evaluate health issues related to electric and magnetic fields from other sources. I also assisted the U.S. EMF Research and Policy Information Dissemination Program to evaluate biological and exposure research as part of its overall risk assessment process.

Most recently, I worked with scientific experts from 10 countries to evaluate possible hazards from exposures to static and extremely low frequency ("ELF") EMF for the International Agency for Research in Cancer ("IARC"), a division of the World Health Organization located in Lyon, France. I also contributed to a workshop convened in March 2006 by the International Committee on Non-Ionizing Radiation Protection ("ICNIRP") to update guidelines for human exposures to AC electric and magnetic fields.

Q. HAVE YOU PRESENTED THE RESULTS OF YOUR RESEARCH IN THIS AND OTHER AREAS TO THE SCIENTIFIC COMMUNITY?

A. I have published or presented more than 50 scientific papers on this and related subjects.

Q. ARE YOU A MEMBER OF ANY PROFESSIONAL ORGANIZATIONS?

A. I am a member of The Rockefeller University Chapter of Sigma Xi, a national scientific honor society; the Health Physics Society; the International Committee on Electromagnetic Safety, Subcommittees 3 and 4 – Safety Levels with respect

to Human Exposure to Fields; the Bioelectromagnetics Society; the IEEE Engineering in Medicine and Biology Society; the American Association for the Advancement of Science; the New York Academy of Sciences; the Society for Neuroscience; the Air & Waste Management Association; the Society for Risk Analysis, and the International Society for Exposure Analysis.

Q. ARE YOUR EDUCATIONAL AND PROFESSIONAL EXPERIENCE SUMMARIZED ELSEWHERE?

A. Yes. Additional details of my educational and professional experience are summarized in my curriculum vitae, which is attached as TrAILCo Exhibit WHB-1. In addition, the publications and other documents referred to in my testimony and used to support my conclusions are listed in TrAILCo Exhibit WHB-2, attached to my testimony.

Q. HAVE YOU EVER APPEARED AS A WITNESS BEFORE REGULATORY AGENCIES?

A. Yes. I have testified in regulatory proceedings on behalf of state public utility commissions and siting boards as well as project applicants in various states.

Q. WILL THE USE OF VARIOUS TERMS IN YOUR TESTIMONY BE CONSISTENT WITH THE DEFINITIONS ASSIGNED TO THOSE TERMS IN THE TABLE OF NOMENCLATURE ATTACHED TO TrAILCo Witness Flitman's Testimony as TrAILCo Exhibit DEF-1?

A. Yes. In addition, I may define other specific terms in my direct testimony.

PROJECT EVALUATION

Q. WHAT IS EXPONENT'S ROLE IN THIS PROJECT?

A. TrAILCo requested that Exponent calculate the levels of EMF and other electrical parameters associated with the operation of the Trans-Allegheny Interstate Line ("TrAIL"). TrAIL in Pennsylvania includes a 500-kV line connecting the 502 Junction Substation and the Prexy Substation, a 500-kV line from 502 Junction Substation to the Pennsylvania-West Virginia state line, three 138-kV lines connecting to the Prexy Substation, the Prexy Substation, and the 502 Junction Substation. The results of field calculations for profiles across the transmission line rights-of-way are summarized in the testimony of Dr. Gary Johnson filed on behalf of TrAILCo in this proceeding. TrAILCo also requested that Exponent evaluate these data and provide information about the current status of health-related research on EMF, which is the subject of my testimony here.

Q. WHAT IS THE PROPOSED ROUTE OF THE TRAIL LINE IN PENNSYLVANIA?

A. TrAIL is to be routed on approximately 36.1 miles of right-of-way that would extend from the Prexy Substation south to 502 Junction Substation. From the 502 Junction Substation the line would continue another 1.2 miles to the Pennsylvania/West Virginia border. For the first 4.8 miles after the Prexy Substation, TrAIL would be constructed on a 430-foot wide right-of-way adjacent to a new 138-kV line supported on double-circuit structures. For the remainder of the route TrAIL would continue alone on a 200 foot-wide right-of-way to the state

border. Two new 138-kV lines would also extend east and west from the Prexy Substation on empty or shared rights-of-way.

It is my understanding that, to the extent possible, the route proposed by TrAILCo was chosen because it minimizes the potential for disruption of existing land uses and enables the line to be situated as far from existing residences and other public facilities as practical, given topographic and other constraints.

Q. WHAT EMF LEVELS ARE ASSOCIATED WITH THE TRAIL IN PENNSYLVANIA?

A. The EMF levels associated with TrAIL as proposed in Pennsylvania have been calculated by standard methods and are described in the testimony of Dr. Johnson. In general, the EMF levels will be highest directly under the conductors, and will decrease with distance from the line. Because of the wide right-of-way, the levels of EMF will have diminished at the right-of-way edges and beyond to levels similar to those outside the rights-of-way of lower voltage transmission lines in the state. The range of magnetic field levels will be similar to those we experience when we are near other sources: on or near the right-of-way the magnitude of the magnetic field is similar to appliances, further from the right-of-way the magnitude is similar to that of distribution lines which run in front or behind our houses, and, at greater distances, the field from the line will drop to background levels commonly measured in residences, schools and workplaces. This is illustrated in TrAILCo Exhibit WHB-3.

Q. WILL TRAIL CONTRIBUTE SIGNIFICANTLY TO THE EXPOSURES OF THE PUBLIC IN PENNSYLVANIA?

A. No. We all encounter EMF at varying levels in our homes, schools, workplaces, and other locations in our communities. Given the nature of the proposed route, it is very unlikely that people will experience higher, average background levels of EMF because of the line. The proposed route is situated mainly in rural areas at a distance from most residences. Exposures to fields from the proposed line would be of limited duration and intermittent, such as those experienced by persons hiking on trails or crossing the right-of-way. Riders in vehicles passing under the line would be largely shielded from exposures to the electric field.

The electric fields associated with the new line would contribute little to exposures at residences because of distance from the line and the effective blocking of these fields by trees, fences, shrubbery, and buildings. Likewise, the magnetic fields from the line would likely contribute little to the average background levels inside nearby residences because of their distance from the line.

Q. ARE THERE ANY STATE OR FEDERAL STANDARDS THAT TRAILCO MUST MEET IN REGARD TO EMF AND HEALTH?

A. There are no federal standards for either magnetic fields or electric fields from power lines or other sources at power frequencies, and there are no state standards in Pennsylvania.

Q. WILL THE EXPECTED TRAIL EMF LEVELS BE BELOW THOSE RECOMMENDED IN EXPOSURE GUIDELINES BY INTERNATIONAL ORGANIZATIONS?

A. The United States government has not adopted the exposure guidelines recommended by the International Committee on Electromagnetic Safety (ICES, 2002) or the limits adopted by the European Union based on recommendations of the ICNIRP (EC, 1999) to protect public health and safety of the general public. However, the levels of EMF associated with operation of the line would be lower than the limits recommended in these guidelines (ICES - 10 kV/m on transmission line right-of-way; EC – induced current density " 2 millamperes/m^2 at locations where people spend significant time).

Q. IS THE ROUTING AND DESIGN OF THE PROPOSED LINE ALSO CONSISTENT WITH THE RECOMMENDATIONS OF THE DIRECTOR OF THE NATIONAL INSTITUTE OF ENVIRONMENTAL HEALTH SCIENCES AND THE WORLD HEALTH ORGANIZATION REGARDING MEASURES TO MINIMIZE POTENTIAL MAGNETIC FIELD EXPOSURES?

A. Yes. In light of marginal scientific support for concerns that exposure to EMF might be a health hazard or what aspect of exposure may be important, e.g., intensity, duration, frequency, alignment with the geomagnetic field, etc., these organizations have suggested that utilities voluntarily undertake measures to minimize public exposure through siting practices or design. In this project, the strategy of attempting to avoid routing TrAIL near residences, where possible, will result in lower EMF exposures. The paralleling of other

transmission line rights-of-way, where available, also reduces potential exposure at other land uses. In addition, the transmission of electric power at a higher voltage (e.g., at 500 kV) reduces the current flow on the line to a level below that required for transport of the same amount of power over lower-voltage lines, and therefore reduces magnetic field levels.

SCIENTIFIC METHODS FOR ASSESSING EMF AND HEALTH

Q. THERE HAS BEEN CONSIDERABLE RESEARCH ON EXPOSURE TO EMF AND HEALTH. ARE THERE STANDARD METHODS FOR INTERPRETING A LARGE BODY OF RESEARCH LIKE THIS?

A. Yes. The standard methods for assessing potential health risks from the relevant scientific research call for a process that involves evaluating all of the evidence, and giving more weight to studies of better quality. For example, the IARC defines this risk assessment process as follows:

> "Each *Monograph* reviews all pertinent epidemiological studies and cancer bioassays in experimental animals. Those judged inadequate or irrelevant to the evaluation may be cited but not summarized." (p. 5, IARC, 2006).

IARC, like many other scientific organizations, considers pertinent studies to be those reports of scientific research or reviews that have been published or accepted for publication in the openly-available scientific literature (IARC, 2006).

Q. WHAT KINDS OF DATA ARE CONSIDERED IN MAKING JUDGMENTS ABOUT POTENTIAL RISKS TO HUMAN HEALTH?

A. To assess the potential health effects from any exposure, data from several types of studies must be critically evaluated: epidemiologic observations in people, experimental studies with laboratory animals, and other biological test systems.

Q. WHAT ARE EPIDEMIOLOGIC STUDIES?

A. Epidemiology is the science that studies the patterns of health and disease in human populations in their normal environments. The objective of environmental epidemiology studies is to quantify and evaluate the associations between exposures to environmental factors (*e.g.*, vegetables in diet) and health outcomes (*e.g.*, diabetes).

Q. WHAT ARE LABORATORY STUDIES?

A. In contrast to epidemiology investigations, laboratory studies are designed to control exposures of the experimental subjects (*e.g.*, human volunteers, animals, tissues, cells, molecules) to other things in the environment, so that the effects of exposure to just one variable at known intensities and durations can be studied in relative isolation to determine cause and effect relationships.

Q. WHY ARE BOTH KINDS OF STUDY IMPORTANT?

A. Epidemiologic studies can help to suggest associations, but they usually cannot be used as the sole basis for inferences about cause-and-effect relationships, and they usually provide information about only a limited range of exposures. To establish cause-and-effect relationships, laboratory research designed to test specific hypotheses under controlled conditions is generally required. Conversely, the

results of laboratory studies, by themselves, may be difficult to extrapolate directly to the human population. Hence, the data from epidemiology studies and laboratory experiments are complementary, balancing the precision of laboratory studies with the real world experience of epidemiology.

It is therefore both desirable and important that biological responses to agents that could present a potential health threat be explored by epidemiologic methods in human populations, whenever feasible, as well as under controlled conditions in the research laboratory.

Q. WHY IS IT IMPORTANT TO EVALUATE ALL OF THE PERTINENT RESEARCH STUDIES?

A. It is essential to evaluate all of the studies, regardless of the direction of their results, in order to ensure that studies are not singled out from those available to support a preconceived position. It is considered a biased approach to evaluate only those studies that support a specific position. The appropriate question to keep in mind is "how strong is the evidence to support the hypothesis of cause and effect?"

Q. WHY IS IT FURTHER IMPORTANT TO CONSIDER THE QUALITY OF EACH STUDY — EXPERIMENTAL LABORATORY STUDIES AS WELL AS EPIDEMIOLOGY STUDIES?

A. Valid conclusions cannot be drawn from studies presenting data that are incomplete, or flawed in their methodology, execution, or interpretation. Hence, it is critically important to evaluate each study and give data from studies with

better quality design and analysis more weight in a weight-of-evidence evaluation.

Q. IS RELIANCE ON RESEARCH THAT IS PUBLISHED AND PEER REVIEWED A FIRST STEP IN THE EVALUATION OF ITS QUALITY?

A. Yes. Peer review is the process by which research proposals and studies reporting research are reviewed and evaluated by other scientists before they are approved for funding or publication. Peer review is one of the important procedures used to ensure that the quality of published information meets the standards of the scientific and technical community. Although it is not a guarantee of validity and varies widely across journals, peer review provides an indication that the data, interpretations and conclusions of the authors have passed a minimal level of scientific assessment and review. Without the procedure of peer review to screen and evaluate material, we could be inundated by material that is incomplete, poorly written, and unsubstantiated.

Q. WHAT IS THE UNIQUE ROLE OF EXPERIMENTAL LABORATORY STUDIES (*I.E.*, ANIMALS AND *IN VITRO* STUDIES) IN THE EVALUATION OF HEALTH RISKS TO HUMANS?

A. For obvious reasons, studies in humans are limited to either naturally occurring exposure, as in epidemiologic studies, or short-term exposure with presumed reversible effects (laboratory studies). Experimental studies can use higher exposures, for long time periods, and study processes in cell and tissues to directly examine for any carcinogenetic effects of EMF. In addition, experimental studies are designed to isolate the effects of a single variable from

other factors. Moreover, they can minimize potential bias and systematic error because the subjects are randomly assigned to exposed and unexposed (control) groups.

Q. HAVE EXPERIMENTAL STUDIES BEEN SHOWN TO PLAY AN IMPORTANT ROLE IN THE IDENTIFICATION AND STUDY OF CANCER-CAUSING AGENTS?

A. Yes. This role was highlighted by the IARC:

> All known human carcinogens that have been studied adequately for carcinogenicity in experimental animals have produced positive results in one or more animal species." (p. 14, IARC, 2006)

And, more generally, experimental studies are the primary basis by which we evaluate the safety of all of our drugs and medicines.

Q. WHAT ORGANIZATIONS HAVE CONDUCTED WEIGHT-OF-EVIDENCE REVIEWS OF RESEARCH STUDIES OF EMF AND HEALTH?

A. Numerous scientific organizations have performed weight-of-evidence reviews of EMF research, including IARC, ICNIRP, the Health Council of Netherlands ("HCN"), UK National Radiological Protection Board ("NRPB"), and the National Institutes of Environmental Health Sciences ("NIEHS"). The scientific consensus among these agencies is that the evidence is insufficient to conclude that EMF is a cause of any long-term health effect.

One of the most comprehensive reviews of the relevant research was performed by the IARC Working Group, which consisted of scientists (including myself) drawn from 10 countries.

ASSESSMENTS OF EMF RESEARCH BY MULTIDISCIPLINARY SCIENTIFIC REVEW PANELS

Q. WHAT WERE THE CONCLUSIONS OF THE IARC WORKING GROUP REGARDING EMF AND HEALTH?

A. The Working Group examined both the epidemiologic and experimental research literature. It concluded that the epidemiologic studies do not provide support for an association between childhood leukemia and residential magnetic fields at intensities less than 4 mG. Yet, because a statistical association between higher-level (*i.e.*, >3-4 mG) average, residential magnetic fields and childhood leukemia was reported in pooled studies, the evidence was judged as providing "limited" epidemiologic evidence for a cancer risk. The IARC Working Group also evaluated the data on animals exposed to EMF and concluded that they were "inadequate" to support a risk for cancer. Overall, magnetic fields were categorized as "possibly carcinogenic to humans" (Group 2B), based on the statistical association of higher magnetic fields with childhood leukemia. In the rating system used by IARC, the recognition of an association between exposure and cancer in epidemiology studies is considered "limited evidence" of carcinogenicity. A rating of "limited evidence" for epidemiology studies requires that the exposure be categorized as a "possible carcinogen", even without any evidence from laboratory studies that an exposure might pose a cancer risk, and even though chance, bias and confounding cannot be ruled out with reasonable confidence, (IARC, 2002).

Q. CAN YOU PROVIDE SOME ADDITIONAL PERSPECTIVE ON THE CONCLUSIONS OF THE IARC REPORT?

A. Yes. It is important to understand that we concluded that the EMF data do not merit classification as "carcinogenic to humans" or "probably carcinogenic to humans." Moreover, the classification of EMF in the 2B category as a "possible carcinogen" does not mean that magnetic fields cause cancer, nor does it mean that they are likely to do so, but only that a possibility exists, given the weak evidence for the association. The category of all possible events includes highly unlikely events.

Many hypotheses have been suggested and tested to explain possible carcinogenic effects of electric or magnetic fields; however, no scientific explanation for carcinogenicity of these fields has been established (IARC, 2002). The Working Group did not find that the scientific evidence supported associations between magnetic fields and any other type of cancer or between electric fields and cancer. Coffee (IARC, 1991), pickled vegetables (IARC, 1993) and gasoline engine exhaust (IARC, 1989) are some other common exposures that have been classified in the Group 2B category. In other words, the scientific evidence to date suggests that magnetic fields (but not electric fields) at certain levels *might* bear some relation to one type of cancer, putting EMF in the same IARC risk category as pickled vegetable beets and coffee.

Q. HAVE ANY OF THE SUBSEQUENT MULTIDISCIPLINARY SCIENTIFIC REVIEWS PERFORMED FOR NATIONAL OR INTERNATIONAL AGENCIES REACHED DIFFERENT CONCLUSIONS?

A. No. Consideration of additional epidemiology and experimental studies has not prompted agencies including the HCN (2006), ICNIRP (2003), NRPB (2004), or Sweden's Radiation Protection Authority (2007) to change the basic conclusions of IARC regarding cancer, or to prompt concern about potential adverse effects of EMF on health.

Q. YOU JUST STATED THAT CONCLUSIONS OF THE IARC WORKING GROUP AND OTHER AGENCIES THAT HAVE ASSEMBLED MULTIDISCIPLINARY PANELS TO REVIEW EMF RESEARCH ARE GENERALLY CONSISTENT. ARE THEY ALSO GENERALLY CONSISTENT WITH THE CONCLUSIONS OF A REVIEW BY THREE SCIENTISTS FROM CALIFORNIA DEPARTMENT OF HEALTH SERVICES (CDHS, 2002)?

A. No. The review by these three scientists gave more weight to the body of research on other health outcomes, expressing their belief that EMF to one degree or another may pose a possible risk of adult leukemia, adult brain cancer, miscarriage, and amyotrophic lateral sclerosis. However, there are a number of procedures used in the preparation of the California report that are of concern and, in my opinion, caused the discrepancy between the reviewers' conclusions and the conclusions of the other scientific reviews. The review represented the opinions of just three scientists and lacked the multidisciplinary expertise of the other

national and international panels (specifically with regard to biological sciences) and, in contrast to the other reviews, did not adequately consider animal studies or other types of laboratory studies, as is required for a valid health risk assessment.

Q. WHY DID THE IARC WORKING GROUP AND OTHER REVIEWERS, INCLUDING THOSE FROM CDHS, NOT REGARD STATISTICAL ASSOCIATIONS BETWEEN ESTIMATES OF MAGNETIC FIELD EXPOSURE AND CHILDHOOD LEUKEMIA AS EVIDENCE CONFIRMING A CAUSAL RELATIONSHIP?

A. It is widely recognized that statistical associations do not by themselves mean that one factor is the cause of another. Other factors must be considered to assess causation, including the limitations and weaknesses of these epidemiology studies, and the biological evidence. For magnetic fields, there was neither sufficient evidence from epidemiology studies that magnetic fields caused cancer in humans, nor sufficient evidence that magnetic fields caused cancer in laboratory studies of animals. Furthermore, there was no strong evidence for a biological mechanism to cause cancer.

Q. WHAT ARE THE RESULTS OF EXPERIMENTAL STUDIES THAT HAVE EXPOSED ANIMALS TO EMF?

A. There are a large number of studies in which animals and cells have been exposed to EMF over a wide range of intensities. With respect to cancer, particularly leukemia, the most important studies are those in which animals had been exposed over most of their lifetime to magnetic fields as high as 50,000 mG and then examined for visible and microscopic evidence of cancer. These studies

conducted in several species provide no evidence for a carcinogenic effect of magnetic fields.

Q. IN SOME OF THESE STUDIES, WERE ANIMALS TESTED THAT WERE ALREADY AT HIGHER RISK OF CANCER, THAT IS, MORE LIKELY TO DEVELOP LEUKEMIA OR RELATED TYPES OF CANCER?

A. Yes. A number of studies were designed to increase the possibility of finding cancer even if the increased risk of magnetic field exposure was quite small, by testing animals with increased susceptibility to these diseases. In some of the studies, mice were tested that were more sensitive to the development of cancer because they had a genetic mutation that increased their risk. In other studies, mice and rats were first exposed to a known carcinogen and then exposed to magnetic fields, to see whether more cancers developed compared to controls. Overall, this collection of studies, which consisted of large sample sizes and high doses, showed no consistent evidence of increased rates of leukemia or any related lymphohematopoietic cancers in the animals exposed to magnetic fields.

Q. HOW WOULD YOU SUMMARIZE THE EVALUATIONS OF THE OVERALL EVIDENCE BY SCIENTIFIC AGENCIES?

A. Several of the epidemiologic studies have reported statistical associations between higher, average exposure levels to magnetic fields (greater than 3-4 mG) and childhood leukemia, although potential biases and other factors cannot be ruled out as the explanation. Other epidemiologic studies provide little evidence suggesting that EMF is the cause of cancer or other long-term adverse health effects. The experimental laboratory data do not support a causal link between

EMF and any adverse health effect because a) laboratory animals were exposed to EMF over their entire lifespan, and these studies have not shown a consistent increase in any cancer including leukemia, and b) the laboratory data in animals, cells, and tissues do not provide evidence of a mechanism to explain how magnetic fields could cause cancer. In the context of all the evidence, the data do not support a cause-and-effect relationship. For these reasons, the organizations that have reviewed the research have not recommended exposure limits at the levels typically produced by sources in communities, including distribution and transmission lines, and appliances.

Q. IS THIS A SUMMARY OF THE CONSENSUS OF THE MULTIDISCIPLINARY REVIEWS UP TO THE PRESENT?

A. Yes. The conclusions in the most recent weight-of evidence review performed by eight scientists for the Swedish Radiation Protection Authority reflect the consensus expressed in earlier reviews by NIEHS (NIEHS, 1998, 1999), IARC (2002), NRPB (NRPB, 2001; NRPB, 2004), ICNIRP (2003) and HCN (2001, 2004, 2006) that the data do not support a causal link between EMF and any adverse health effects.

CONCLUSIONS

Q. IF EMF AT LEVELS TYPICALLY FOUND IN OUR COMMUNITIES WHERE INDIVIDUALS WORK AND PLAY IS NOT HARMFUL, WHY IS RESEARCH STILL CONTINUING?

A. As in other areas of science, research on EMF is an ongoing activity. Even though no adverse effects of EMF exposure at the levels found in our

communities have been confirmed, research is continuing to explore new questions that arise, to attempt to replicate previous studies, and to ensure that even the smallest possibility of a risk has not been overlooked. Because essentially everyone in developed countries like the United States is exposed to EMF throughout the day from a variety of sources, even a very small risk applied to these large populations would be of public health importance. However, given the limitations of epidemiology and the absence of data from laboratory studies to suggest that magnetic fields are carcinogenic, scientists have not concluded that the research, in total, suggests that electric or magnetic field have an adverse effect on human health.

Q. DOES SCIENTIFIC RESEARCH SHOW THAT ELECTRIC AND MAGNETIC FIELDS ARE HARMFUL TO HUMAN HEALTH?

A. Electric and magnetic fields are not harmful at the levels people are exposed to under transmission lines, in homes, or near machines and electrical appliances. With some appliances, an electric shaver and hair dryer for example, the user is exposed to magnetic fields that can be tens to hundreds of times higher than transmission line fields. Electric and magnetic fields can be harmful at extremely high levels, but not at the levels found under transmission lines or even near home appliances.

Q. DOES THIS CONCLUDE YOUR TESTIMONY?

A. Yes. However, I reserve the right to file such additional testimony as may be necessary or appropriate.

William H. Bailey, Ph.D.

Principal Scientist and Director, New York Office

Professional Profile

Dr. William H. Bailey is a Principal Scientist in Exponent's Health Sciences practice and Director of the New York office. Before joining Exponent, Dr. Bailey was President of Bailey Research Associates, Inc., the oldest research and consulting firm with specialized expertise in electromagnetic fields and health. Dr. Bailey specializes in applying state-of-the-art assessment methods to environmental and occupational health issues. His 30 years of training and experience include laboratory and epidemiologic research, health risk assessment, and comprehensive exposure analysis. Dr. Bailey has investigated exposures to alternating current, direct current, and radiofrequency electromagnetic fields, 'stray voltage', and electrical shock, as well as to a variety of chemical agents and air pollutants. He is particularly well known for his research on potential health effects of electromagnetic fields and has served as an advisor to numerous state, federal, and international agencies. Dr. Bailey was one of the scientists invited from the U.S. and 9 other countries to evaluate possible health hazards of exposures to static and extremely low frequency (ELF) electric and magnetic fields for the International Agency for Research in Cancer in 2002. Most recently, he has been invited to participate in the International Workshop on EMF dosimetry and biophysical aspects relevant for setting exposure guidelines, organized by the International Commission on Non-ionizing Radiation Protection (ICNIRP). He also participated in a working group that advises a committee of the World Health Organization on risk assessment, perception, and communication. Currently, he is involved in research on respiratory exposures to ultrafine- and nanoparticles. Dr. Bailey is a visiting scientist at the Cornell University Medical College and has lectured at Rutgers University, the University of Texas (San Antonio), and the Harvard School of Public Health. He was formerly Head of the Laboratory of Neuropharmacology and Environmental Toxicology at the New York State Institute for Basic Research, Staten Island, New York, and an Assistant Professor and NIH postdoctoral fellow in Neurochemistry at The Rockefeller University in New York.

Credentials and Professional Honors

Ph.D., Neuropsychology, City University of New York, 1975
M.B.A., University of Chicago, 1969
B.A., Dartmouth College, 1966

Sigma Xi; The Institute of Electrical and Electronics Engineers/International Committee on Electromagnetic Safety (Subcommitee 3, Safety Levels with Respect to Human Exposure to Fields (0 to –3 kHz) and Subcommitte 4, Safety Levels with Respect to Human Exposure to Radiofrequency Fields (3 kHz to 3 GHz); Elected member of the Committee on Man and Radiation (COMAR) of the IEEE Engineering in Medicine and Biology Society (1998-2001); Invited Speaker, First Institute of Neurological Sciences Symposium in Neurobiology, University of Pennsylvania (1980); Invited Speaker, National Heart and Lung Institute (1977).

Prior Experience

Bailey Research Associates, Inc., President, 1991-2000
Environmental Research Information, Inc., Vice President, 1987-1990
New York State Institute for Basic Research, Head of Laboratory of Environmental Toxicology and Neuropharmacology, 1983-1987
The Rockefeller University, Assistant Professor, 1976-1983

Publications

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Academic and Research Appointments

- Visiting Fellow, Department of Pharmacology, Cornell University Medical College, New York, NY (1986–present)
- Visiting Scientist, The Jackson Laboratory, Bar Harbor, ME (1984–1985)
- Head, Laboratory of Neuropharmacology and Environmental Toxicology, NYS Institute for Basic Research in Developmental Disabilities, Staten Island, NY (1983–1987)
- Assistant Professor, The Rockefeller University, New York, NY (1976–1983)
- Postdoctoral Fellow, Neurochemistry, The Rockefeller University, New York, NY (1974–1976)

- Dissertation Research, The Rockefeller University, New York, NY (1972–1974)
- CUNY Research Fellow, Dept. of Psychology, Queens College, City University of New York, Flushing, NY (1969–1971)
- Clinical Research Assistant, Department of Psychiatry, University of Chicago; Psychiatric Psychosomatic Inst., Michael Reese Hospital, and Illinois State Psychiatric Inst, Chicago, IL (1968–1969)

Teaching Appointments

- Lecturer, University of Texas Health Science Center, Center for Environmental Radiation Toxicology, San Antonio, TX (1998)
- Lecturer, Harvard School of Public Health, Office of Continuing Education, Boston, MA (1995, 1997)
- Lecturer, Rutgers University, Office of Continuing Education, New Brunswick, NJ (1991–1995)
- Adjunct Assistant Professor, Queens College, CUNY, Flushing, NY (1978)
- Lecturer, Queens College, CUNY, Flushing, NY (1969–1974)

Advisory Positions

- National Institute of Environmental Health Sciences/ National Institutes of Health, Review Committee, Neurotoxicology, Superfund Hazardous Substances Basic Research and Training Program (2004)
- National Institute of Environmental Health Sciences, Review Committee Role of Air Pollutants in Cardiovascular Disease (2004)
- Working Group on Non-Ionizing Radiation, Static and Extremely Low-Frequency Electromagnetic Fields, International Agency for Research on Cancer (2000–2002)
- Working Group, EMF Risk Perception and Communication, World Health Organization (1998–2005)
- Associate Editor, Non-Ionizing Radiation, *Health Physics* (1996–present)
- Member, International Committee on Electromagnetic Safety, Subcommittee 3 - Safety Levels with Respect to Human Exposure to Fields (0 to 3 kHz) and Subcommitee 4 - Safety Levels with Respect to Human Exposure (3kHz to 3GHz) Institute of Electrical and Electronics Engineers (IEEE) (1996–present)

- Invited participant, National Institute of Environmental Health Sciences EMF Science Review Symposium: Clinical and *In Vivo* Laboratory Findings (1998)
- Working Group, EMF Risk Perception and Communication, International Commission on Non-Ionizing Radiation Protection (1997)
- U.S. Department of Energy, RAPID EMF Engineering Review (1997)
- Oak Ridge National Laboratory (1996)
- American Arbitration Association International Center for Dispute Resolution (1995–1996)
- U.S. Department of Energy (1995)
- National Institute for Occupational Safety and Health (1994–1995)
- Federal Rail Administration (1993–1996)
- U.S. Forest Service (1993)
- New York State Department of Environmental Conservation (1993)
- National Science Foundation
- National Institutes of Health, Special Study Section—Electromagnetics (1991–1993)
- Maryland Public Service Commission and Maryland Department of Natural Resources, Scientific Advisor on health issues pertaining to HVAC Transmission Lines (1988–1989)
- Scientific advisor on biological aspects of electromagnetic fields, Electric Power Research Institute, Palo Alto, CA (1985–1989)
- U.S. Public Health Service, NIMH: Psychopharmacology and Neuropsychology Review Committee (1984)
- Consultant on biochemical analysis, Colgan Institute of Nutritional Science, Carlsbad, CA (1982–1983)
- Behavioral Medicine Abstracts, Editor, animal behavior and physiology (1981–1983)
- Consultant on biological and behavioral effects of high-voltage DC transmission lines, Vermont Department of Public Service, Montpelier, VT (1981–1982)
- Scientific advisory committee on health and safety effects of a high-voltage DC transmission line, Minnesota Environmental Quality Board, St. Paul, MN (1981–1982)

- Consultant on biochemical diagnostics, Biokinetix Corp., Stamford, CT (1978–1980)

Professional Affiliations

- The Health Physics Society (Affiliate of the International Radiation Protection Society)
- Society for Risk Analysis
- New York Academy of Sciences
- American Association for the Advancement of Science
- Air and Waste Management Association
- Society for Neuroscience/International Brain Research Organization
- Bioelectromagnetics Society
- The Institute of Electrical and Electronics Engineers/Engineering in Medicine and Biology Society

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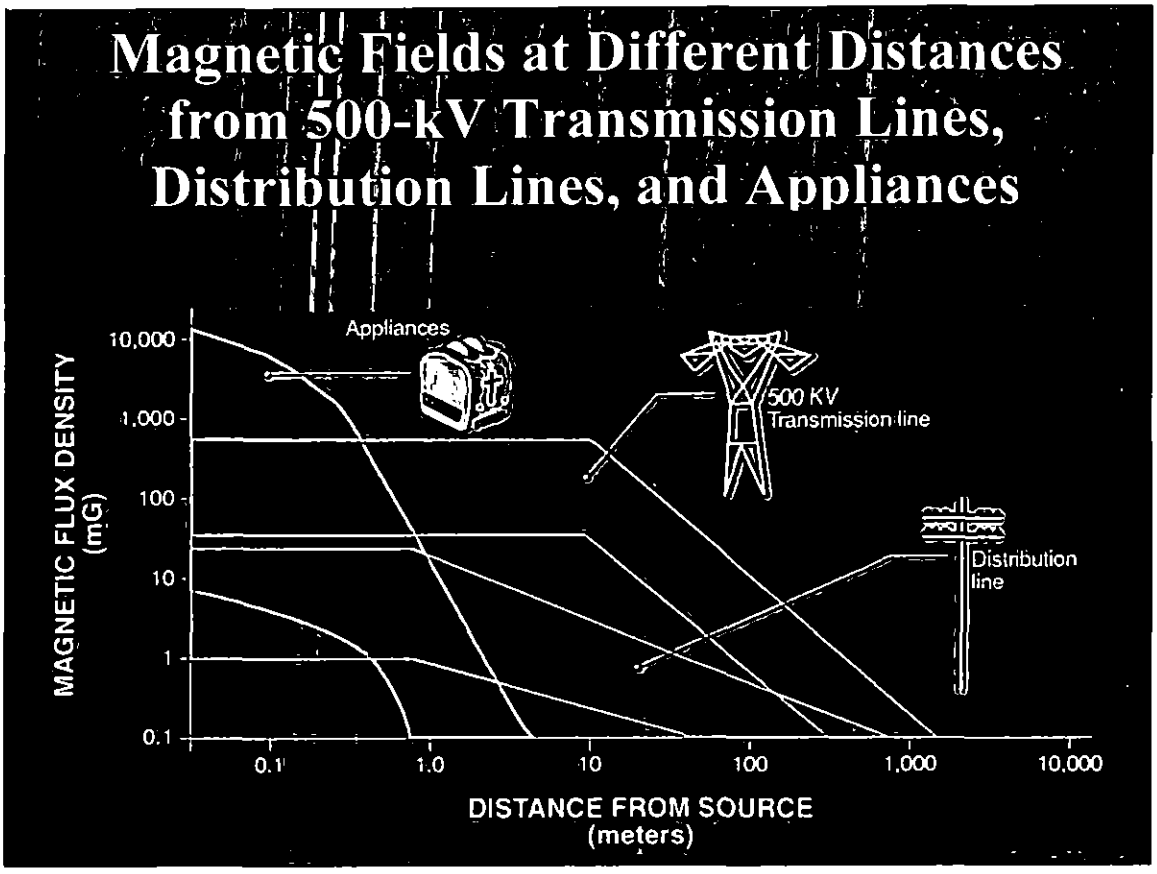
Magnetic Fields at Different Distances from 500-kV Transmission Lines, Distribution Lines, and Appliances
Appliances
500 KV Transmission line
Distribution line
MAGNETIC FLUX DENSITY (mG)
10,000
1,000
100
10
1
0.1
0.1
1.0
10
100
1,000
10,000
DISTANCE FROM SOURCE (meters)

TrAILCo Rebuttal Statement No. 8-R
Witness: William H. Bailey, Ph.D.

BEFORE THE

PENNSYLVANIA PUBLIC UTILITY COMMISSION

IN RE: APPLICATION OF TRANS-ALLEGHENY INTERSTATE LINE COMPANY FOR (I) A CERTIFICATE OF PUBLIC CONVENIENCE TO OFFER, RENDER, FURNISH AND/OR SUPPLY TRANSMISSION SERVICE IN THE COMMONWEALTH OF PENNSYLVANIA; (II) AUTHORIZATION AND CERTIFICATION TO LOCATE, CONSTRUCT, OPERATE AND MAINTAIN CERTAIN HIGH VOLTAGE ELECTRIC TRANSMISSION LINES AND RELATED ELECTRIC SUBSTATION FACILITIES; (III) AUTHORITY TO EXERCISE THE POWER OF EMINENT DOMAIN FOR THE CONSTRUCTION AND INSTALLATION OF AERIAL ELECTRIC TRANSMISSION FACILITIES ALONG THE PROPOSED TRANSMISSION LINE ROUTES IN PENNSYLVANIA; (IV) APPROVAL OF AN EXEMPTION FROM MUNICIPAL ZONING REGULATION WITH RESPECT TO THE CONSTRUCTION OF BUILDINGS; AND (V) APPROVAL OF CERTAIN RELATED AFFILIATED INTEREST ARRANGEMENTS	:	Dockets No. A-110172 A-110172F0002 A-110172F0003 A-110172F0004 G-000721229

REBUTTAL TESTIMONY OF WILLIAM H. BAILEY, Ph.D.

Re: Electric and Magnetic Fields and Possible Public Health Effects

December 10, 2007

REBUTTAL TESTIMONY OF WILLIAM H. BAILEY, Ph.D.

Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.

A. My name is William H. Bailey. My business address is Exponent, Inc., 420 Lexington Avenue, Suite 1740, New York, NY 10170.

Q. WHAT IS YOUR POSITION AT EXPONENT, INC.?

A. I am a Principal Scientist in the Health Sciences practice and Director of Exponent's New York office.

Q. HAVE YOU PREVIOUSLY SUBMITTED DIRECT TESTIMONY IN THIS PROCEEDING ON BEHALF OF THE TRANS-ALLEGHENY INTERSTATE LINE COMPANY ("TRAILCO")?

A. Yes. My direct testimony was previously submitted in this proceeding as TrAILCo Statement No. 8.

Q. WILL THE USE OF VARIOUS TERMS IN YOUR REBUTTAL TESTIMONY BE CONSISTENT WITH THE DEFINITIONS ASSIGNED TO THOSE TERMS IN THE TABLE OF NOMENCLATURE, ATTACHED TO TRAILCO WITNESS FLITMAN'S DIRECT TESTIMONY AS TRAILCO EXHIBIT DEF-1?

A. Yes. In addition, I may define new terms in my rebuttal testimony.

Q. PLEASE DESCRIBE THE PURPOSE OF YOUR REBUTTAL TESTIMONY.

A. The purpose of my rebuttal testimony is to respond to the direct testimonies of the Office of Trial Staff ("OTS") witness Gary L. Yocca, the Pennsylvania Office of Consumer Advocate ("OCA") witness Peter J. Lanzalotta, and the Energy Conservation Council of Pennsylvania ("ECC") witness Dr. Robert Q. Hanham. My rebuttal testimony will also respond to various concerns raised or allegations made during the public input hearings in Pennsylvania. With regard to the issues raised by the witnesses listed above, my rebuttal testimony will address:

1. The "competing reports" that attempt to relate a variety of health-related issues to the electric and magnetic fields ("EMF") emitted by high-voltage transmission lines and the concerns expressed by persons at the public input hearings regarding the possible adverse health effects of EMF. Several of these reports and concerns were described in the direct testimony of OTS witness Gary L. Yocca to refute the conclusions I reached in my direct testimony. I firmly believe they do not, and in this regard I am supported, *inter alia,* by the assessments of EMF research completed by national and international health agencies that were cited in my testimony. In addition, numerous reviews have been published since the time of my testimony that support my conclusions, most notably a review by the World Health Organization ("WHO").

2. The recommendation of OCA witness Peter J. Lanzalotta that EMF levels be lowered at some locations by eliminating the proposed 500-kV line to Prexy Substation and the Prexy Substation, and by requiring reverse phasing for the 138-kV segments of TrAIL, if material costs would not be significantly increased. For the reasons discussed below, these recommendations to lower magnetic fields at some locations by such means are not consistent with recommendations by scientific organizations on the need or extent of precautionary measures and should, therefore, be rejected.

3. The claim that there are "numerous problems" in my direct testimony, as alleged by ECC witness Dr. Robert Q. Hanham. For the reasons described below, the conclusions of my direct testimony reflect an accurate and reasoned application of the assessments provided by national and international health agencies to the question of whether the TrAIL project will present health risks related to EMF.

Q. FIRST, IS THE EXPERTISE OF WITNESSES YOCCA, HANHAM, AND LANZALOTTA AT ALL RELEVENT AND APPLICABLE TO THE EVALUATION OF EMF FROM THE PERSPECTIVE OF PUBLIC HEALTH?

A. No, it is not. Robert Hanham (a geographer), Gary Yocca (a ceramic scientist), and Peter Lanzalotta (an electrical engineer) have no claim to specialized knowledge and training regarding public health and EMF. This is certainly

true in connection with OCA witness Lanzalotta's claim that there is a public health "need" to delete the transmission line between 502 Junction and Prexy or to convert the proposed single circuit 138 kV lines to double circuit 138 kV lines solely for the purpose of reverse phasing the circuits.

REBUTTAL TO OTS WITNESS GARY L. YOCCA

Q. IN ADDRESSING EMF, DOES OTS WITNESS GARY L. YOCCA, CONCLUDE IN OTS STATEMENT NO. 1 THAT THE EMF LEVELS ASSOCIATED WITH THE OPERATION OF TRAIL REPRESENT A HEALTH DANGER?

A. No, he does not. Mr. Yocca does refer, however, to "many competing reports relating the incidence of certain childhood leukemia's [sic] and other health-related issues to EMF's [sic] such as those emitted by high-voltage lines" (p. 27, lines 9-12; p. 49, lines 15-18). He also describes his general review of the public input hearing transcripts as indicating concerns regarding suspected adverse health effects (p. 27, lines 13-15).

Q. DID THE REVIEWS OF THE RESEARCH THAT YOU SUMMARIZED IN YOUR TESTIMONY ADDRESS THE "COMPETING REPORTS" REFERENCED BY MR. YOCCA?

A. Yes. The reviews of the research performed for health agencies (including the International Agency for Research on Cancer ("IARC"), the Health Council of the Netherlands ("HCN"), the International Commission on Non-Ionizing

Radiation Protection ("ICNIRP"), the National Radiological Protection Board ("NRPB") of Great Britain, and the Swedish Radiation Protection Authority ("SSI")) that I cited in my direct testimony, TrAILCo Statement No. 8, at pp. 14 (lines 6-23), 16 (lines 4-8), and 19 (lines 12-17), applied appropriate weight of evidence methods, including a comprehensive evaluation of all of the relevant reports in the literature.

Q. DO THE "COMPETING REPORTS" IN THE SCIENTIFIC LITERATURE MEAN THAT THESE NATIONAL AND INTERNATIONAL HEALTH AGENCIES HAVE NOT ADDRESSED ISSUES RAISED BY SOME STUDIES IN THE LITERATURE OR HAVE BEEN UNABLE TO REACH A CONCLUSION AS TO THE LIKELIHOOD OF ANY PUTATIVE HEALTH HAZARD OF EMFS?

A. No. Health agencies have carefully prepared comprehensive reviews of the research, evaluated the studies by their quality and reliability, and drawn conclusions based on the strength and weight of the evidence.

Q. SO THE ATTENTION THAT OTS WITNESS YOCCA HAS DRAWN TO THESE "COMPETING REPORTS" DOES NOT IMPLY THAT YOUR TESTIMONY IS INCONSISTENT WITH THE CONCLUSIONS OF THE ABOVE CITED HEALTH AGENCIES?

A. No, not at all. My testimony summarized the evaluations of the scientific evidence by the health agencies on pages 18-20, and that testimony is clearly

consistent with the conclusions reached in these reviews by authoritative health agencies. Moreover, my testimony is consistent with several reports published *after* my testimony was submitted, including the most recent assessment of the scientific evidence published by the WHO in June 2007 (WHO, 2007a, b).

Q. DO YOU AGREE WITH MR. YOCCA'S CHARACTERIZATIONS OF YOUR TESTIMONY WHICH SUGGESTS THAT YOUR CONCLUSIONS ARE UNSUBSTANTIATED?

A. No. All of the statements have a technical basis and are clearly substantiated. If Mr. Yocca had any doubts about the statements he refers to on page 27, lines 6-8, he could have easily verified my statements from my responses to various data requests and interrogatories.

Q. PLEASE COMMENT ON MR. YOCCA'S STATEMENTS THAT A LARGE PERCENTAGE OF PEOPLE ARE DIRECTLY AFFECTED BY THE PROPOSED PROJECT AND HAVE EXPRESSED HEALTH CONCERNS AND FEARS.

A. With all due respect to Mr. Yocca, the public expression of concern or fear does not provide evidence or proof as to the accuracy of these concerns. TrAILCo recognizes these concerns, but there is no substitute for accurate and objective information regarding the health research.

Q. DO YOU AGREE WITH MR. YOCCA'S CONCLUSION ON PAGE 49 OF OTS STATEMENT NO. 1, AT LEAST FROM AN EMF PERSPECTIVE, THAT TRAIL WOULD CREATE AN UNREASONABLE RISK TO THE HEALTH AND SAFETY OF THE PUBLIC?

A. No. His suggestion - not apparently based upon any expert knowledge or reading of the relevant research - is directly contradicted by the conclusions of reviews of the scientific research performed by multidisciplinary groups of scientists convened by national and international health agencies that I referenced in my direct testimony.

REBUTTAL TO OCA WITNESS PETER J. LANZALOTTA

Q. IS OCA WITNESS LANZALOTTA'S RECOMMENDATION, ON PAGE 39 OF OCA STATEMENT NO. 1, TO ELIMINATE THE PROPOSED 500-KV LINE FROM 502 JUNCTION TO PREXY SUBSTATION TO DECREASE EMF LEVELS, CONSISTENT WITH THE RECOMMENDATIONS OF THE 1999 REPORT BY THE DIRECTOR OF THE NATIONAL INSTITUTE OF ENVIRONENTAL HEALTH SCIENCES ("NIEHS") TO CONGRESS OR THOSE OF THE WHO?

A. No. The elimination of transmission facilities designed to address a need under consideration by the Commission solely to minimize the EMF associated with the proposed line is not consistent with the recommendations of the NIEHS or the WHO. Following Mr. Lanzalotta's logic would lead to the rejection of the entire project, not just this one proposed segment of the line.

The NIEHS and the WHO have recommended only no or low cost activities to minimize levels of EMF where practical; neither organization recommended suspending the construction of electrical facilities as appropriate means of minimizing field levels.

Q. WHAT JUSTIFICATION DOES MR. LANZALOTTA PROVIDE FOR THIS EXTREME PROPOSAL?

A. On page 37 of OCA Statement No. 1, Mr. Lanzalotta cites the "expressed *misgivings about the magnetic fields from the proposed lines*" by local residents and others at public input hearings as evidence for his proposals. He has not performed or referenced a reasoned risk assessment or public health policy approach, however, which would justify his proposal.

REBUTTAL TO ECC WITNESS ROBERT Q. HANHAM

Q. DO YOU AGREE WITH DR. HANHAM'S CRITICISMS OF YOUR TESTIMONY THAT ARE PREDICATED UPON YOUR EDUCATION, PROFESSIONAL TRAINING, AND WORK EXPERIENCE?

Q. No. Dr. Hanham's three listed claims on pages 8-10 are fallacious. He has mischaracterized my expertise by narrowly limiting it to the area of study in which I was awarded my Ph.D. and has ignored my training in statistical analysis at both the master's and Ph.D. level. He has also failed to acknowledge my vast expertise in the field of bioelectromagnetics as described by my publications, scientific lectures, teachings, and advisory consultations

over the past 25 years, which have largely focused on EMF health issues, and in particular, the interpretation of relevant epidemiology studies.

Q. DO YOU AGREE WITH ECC WITNESS HANHAM'S CLAIM ON PAGE 9 OF ECC STATEMENT NO. 2, THAT YOUR TESTIMONY "INCLUDES MANY UNSUPPORTED ASSERTIONS"?

A. No. I will address each of his unsupported allegations in turn.

1. The statements from my testimony that Dr. Hanham claims are unsupported, pertain to the implications of the largely rural nature of the proposed TrAIL route to the potential for public exposure to EMF, which is described in the Line Route Evaluation ("LRE") Report sponsored by witness Jack Halpern as TrAILCo Exhibit JH-1. I clearly supported my opinion by referring to the testimony and exhibits of TrAILCo's siting expert in this proceeding.

2. Regarding my statement that exposure to the line would be of limited duration and intermittent, it is obvious that persons would have no reason to spend long periods of uninterrupted time on the right-of-way or near the right-of-way because, as shown in the LRE, the proposed route would pass through a sparsely populated area and non-residential exposures to EMF would be of short-duration.

Q. DO YOU AGREE WITH DR. HANHAM'S CLAIM ON PAGE 9 OF ECC STATEMENT NO. 2 THAT YOUR STATEMENT THAT PERSONS WOULD BE LARGELY SHIELDED FROM THE ELECTRIC FIELD WHILE IN VEHICLES OR BY INTERVENING TREES, SHRUBBERY, AND BUILDINGS IS UNSUPPORTED?

A. No. Any expert in the field of bioelectromagnetics or electrical engineering knows that electric fields are easily shielded or blocked by conductive materials, such as trees, fences, shrubbery, and buildings. This can be readily confirmed by consultation with standard references. An example pertinent to this case is the finding that the electric field from a 500-kV transmission line outside a residence, is attenuated within the residence by about 90% by the building materials (Caola, et al., 1983).

Q IS YOUR SUMMARY OF THE SCIENTIFIC CONSENSUS AS EXPRESSED IN THE NUMEROUS MULIDISCIPLINARY REVIEWS NOT SUPPORTED BY STATEMENTS IN THESE REVIEWS AS CLAIMED BY ECC WITNESS HANHAM AT PAGES 9-10?

A. No, and to support this statement, the conclusions of NIEHS and IARC are provided below.

NIEHS:

> 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 ELF-EMF exposure is truly a health hazard is currently small. The weak epidemiological associations and lack of any laboratory support for these associations provide only marginal, scientific support that exposure to this agent is causing any degree of harm. The NIEHS concludes that ELF-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.

The NIEHS does not believe that other cancers or non-cancer health outcomes provide sufficient evidence of a risk to currently warrant concern. (NIEHS, p. 36, 1999).

IARC:

There is *limited evidence* in humans for the carcinogenicity of extremely low- frequency magnetic fields in relation to childhood leukemia.

"There is *inadequate evidence* in humans for the carcinogenicity of extremely low-frequency magnetic fields in relation to all other cancers."

"There is *inadequate evidence* in humans for the carcinogenicity of static electric or magnetic fields and extremely low-frequency electric fields."

"There is *inadequate evidence* in experimental animals for the carcinogenicity of extremely low-frequency magnetic fields." (IARC, p. 338, 2002).

Q. *DO YOU AGREE WITH DR. HANHAM'S CRITICISM AT PAGES 9-11 OF* ECC STATEMENT NO. 2, THAT BASED UPON HIS READING OF THE CALIFORNIA DEPARTMENT OF HEALTH SERVICES ("CDHS") REVIEW THERE ARE PROBLEMS WITH YOUR CONCLUSIONS BASED UPON THE IARC AND NIEHS REVIEWS?

A. No. Dr. Hanham's knowledge of the review by three scientists at the CDHS appears to be limited to his reading of the Executive Summary of their report. It also appears from his comments that he confuses the presence of a statistical association between magnetic fields and childhood leukemia with proof of a causal relationship. I described this statistical association in my direct testimony at pages 15-16 and page 18, as did each of the reviews I cited. But, unlike Dr. Hanham, both the scientists who prepared these reviews and I have *first-hand knowledge* of the relevant primary epidemiologic and experimental studies that constitute the body of literature for evaluating causation. I will address other examples of Dr. Hanham's limited knowledge of the issue later in this testimony.

Q. ON PAGE 10 OF ECC STATEMENT NO. 2, DR. HANHAM REFERS TO "OTHER INDIVIDUALS, AUTHORITIES, AND AGENCIES, INCLUDING THE CALIFORNIA DEPARTMENT OF HEALTH SERVICES" AS REACHING DIFFERENT CONCLUSIONS FROM THE IARC AND NIEHS "STUDIES" UPON WHICH YOU RELIED. ARE THESE SOURCES IDENTIFIED IN HIS TESTIMONY?

A. No. It is unclear who these individuals and agencies are and the "agencies" to which he refers as the support for his claim is a single reference to the review of the research by the CDHS scientists that I discussed on pages 16-17 of my direct testimony, TrAILCo Statement No. 8. He also alludes to individual epidemiology studies (but not to authorities or agencies) discussed at the public input hearings.

B.

It is important to note here that Dr Hanham appears to mistake my summary of the conclusions expressed by the NIEHS and IARC (and the similar conclusions of agencies that I cited but he did not mention, including the ICNIRP[1], the NRPB[2], SSI, and the HCN) with his belief that my summary reflects my own personal opinion of individual studies and a pre-conceived position, or at least one tailored to support TrAILCo. The conclusions outlined in my testimony represent a scientific consensus arrived at by independent, multidisciplinary evaluations by qualified scientists.

[1] ICNIRP is an affiliate of the World Health Organization.
[2] The NRPB is now a part of the Health Protection Agency.

Q. IS IT TRUE THAT THE CDHS REVIEW ARRIVED AT MOSTLY DIFFERENT CONCLUSIONS FROM THOSE REACHED BY THE OTHER REVIEWS OF THE RESEARCH YOU CITED?

A. Yes. The conclusions of these reviews differ for the reasons I gave in my testimony at pages 16-17 of TrAILCo Statement No. 8.

Q. HAVE EITHER THE CDHS OR THE PUBLIC UTILITY COMMISSION OF CALIFORNIA CHANGED THEIR POLICIES TOWARD EMF OR CHANGED THEIR RECOMMENDATIONS AS A RESULT OF THE REPORT BY THESE THREE SCIENTISTS EMPLOYED BY CDHS?

A. No. The recommendations to the public regarding EMF on the CDHS website today are the same as in 1999 (CDHS, 1999). Furthermore, the California Public Utility Commission, which considered the report by CDHS (2002), expresses the same view of the research as in 1993 – "The Commission is unable to determine whether there is a significant scientifically verifiable relationship between EMF exposure and negative health consequences" – and has reaffirmed the Commission's 1993 "low-cost/no-cost, policy to mitigate EMF exposure for new utility transmission and substation projects" (CPUC, 2007). Thus, it appears that Dr. Hanham is attempting to elevate the status and value of the CDHS report to a level in this proceeding that has not even been recognized in California, where the review was performed and authored.

Q. DR. HANHAM OPINES ON PAGE 11 OF ECC STATEMENT NO. 2, THAT YOUR CRITICISM OF THE REVIEW BY THE THREE CDHS SCIENTISTS IS UNPERSUASIVE, NOT BALANCED, AND NOT OBJECTIVE. DO YOU AGREE?

A. No. Dr. Hanham mistakes legitimate scientific criticism of the methodology employed by the three scientists as not objective. This scientific criticism has also been expressed by the NRPB (NRPB, 2004), the HCN (HCN, 2004), and the Minnesota Department of Health (MDH, 2002). The MDH expressly stated the following criticisms of the CDHS review and I quote them in their entirety:

> While some scientists praised the California reviewers for using a novel approach, other researchers raised substantial concerns regarding the report's conclusions, and more fundamentally, the process used to conduct the evaluation (CDHS 2002). Based on these comments and a review of the report, MDH concluded that there is no scientific consensus at this time on the report's conclusions, including the degrees of confidence that the reviewers assigned regarding a causal relationship between EMF and adverse health effects.
>
> MDH also concluded that there are some significant limitations in California's EMF evaluation. For example, the California reviewers failed to adequately address the lack of supporting

data from animal laboratory studies and the lack of a plausible biological mechanism of how EMF may cause harm in their evaluation. Furthermore, they failed to adequately address several well-recognized limitations (e.g., selection bias, confounding, exposure misclassification) in EMF epidemiological research." (p. 23).

MDH also has concluded that there are several important distinctions between California's evaluation process and the processes used by other scientific EMF review panels. The California evaluation was conducted by three reviewers, all from the same agency, and all with primary expertise in epidemiology. Other recent scientific EMF panels (listed above) have taken advantage of a broader review panel selected from leading U.S. and international health agencies and research organizations, representing expertise in a wide variety of disciplines (e.g., epidemiology, cellular biology, physics, statistics). (p. 24).

Q. DID YOU ERRONEOUSLY ASSUME THAT "EVIDENCE OF A CAUSAL LINK BETWEEN EMFs AND ADVERSE HEALTH EFFECTS CAN ONLY COME FROM ANIMAL STUDIES, NOT EPIDEMIOLOGICAL ONES" AS CLAIMED BY ECC WITNESS HANHAM ON PAGE 11, LINES 16-18?

A. No, I did not. Again, Dr. Hanham has mischaracterized my testimony. I described the methodology used by health and scientific agencies to perform assessments of health risk, including how reviews of the scientific evidence need to consider all of the evidence (Bailey, p. 10, lines 3-5), the importance of both human epidemiology and animal laboratory studies (Bailey, pp. 10-11), and the importance of assessing the quality of individual studies (Bailey, pp. 11-12). Dr. Hanham had not addressed the relevance of experimental studies, and so I also pointed out the relevance and use of these studies at page 13.

Q. IS YOUR COMPARISON OF THE METHODOLOGY AND APPROACH OF EPIDEMIOLOGY AND LABORATORY STUDIES IN YOUR TESTIMONY A "STRATEGY" TO DISCREDIT EPIDEMIOLOGY STUDIES?

A. On the contrary, my comparison describes the standard and well-documented approach that the scientific and health agencies I cited understand and applies data obtained by these two approaches.

Q. DO HEALTH AND REGULATORY AGENCIES RELY EXCLUSIVELY ON ANIMAL EXPERIMENTS TO ASSESS RISKS TO HUMAN HEALTH?

A. No, where epidemiology data are available, they are evaluated and considered alongside the data from experimental studies of animals and humans as I describe on page 11 of my direct testimony. A valid risk assessment is supported by the complementary data from *both* lines of research. In the case of EMF, we are indeed fortunate that a large number of epidemiology studies have been performed, and they have played an important role in the evaluation of questions about potential links between EMF exposures and a wide variety of diseases. Without these epidemiology studies, there would be inadequate data to assess a wide range of potential risks to human health from exposures associated with the electric utility infrastructure and electrical devices. Dr. Hanham's attack on animal experiments is misguided and flawed.

Q. WHY IS HIS ATTACK ON ANIMAL EXPERIMENTS MISGUIDED?

A. It is a 'straw man' argument that he is using to attack the methodology and conclusions of the scientific agencies I have cited. For example, he tries to make it appear that the drug Vioxx, which has been linked to heart attacks and stroke in humans with chronic use, was put on the market (following approval by the Food and Drug Administration) solely on the basis of "animal experiments that did not relate to human conditions." (Hanham, p. 11, lines 25-27). What he fails to point out is that no drug is approved by the FDA solely based upon animal testing and that additional studies that typically involve

more than 3,000 human subjects enrolled well-designed clinical trials are required (FDA, 2007). The value of animal studies in human health risk is undisputed; and for a number of chemicals and agents, the evidence of carcinogenicity in experimental animals was established or highly suspected *before* epidemiologic studies supported this conclusion (IARC, 2002).

It should additionally be noted, that safety trials in human subjects, typically described as randomized clinical trials, differ from simple observational epidemiology studies because they are designed to protect against systematic bias by randomly assigning subjects to treatment or control conditions. So, while there are important differences, of course, between animal and human subjects, this should not overshadow or be confused with the difference between observational epidemiology studies and experimental human clinical trials.

Q. DR. HANHAM FAVORS THE CDHS REPORT IN HIS TESTIMONY. DID HE CALL THE COMMISSION'S ATTENTION TO THE CONCLUSIONS OF ANY OF THE OTHER REVIEWS YOU DISCUSSED THAT PRESENTED LARGELY DIFFERING CONCLUSIONS?

A. No, he did not.

Q. AND BY LIMITING HIS RELIANCE ON THIS SOLE REVIEW, DOES HE HIMSELF PRESENT A "SELECTIVE ANALYSIS," WHICH HE DECRIES ON PAGE 14?

A. Yes.

Q. DR. HANHAM ARGUES, "THE CDHS REPORT CONSIDERED ANIMAL STUDIES IN ITS REVIEW, BUT ON EQUAL TERMS WITH OTHER FORMS OF EVIDENCE, NOT PREFERENTIALLY." (HANHAM, P. 12, LINES 4-5). DOES IARC WEIGHT THE ANIMAL STUDIES ON EQUAL TERMS WITH HUMAN EPIDEMIOLOGIC STUDIES?

A. Yes, neither the process followed by IARC nor by NIEHS gives preferential weighting to animal studies over epidemiologic data as Dr. Hanham's statement might suggest. The standard risk assessment process is not designed to give either line of evidence preference; rather, each study type has its strengths and weaknesses and it is the combined consideration of both types of research that defines a valid risk assessment.

Q. At PAGE 12 OF ECC STATEMENT NO. 2, DOES HE SHOW THAT HE HAS MISUNDERSTOOD THE PROCESS FOLLOWED BY THE IARC WORKING GROUP, OF WHICH YOU WERE A MEMBER, IN ITS EVALUATION OF THE POTENTIAL CARCINOGENICITY OF ELF FIELDS?

A. Yes. He is in no position to evaluate the respective merits of any of the risk assessments and he has erroneously described the process used by IARC and NIEHS. Contrary to Dr. Hanham's description, the IARC Working Group did not use a "simple binary response (yes or no) in evaluating studies," or simply give "a majority opinion," or draft the entire 395 page report "over five days."

Both reviews of the research by IARC and NIEHS involved many months of research, review, and evaluation by the participants. In each topic area, the members charged with the evaluation of the relevant studies presented their assessment and conclusions, which were shared with the group before and during the meetings. In the final meetings that took place over seven to eight days, the participants discussed and finalized the text of the review and formulated the evaluations.

Dr. Hanham also states "the CDHS report incorporated the assessments of all reviewers, positive or negative." (ECC Statement No.2, p. 12, lines 21-22). While CDHS did solicit comments on drafts of their report and published some comments received, there were criticisms even by members of their own hand-picked scientific advisory panel that the authors were not responsive to criticisms and suggestions.

Q. DO THE THREE REASONS LISTED BY DR. HANHAM ON PAGE 12 OF HIS ECC REBUTTAL TESTIMONY AS TAKEN FROM THE CDHS REPORT EXPLAIN WHY "ANIMAL EXPERIMENTS OF THE EMF MIXTURE MIGHT MISS THE TRUE EFFECT OF EMFs ON HEALTH," AND THUS, UNDERMINE THE USE OF SUCH STUDIES?

A. No. First, the use of animal data in the evaluation of potential health effects of EMF is not hampered because of a "problem in finding the right animal, one that mimics the human anatomy." There is no biological basis to assert that animals lack some anatomical feature that we, humans, possess that renders us uniquely susceptible to EMF, nor has this argument been accepted or even asserted in the scientific community. Second, the exposures to EMF in most animal studies replicate the exposures produced by transmission lines, i.e., fields with a frequency of 60 Hertz without significant mixtures of other harmonic frequencies. Third, the analysis of animal studies does not involve the *a priori* judgment that there is a monotonic relationship between exposure and biological change. In fact, consideration of the shape of the dose-response relationship in animal studies has not been a factor because almost all of the studies report no differences between exposed animals and untreated control animals at any level of magnetic field exposure, including levels up to 50,000 times larger than the average level found in residences.

Q. DR. HANHAM CLAIMS THAT THE APPROACH USED BY CDHS TO EVALUATE SCIENTIFIC RESEARCH IS MORE RELIABLE THAN THE APPROACH USED BY IARC AND NIEHS. DO YOU AGREE?

A. No, I do not. The review method developed and applied by the three scientists at CDHS to evaluate the EMF research had never been tried or tested either by them or any other review group. In contrast, the reliability of the IARC approach has been used in the evaluation of over 900 chemicals, physical agents, and mixtures.

Q. DR. BAILEY, BASED ON YOUR REVIEW OF DR. HANHAM'S TESTIMONY (AND NEAR IDENTICAL SUBMISSION AT A PUBLIC HEARING), WHAT WEIGHT SHOULD THE COMMISSION ACCORD HIS TESTIMONY?

A. None whatsoever. His allegations regarding my testimony are false. Geography, his area of study, is not the same as biomedical research or epidemiology. Dr. Hanham's cursory reading of studies and reviews provides no clarifying insights to the Commission, and his view that "credible, vetted epidemiology evidence" (p. 14, lines 1-2) reaches a conclusion opposite to those of the national and international reviews that I cited and is misguided. Scientific conclusions about causality are not based solely on epidemiologic evidence, and the reviews that considered the cumulative body of evidence (including epidemiology and experimental research) characterized this

epidemiologic evidence as "weak", in supporting their conclusion that the research suggests no adverse health effects.

Q. WOULD YOU PLEASE BRIEFLY ADDRESS AND RESPOND TO THE FOLLOWING STATEMENTS AND DOCUMENTS ON EMF ISSUES THAT WERE PRESENTED AT THE PUBLIC INPUT HEARINGS: (I) THE "DRAPER STUDY," (II) CITATIONS TO INDIVIDUAL STUDIES BY EDWARD PETSONK, M.D., (III) STUDIES OF THE IMMUNE SYSTEM AND EMF, (IV) STUDIES OF DEPRESSION, (V) A UK CROSS PARTY REPORT, (VI) FARM AND WILDLIFE STUDIES, AND (VII) THE BIOINITIATIVE REPORT?

A. Yes.

a) Several persons at the public input hearings referred to the study by Draper, et al. (2005) when expressing concern about the proposed transmission line. These investigators reported that the birth addresses of childhood leukemia cases in the United Kingdom were more likely to be within 200 meters of a high voltage power line than outside of 600 meters. No measurements or calculations of EMF were provided. The authors commented "There is no accepted biological mechanism to explain the epidemiological results; indeed, the relation may be due to chance or confounding" (p. 1290) and concluded "We have no satisfactory explanation for our results in terms of causation by magnetic fields, and the findings are not supported by convincing laboratory data or any accepted biological mechanism." (p. 1291). Therefore,

while the study by Draper, et al. reported a statistical association between birth address in the vicinity of a power line and childhood leukemia, conclusions about whether magnetic fields cause childhood leukemia are based on the *entire* body of literature, which includes approximately 20 epidemiologic studies, many of which actually measured magnetic field exposure (including large studies in the UK, Canada, and in the US by the National Cancer Institute) that did not report an association between personal magnetic field exposure and childhood leukemia). The WHO review considered the study by Draper, et al. when it concluded that the research does not suggest a cause-and-effect relationship between childhood leukemia and magnetic fields. Thus, when considered alone, the study by Draper, et al. may seem concerning, but (just like any area of study in the field of health) a statistical association reported from one study cannot be used as the basis for conclusions regarding causation, or public policy.

b) Edward Petsonk, M.D., Michael Faust, M.D., and Ann McCune, M.D., and other public input hearing witnesses alluded to several individual epidemiology studies of childhood and adult cancer in their statements at the public input hearings. These studies represent just a few of the many epidemiology studies in the literature, and valid assessments about the potential relationship between magnetic fields and cancer cannot be performed by 'cherry picking' studies. As I explained above, and in my testimony on page 11, all of the studies, not just selected ones, are considered in a valid

epidemiologic assessment. A Task Group of the WHO reviewed the literature earlier this year, and concluded the following:

> "New human, animal, and in vitro studies published since the 2002 IARC Monograph, 2002 [sic] do not change the overall classification of ELF as a possible human carcinogen" (WHO, p. 347, 2007b).
>
> "Consistent epidemiological evidence suggests that chronic low-intensity ELF magnetic field exposure is associated with an increased risk of childhood leukaemia. However, the evidence for a causal relationship is limited, therefore exposure limits based upon epidemiological evidence are not recommended, but some precautionary measures are warranted" (WHO, p. 355, 2007b).

While Dr. Petsonk's statement that "for the childhood leukemias it's no longer a hypothesis" (Tr. 838) is open to interpretation as to its meaning, it should be clarified that the only conclusion that scientists on expert panels have reached is that a statistical association has been observed. Explanations for statistical associations include causation, chance, bias, and confounding; scientific panels have not ruled out the latter two explanations, nor has any scientific panel concluded that the hypothesis that magnetic fields cause childhood leukemia has been proven. His assessment of the literature is not shared by scientists who have reviewed the epidemiology and experimental studies of EMF and

cancer for IARC, NIEHS, WHO, or the U.S. National Cancer Institute (NCI, 2005).

c) The basis for concern about adverse effects of EMF on the immune system is also limited. The WHO Task Group concluded "Evidence for the effects of ELF electric or magnetic field on components of the immune system is generally inconsistent ... Overall therefore, the evidence for effects of ELF electric or magnetic fields on the immune and haematological system is considered inadequate." (WHO, p. 8, 2007b). According to the WHO, the classification "inadequate" is used when the studies cannot be interpreted as showing either the presence or absence of an effect because of major qualitative or quantitative limitations, or when no data are available.

d) Mr. Levy, at the public input hearings, suggested that his reading of "studies in the psychological and epidemiological literature regarding the repercussions of power line emissions" suggest a link to "safety, health, and mental well-being" but "are neither unequivocal nor conclusive." (Tr. 2129-2130). He cites two 1997 studies from Finland and Australia. In 2007, the WHO Task Group concluded "There is only inconsistent and inconclusive evidence that exposure to ELF electric and magnetic fields cause depressive symptoms or suicide. Thus, the evidence is considered inadequate." (p. 161).

e) A few other public input hearing witnesses discussed a "Report by a Cross-Party Inquiry into Childhood Leukaemia and Extremely Low Frequency Electric and Magnetic Fields (ELF EMF)," dated July 2007. The report was authored by members of Parliament who heard testimony primarily from those who oppose transmission lines in the UK, and was not a scientific summary of the weight of the evidence. The recommendations of the report appear to be political in nature and are contrary to the advice of the UK's Health Protection Agency and to the WHO regarding the need for and extent of precautionary measures. No response of the UK government to this report has appeared yet.

f) A number of general concerns about the effects of EMF on farm animals and wildlife were raised at the public input hearings. Regarding farm animals, a variety of studies have been conducted in which the behavior, health and performance of farm animals (i.e., cows, pigs, and sheep) confined directly under the conductors or in conditions designed to replicate high magnetic and electric field exposure conditions have been reported. Altogether, these studies have not indicated that a transmission line would have adverse effects on the health, behavior or productivity of farm animals. A more specific concern was mentioned about the effect of EMF on honey bees. (Tr. 2014-2015). Studies have reported that when bee hives are placed on the right-of-way of 765 kV transmission lines, the heating of metallic hive components and/or shocks within the hive adversely affects the colony. These effects can be mitigated by placing a grounded screen over the hive to shield the electric field or by

moving the hive some distance away from the line. (Bindokas, et al., 2005). No direct effects on the bee's health or productivity have been reported.

g) There was also mention of the "BioInitiative Report: A Rationale for a Biologically-based Public Exposure Standard for Electromagnetic Fields (ELF and RF)," an unpublished document posed at www.bioinitiative.org. This report has been posted on a website by one of the editors of the report who is not a health scientist. The objective of the report was to "document reasons why the current public exposure standards (i.e., the ICNIRP and ICES guidelines for ELF fields and the ICNIRP guideline for radiofrequency fields) for non-ionizing electromagnetic radiation are no longer good enough to protect public health." (Section 2, p. 1). The scientific methods used in the review are, in a number of important respects, seriously flawed and do not represent a valid weight of evidence review of the literature. Furthermore, the data considered in this report have been assessed by the WHO, which did not recommend any reduction in exposure standards. Unlike the BioInitiative report, the WHO report was the product of a multidisciplinary scientific panel assembled by an established public health agency that followed appropriate scientific methods, including the systematic and critical examination of all the relevant evidence.

CONCLUSIONS

Q. HAVE THE REBUTTAL WITNESSES YOCCA, LANZALOTTA, AND HANHAM PROVIDED COGENT, SCIENTIFICALLY SUPPORTED ARGUMENTS TO PERSUADE THE COMMISSION THAT THE REVIEWS OF SCIENTIFIC RESEARCH PUBLISHED BY NATIONAL AND INTERNATIONAL HEALTH AGENCIES THAT YOU SUMMARIZED IN YOUR TESTIMONY SHOULD BE DISREGARDED?

A. No. The information they have submitted in support of their criticisms is incomplete and does not represent the application of appropriate scientific methods.

Q. DO ANY OF OCA WITNESS LANZALOTTA'S RECOMMENDATIONS FOR MODIFICATION OF THE TRAIL PROJECT APPEAR TO BE AN APPROPRIATE RESPONSE TO CONCERNS ABOUT EMF?

A. No, they would appear to go far beyond policies that have been recommended by the NIEHS and the WHO to address public concern.

Q. WHAT ABOUT THE COMMENTS AND SUBMISSIONS OF MEMBERS OF THE PUBLIC AT THE PUBLIC INPUT MEETINGS?

A. Those who participated in those meetings should be commended for making the effort to become acquainted with EMF, as well as other topics. The problem for them, however, is that the number of studies on this topic is very large and highly technical; therefore, it is difficult for them, regardless of their

background and training, to take the individual studies they have read or descriptions of studies on Internet websites and "put them all together." I believe this is the reason that both the public and policy makers should give great weight to the assessments provided by national and international health agencies. Given the degree of public concern about EMF in relation to this project, it is absolutely critical that all parties recognize how important it is for the basis for any decision regarding EMF, whatever the source, be grounded on the highest level of scientific rigor and evidence. Reliance on lesser evidence is unacceptable, where matters of broad public health and welfare are concerned.

Q. DOES THIS CONCLUDE YOUR REBUTTAL TESTIMONY?

A. Yes. However, I reserve the right to file such additional testimony as may be necessary or appropriate.

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TrAILCo Rejoinder Statement No. 8-RJ
Witness: William H. Bailey, Ph.D.

APR 01 2008 Pgh JK A-110172

BEFORE THE

PENNSYLVANIA PUBLIC UTILITY COMMISSION

IN RE: APPLICATION OF TRANS-ALLEGHENY INTERSTATE LINE COMPANY FOR (I) A CERTIFICATE OF PUBLIC CONVENIENCE TO OFFER, RENDER, FURNISH AND/OR SUPPLY TRANSMISSION SERVICE IN THE COMMONWEALTH OF PENNSYLVANIA; (II) AUTHORIZATION AND CERTIFICATION TO LOCATE, CONSTRUCT, OPERATE AND MAINTAIN CERTAIN HIGH VOLTAGE ELECTRIC TRANSMISSION LINES AND RELATED ELECTRIC SUBSTATION FACILITIES; (III) AUTHORITY TO EXERCISE THE POWER OF EMINENT DOMAIN FOR THE CONSTRUCTION AND INSTALLATION OF AERIAL ELECTRIC TRANSMISSION FACILITIES ALONG THE PROPOSED TRANSMISSION LINE ROUTES IN PENNSYLVANIA; (IV) APPROVAL OF AN EXEMPTION FROM MUNICIPAL ZONING REGULATION WITH RESPECT TO THE CONSTRUCTION OF BUILDINGS; AND (V) APPROVAL OF CERTAIN RELATED AFFILIATED INTEREST ARRANGEMENTS	:	Dockets No. A-110172 A-110172F0002 A-110172F0003 A-110172F0004 G-000721229

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2008 APR 14 PM 3:18
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REJOINDER TESTIMONY OF WILLIAM H. BAILEY, Ph.D.

Re: Electro And Magnetic Fields and Related Public Health Effects

March 19, 2008

REJOINDER TESTIMONY OF WILLIAM H. BAILEY, Ph.D.

Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.

A. My name is William H. Bailey. My business address is Exponent, 420 Lexington Avenue, Suite 1740, New York, New York 10170.

Q. WHAT IS YOUR POSITION AT EXPONENT, INC.?

A. I am a Principal Scientist in the Health Sciences practice and Director of Exponent, Inc.'s New York office.

Q. HAVE YOU PREVIOUSLY SUBMITTED TESTIMONIES IN THIS PROCEEDING ON BEHALF OF THE TRANS-ALLEGHENY INTERSTATE LINE COMPANY ("TRAILCO")?

A. Yes. My direct testimony was previously submitted in this proceeding as TrAILCo Statement No. 8, and my rebuttal testimony was previously submitted as TrAILCo Statement No. 8-R.

Q. WILL THE USE OF VARIOUS TERMS IN YOUR REJOINDER TESTIMONY BE CONSISTENT WITH THE DEFINITIONS ASSIGNED TO THOSE TERMS IN THE TABLE OF NOMENCLATURE ATTACHED TO TrAILCo WITNESS FLITMAN'S DIRECT TESTIMONY AS TRAILCO EXHIBIT DEF-1?

A. Yes. In addition, I may define new terms in my rejoinder testimony.

Q. PLEASE DESCRIBE THE PURPOSE OF YOUR REJOINDER TESTIMONY.

A. The purpose of my rejoinder testimony is to respond to the surrebuttal testimony of the Energy Conservation Council of Pennsylvania ("ECC") witness Dr. Robert Q. Hanham.

REJOINDER TO ECC WITNESS DR. ROBERT Q. HANHAM

Q. DO THE THREE STUDIES CITED BY ECC WITNESS HANHAM ON PAGES 7-8 OF HIS SURREBUTTAL TESTIMONY CONTRADICT OR OTHERWISE REBUT THE EVALUATIONS AND SUMMARIES PRESENTED IN THE HEALTH RISK ASSESSMENTS OF MAGNETIC FIELDS THAT YOU HAVE PRESENTED IN YOUR DIRECT AND REBUTTAL TESTIMONIES?

A. No. The three studies cited on pp. 7-8 of Dr. Hanham's surrebuttal testimony as "examples of studies that discuss the heightened risk of childhood leukemia posed by exposure to EMFs" are among the numerous epidemiology studies of childhood leukemia and magnetic fields in the literature. "Cherry picking" studies from the literature to support a particular conclusion is not a valid scientific method and does not rebut comprehensive evaluations of the research literature that considered the weight of the evidence from *all* of the epidemiology studies, as well as *in vivo* and *in vitro* experimental studies, as I have previously described in my testimony. Because of the high visibility of the Draper, *et al.* study, I specifically addressed it at pp. 24-25 of my rebuttal testimony, where I

stated that the study was limited by the fact that no measurements or calculations of EMF were conducted. I noted, at page 24 of my rebuttal testimony, that the study's authors commented that:

> "There is no accepted biological mechanism to explain the epidemiological results; indeed, the relation may be due to chance or confounding" (p. 1290) and concluded "We have no satisfactory explanation for our results in terms of causation by magnetic fields, and the findings are not supported by convincing laboratory data or any accepted biological mechanism." (p. 1291)

I also stated that the Draper study, when considered alone, may seem concerning, but that a statistical association reported from one study cannot be used as the basis for a conclusion about causation. The Task Group of the World Health Organization ("WHO"), which I referenced in my rebuttal testimony, considered the Draper study, as well as the numerous other epidemiology, *in vivo* and *in vitro* studies in the literature, and concluded that the cumulative body of evidence supports the classification of "possible carcinogen," but does not support the conclusion that magnetic fields are a cause of childhood leukemia.

Q. DO YOU AGREE WITH ECC WITNESS HANHAM'S CONTENTION AT PAGE 8 OF HIS SURREBUTTAL TESTIMONY THAT YOU HAVE NOT CONDUCTED "AN INDEPENDENT AND NEUTRAL" ASSESSMENT OF THE CALIFORNIA DEPARTMENT OF HEALTH SERVICES ("CDHS") REPORT ON MAGNETIC FIELDS?

A. No, I do not agree with his contention. My review of the CDHS report was independent and my criticisms were based on standard scientific procedures for conducting reviews of research. My description of the limitations of the CDHS report are mirrored in the independent critiques of the report by the Minnesota Department of Health, the National Radiation Protection Board ("NRPB") and the Health Council of the Netherlands ("HCN") that I cited in my rebuttal testimony at pages 15-16.

Dr. Hanham contends that my appearance in this proceeding on behalf of TrAILCo has rendered me incapable of independently assessing EMF research and health risk assessments. I will be certifying my direct and rebuttal testimonies under oath and, accordingly, they constitute my sworn evidence in this proceeding. My assessment of the current status of research in the area of EMF is based on the extensive background and experience that I have in the field, all of which I have brought to bear in my testimony, and my conclusions were formed independently and in a completely objective fashion. The fact that I appear in this proceeding on behalf of TrAILCo had no bearing on the assessment

and, indeed, the conclusions that I presented to TrAILCo are those of multiple independent reviews and evaluations performed for scientific and health agencies.

Q. ECC WITNESS HANHAM CONTENDS THAT YOUR "DIRECT PARTICIPATION AND THE POWER INDUSTRIES' OVERALL PARTICIPATION" PLACES THE VALIDITY OF THE REVIEW PROCESSES OF WHO, IARC, AND ICNIRP IN QUESTION. DO YOU AGREE?

A. Again, I absolutely cannot agree. Dr. Hanham and the author he cites, Maisch (2006), raise unsubstantiated allegations that the WHO Task Force "must have been tainted" by industry participation. It appears that, because Hanham and Maisch disagree with the conclusions of WHO and other agencies whose conclusions I presented, they raise *ad hominum* arguments. Neither Dr. Hanham nor Maisch (2006) present credible evidence to support the claim that the interests of industry biased the conclusions reached by the WHO Task Force. Because of my knowledge and expertise, I have been asked to advise a wide variety of organizations, including the electric utility industry and many government and scientific agencies, about research in this field. Neither Hanham nor Maisch can explain why ALL of the independent national and international scientific and regulatory agencies reach similar conclusions. Hanham and Maisch express concern about the WHO, and Hanham about ICNIRP and IARC as well, but their premise would also require that all other organizations that reached similar conclusions, including the panels who reviewed research for the U.S. National Academy of Sciences, the National Institute of Environmental Health Sciences,

the National Radiation Protection Board and Health Protection Agency of Great Britain, the Health Council of the Netherlands, the Swedish Radiation Protection Authority, and Health Canada, etc. are also biased.

Q. AT PAGE 10 OF HIS REBUTTAL TESTIMONY, ECC WITNESS HANHAM DISPUTES YOUR EARLIER REBUTTAL STATEMENT THAT INTERVENING TREES AND SHRUBBERY WOULD LARGELY SHIELD PERSONS FROM ELECTRIC FIELDS BY RESPONDING THAT PEOPLE WILL NOT BE SHIELDED BECAUSE A TRANSMISSION LINE RIGHT-OF-WAY WILL BE TOTALLY CLEARED OF TREES. WOULD YOU PLEASE RESPOND?

A. I continue to stand by my direct and rebuttal testimony in this regard. While the TrAILCo rights-of-way will be cleared of tall trees that could pose a line clearance danger in advance of construction, any such clearing would not necessarily remove vegetation, which presents no clearance danger, that would attenuate the electric field. Existing trees or other shrubbery or vegetation left outside of the rights-of-way would provide an additional opportunity for shielding or blocking the electric field from the TrAILCo line. Furthermore, "Following a standard health risk assessment process, the Task Group [of the WHO] concluded that there are no substantive health issues related to electric fields at levels generally encountered by members of the public." So the degree of shielding by vegetation does not diminish or increase a health risk to the public.

Q. DOES THIS CONCLUDE YOUR REJOINDER TESTIMONY?

A. Yes. However, I reserve the right to file such additional testimony as may be necessary or appropriate.

TrAILCo Statement No. 9
Witness: Gary B. Johnson, Ph.D.

APR 01 2008 Pgh PUC A-110172

BEFORE THE
PENNSYLVANIA PUBLIC UTILITY COMMISSION

IN RE: APPLICATION OF TRANS-ALLEGHENY INTERSTATE LINE COMPANY FOR (I) A CERTIFICATE OF PUBLIC CONVENIENCE TO OFFER, RENDER, FURNISH AND/OR SUPPLY TRANSMISSION SERVICE IN THE COMMONWEALTH OF PENNSYLVANIA; (II) AUTHORIZATION AND CERTIFICATION TO LOCATE, CONSTRUCT, OPERATE AND MAINTAIN CERTAIN HIGH VOLTAGE ELECTRIC TRANSMISSION LINES AND RELATED ELECTRIC SUBSTATION FACILITIES; (III) AUTHORITY TO EXERCISE THE POWER OF EMINENT DOMAIN FOR THE CONSTRUCTION AND INSTALLATION OF AERIAL ELECTRIC TRANSMISSION FACILITIES ALONG THE PROPOSED TRANSMISSION LINE ROUTES IN PENNSYLVANIA; (IV) APPROVAL OF AN EXEMPTION FROM MUNICIPAL ZONING REGULATION WITH RESPECT TO THE CONSTRUCTION OF BUILDINGS; AND (V) APPROVAL OF CERTAIN RELATED AFFILIATED INTEREST ARRANGEMENTS	:	Docket Nos. A-110172 A-110172F0002 A-110172F0003 A-110172F0004 G-00071229

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2008 APR 14 PM 3:18
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DIRECT TESTIMONY OF GARY B. JOHNSON, Ph.D.

Re: *Measurement of Electric and Magnetic fields; Corona Effects;* Audible and Radio Noise; Compliance with Health and Safety Standards

April 13, 2007

Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.

A. My name is Gary B. Johnson. My business address is Exponent, 185 Hansen Court, Suite 100, Woodale, IL 60191.

Q. WHAT IS YOUR POSITION AT EXPONENT, INC.?

A. I am a Senior Managing Engineer in Exponent Inc.'s Electrical and Semiconductors practice in our Chicago office.

Q. PLEASE DESCRIBE YOUR CURRENT RESPONSIBILITIES AND PROFESSIONAL EXPERIENCE.

A. Exponent, Inc. ("Exponent") is a research and consulting firm engaged in a broad spectrum of activities in science and technology. My work in this practice relates to electrical engineering issues particularly relating to the electrical environment of power systems. I have extensive experience in modeling and measuring electric and magnetic fields from transmission and distribution systems as well as the audible noise, radio noise and other phenomena associated with high voltage power systems.

EDUCATION AND EXPERIENCE

Q. PLEASE SUMMARIZE YOUR EDUCATION AND RESEARCH EXPERIENCE.

A. I obtained my Ph.D. in Electrical Engineering from the University of Illinois in 1979. I have a M.S. degree in Physics and a B.S. degree in Engineering Physics, also from the University of Illinois. From 1979 to 1996, I was at the High Voltage Transmission Research Center in Lenox, Massachusetts, where I performed research, measurements, and studies related to high voltage power lines and power systems. General Electric and the Electric Power Research Institute ("EPRI") primarily operated the Center and performed studies for a

number of clients, including utilities and state and federal agencies. Since 1996, I have been involved in a variety of power line issues involving measurements, modeling, and calculations related to the performance of power lines such as electric and magnetic fields ("EMF"), audible noise, radio and television ("TV") noise, nuisance and ground currents, and stray voltage, initially as head of Power Research Engineering, and since 2001 as part of Exponent's Electrical and Semiconductors Practice.

Q. PLEASE OUTLINE YOUR ENGINEERING AND RESEARCH EXPERIENCE CONCERNING ELECTRIC AND MAGNETIC FIELDS AND OTHER ELECTRICAL PHENOMENA.

A. I have made measurements and performed investigations of the electrical and magnetic performance of power lines and power systems for over 25 years. My research has included measurements, modeling, and calculations of the electrical characteristics of alternating current ("AC") and direct current ("DC") power lines, including electric and magnetic fields, audible noise, radio noise, and air ions.

Q. IN THE COURSE OF YOUR INVESTIGATIONS HAVE YOU HAD THE OCCASION TO EVALUATE POTENTIAL SAFETY RISKS FROM TRANSMISSION LINES AND OTHER ELECTRICAL SOURCES?

A. Yes, many times. I have evaluated power lines for their compliance with the National Electric Safety Code ("NESC"), estimated the levels of currents and voltages coupled onto vehicles near power lines, determined the probable cause and origin of injuries to persons and animals from contact with electrical facilities such as 'stray voltage', and investigated electrical fires and their probable causes.

Q. HAVE YOU SERVED AS A TECHNICAL ADVISOR OR RESEARCHER TO GOVERNMENT AGENCIES?

A. Yes. I worked for the Vermont Department of Public Service performing tests and measurements on a proposed high voltage power line. I also worked for the U.S. Department of Energy, assisting the U.S. EMF Research and Policy Information Dissemination (RAPID) Program in the identification and evaluation of engineering issues related to EMF as part of its overall risk assessment program.

Q. HAVE YOU PUBLISHED ANY OF THE RESULTS OF YOUR RESEARCH IN ENGINEERING JOURNALS?

A. I have published or presented more than 35 papers on this and related subjects.

Q. ARE YOU A MEMBER OF ANY PROFESSIONAL ORGANIZATIONS?

A. Yes. I am a member of the IEEE Power Engineering Society, the American Association for the Advancement of Science, the Bioelectromagnetics Society, and Tau Beta Pi, a national engineering honor society.

Q. ARE YOUR EDUCATIONAL AND PROFESSIONAL EXPERIENCE SUMMARIZED ELSEWHERE?

A. Yes. Additional details of my educational and professional experience are summarized in my curriculum vitae, which is attached as TrAILCo Exhibit GBJ-1. *In addition, the publications and other documents referred to in my testimony* and used to support my conclusions are listed in TrAILCo Exhibit GBJ-2.

Q. HAVE YOU EVER APPEARED AS A WITNESS BEFORE REGULATORY AGENCIES?

A. Yes. I have testified in regulatory proceedings on behalf of public utility commissions and state siting boards as well as project applicants in various states.

Q. WILL THE USE OF VARIOUS TERMS IN YOUR TESTIMONY BE CONSISTENT WITH THE DEFINITIONS ASSIGNED TO THOSE TERMS IN THE TABLE OF NOMENCLATURE ATTACHED TO TrAILCo Witness Flitman's Testimony as TrAILCo Exhibit DEF-1?

A. Yes. In addition, I may define other specific terms in my direct testimony.

ELECTRIC AND MAGNETIC FIELDS – BACKGROUND

Q. WHAT IS EMF?

A. EMF refers to the electric and magnetic fields associated with the operation of AC power lines or devices supplied with AC electricity. These fields describe properties of a location or point in space and its electrical environment, including the forces that would be experienced by a charged body in that space by virtue of its charge or the movement of charges. The voltage, which is the 'pressure,' produces an electric field that moves the electricity through wires. The current produces a magnetic field, which is a measure of how much electricity is flowing. Thus, wherever you have electric current flowing (including through any type of wiring), you have both an electric and a magnetic field.

The standard unit for measuring the strength of an electric field is "volts per meter," (V/m). The unit in which magnetic field levels are measured is "milligauss," (mG). Electric and magnetic fields are characterized by the frequency at which their direction and magnitude oscillate each second. The fields produced by the use of electricity oscillate at a frequency of 60 cycles per second, or 60 Hertz (Hz).

Q. WHAT ARE TYPICAL SOURCES OF 60-HZ EMF?

A. Typical sources of these fields include power lines (both transmission and distribution lines), home and office appliances, tools, building wiring, and

currents flowing on water pipes. The importance of these sources to overall exposure varies considerably. For example, if a residence is very close to a transmission line, or even a distribution line (which runs near most everyone's residence), these sources could be the dominant, but not necessarily the only, source of magnetic fields in the home. Depending on the circumstances, other sources may be of equal or greater importance. For example, a random survey of 1,000 residences in the United States reported that currents flowing on water pipes and on other components of house grounding systems are twice as likely as outside power lines to be the source of the highest magnetic fields measured in homes (Zaffanella, 1993).

Q. ARE CELLULAR PHONES OR THEIR BASE STATION ANTENNAS SOURCES OF 60-HZ ELECTRIC AND MAGNETIC FIELDS?

A. No. Mobile phones do not operate at the power frequency, 60 Hz. They operate in the radiofrequency range, at about 800 million or 1,900 million Hz, which is 1,900 megahertz (MHz). Fields at these high frequencies have different physical characteristics from 60-Hz fields, which affect their interaction with conductive objects (including biological organisms), and therefore are studied separately with regard to potential health and biological effects.

Q. WHAT IS THE RELATIONSHIP BETWEEN EMF AND WHAT FARMERS REFER TO AS 'STRAY VOLTAGE'?

A. Stray voltage refers to a phenomenon that is primarily of concern in the wet environment of a dairy barn or feedlot. Stray voltage is not the same thing as EMF; it arises only when an animal makes contact with a metal object that is at a different potential from another contact point, i.e., the nearby ground or earth potential. This may occur when there is poor grounding or bonding of the metal object to the earth and the electrical ground. These power-quality issues typically arise due to issues with the customers' electrical equipment and local electrical wiring, not because of the operation of nearby transmission lines, such as the

proposed Trans-Allegheny Interstate Line Company ("TrAILCo") project. For example, faulty or improperly wired motorized appliances, portable electric heaters, and fluorescent lights can lead to stray voltage issues. The issue of stray voltage is not relevant to an assessment of the potential electrical effects of the proposed TrAIL project.

PROJECT EVALUATION

Q. WHAT IS YOUR ROLE IN THIS PROJECT?

A. TrAILCo requested that Exponent calculate the levels of EMF and other electrical parameters associated with the operation of the Trans-Allegheny Interstate Line ("TrAIL"). These calculations include fields from the 500-kV line and three proposed 138-kV lines that would connect to the TrAIL terminus at Prexy substation. The results of these calculations are summarized below, with the details included in TrAILCo Exhibit GHB-3 attached to this testimony.

Q. WHAT ELECTRICAL CHARACTERISTICS OF TRAIL DID YOU CALCULATE?

A. Magnetic fields, electric fields, audible noise and radio noise.

Q. HOW DID YOU CALCULATE THESE PHYSICAL CHARACTERISTICS ASSOCIATED WITH THE PROPOSED OPERATION OF TRAIL?

A. I used calculation algorithms developed by the U.S. Department of Energy, Bonneville Power Administration that have been validated and used by engineers and scientists for many years. The inputs to the model are line voltage, load flow, and the physical dimensions of the line (conductor diameter, spacing, and height). The field values were calculated at a reference height of one meter above ground. For modeling purposes, it was assumed that the maximum voltage of the circuit was 10% above the nominal 500-kV value and voltages of 138-kV circuits were 5% above their nominal values. TrAILCo provided information on the design and

routing of existing and proposed lines, as well as estimates of expected circuit loadings.

ELECTRIC AND MAGNETIC FIELDS – CALCULATIONS

Q. WHAT FACTORS AFFECT THE LEVEL OF ELECTRIC AND MAGNETIC FIELDS ASSOCIATED WITH A TRANSMISSION LINE?

A. Electric field levels depend primarily on the line's voltage; the higher the voltage on the line, the higher the electric field levels associated with that line. Little variation is expected with electric field levels from a power line because a line's voltage does not vary significantly. Conducting objects including fences, shrubbery, and buildings easily block electric fields. Magnetic-field levels depend primarily on the current, or load, flowing on the line; as electricity demand increases and the current on the line increases, the magnetic field levels associated with the line increase. The transmission of electric power at a higher voltage (e.g., at 500 kV) reduces the current flow on the line to a level below that required to transport the same amount of power over lower-voltage lines. The 500-kV portion of the TrAIL project is therefore a design that reduces magnetic-field levels. Both electric and magnetic field levels decrease rapidly with distance from a distribution or transmission line.

Q. FOR WHAT CONDITIONS DID YOU CALCULATE THE MAGNETIC FIELDS FROM THE TRAIL PROJECT?

A. The magnetic fields were calculated to predict the typical and maximum values that could be measured near the proposed line, 1.0 m (3.28 ft) above ground in accordance with IEEE Std. 0644-1994. Magnetic-field values are dependent on the orientation of current-carrying conductors and the amount of current they carry. I calculated field profiles for four sections of the proposed TrAIL right-of-way in Pennsylvania: (1) the 500-kV line, where it runs alone on the right-of-way; (2) the 500-kV line, where it runs parallel to a 138-kV line south of the Prexy

Substation; (3) the 138-kV corridor running west from Prexy Substation; (4) the 138-kV corridor running east from Prexy Substation. For all four cases, the magnetic field from the proposed transmission line was calculated for average loading (current flow) under normal operating conditions. The magnetic field was also calculated for peak load flow conditions that might occur for a limited number of hours each year under normal system operating conditions. The calculations assumed a conservative minimum height of 34 feet above the ground for the overhead conductors of the proposed 500-kV line, and a ground clearance of 22 feet for the 138-kV lines. Such conductor heights describe the minimum conductor clearance at mid-span, between supporting structures at peak loading.

Q. WHAT ARE THE CALCULATED MAGNETIC-FIELD VALUES?

A. The magnetic field is highest directly under the conductors, and decreases with distance from the proposed line. At the edge of the right-of-way near the proposed 500-kV circuit, the field levels are below 16 mG under average loading conditions. These values would be common outside the rights-of-way of lower-voltage transmission lines in the state. For 138-kV corridors around Prexy substation, the magnetic field at the edge of the right-of-way is below 8.7 mG for average-load conditions. Higher magnetic field profiles are shown for peak loading conditions that would occur for limited times during the year.

Q. FOR WHAT CONDITIONS DID YOU CALCULATE THE ELECTRIC FIELDS FROM THE TRAIL PROJECT?

A. Electric fields were calculated for the same conductor positions and heights as the magnetic fields. Field values at 1.0 m (3.28 ft) above ground were once again considered, in accordance with IEEE Std. 0644-1994. The voltage of the proposed 500-kV line was set at a 10% overvoltage, and the voltage of proposed 138-kV lines was set at 5% overvoltage.

Q. WHAT ARE THE CALCULATED ELECTRIC-FIELD VALUES?

A. The electric field is highest directly under the 500-kV conductors, and decreases with distance from the proposed line. At the edge of the right-of-way and beyond, the field levels are below 1.5 kV/m. These values can be found on the rights-of-way of lower-voltage transmission lines in the state. For 138-kV corridors around Prexy substation, the electric field at the edge of the right-of-way is below 0.2 kV/m.

Q. WHAT ABOUT EFFECTS OF THE LINE ON PEOPLE WHO HAVE PACEMAKERS?

A. Electric and magnetic fields from a variety of sources, including some industrial equipment, automobile ignition wiring, anti-theft devices in stores, MRI machines, slot machines, cell phones, and certain medical procedures (e.g., radiation therapy, electrocautery and defibrillation), have been reported to affect the operation of implanted cardiac pacemakers and defibrillators. High-voltage transmission lines have not been reported to cause interference with pacemaker function, but in theory pacemaker interference from the electric fields associated with transmission lines might be possible depending upon the type of pacemaker and the person's orientation under the conductors. The manufacturers of pacemakers have designed their devices in various ways to minimize potential interference from external sources, including power line EMF. For example, the increasingly prevalent bipolar pacemaker models are virtually immune to interference. Medtronic, a leading producer of pacemakers, notifies users of its products to limit their exposure to power frequency fields to below 6 kV/m and 1,000 mG to protect against possible electrical interference (Medtronic, 2006) Before walking under the conductors on the right-of-way (a vehicle shields occupants from the electric field), those with pacemakers/defibrillators should check with their physician if they have concerns.

CORONA EFFECTS

Q. WHAT ARE CORONA EFFECTS?

A. Corona phenomena occur when the 60 Hz electric fields at the surface of power-line conductors are large enough to cause a local breakdown in the insulating properties of the air. If there is sufficient corona activity, audible noise and radio/television interference can be noticeable within a few hundred feet of the transmission line, and small amounts of ozone and nitrous oxide can be released. These effects are most pronounced directly underneath the line conductors, and decrease with distance from the transmission line.

Q. WHERE AND WHEN ARE CORONA PHENOMENONA MORE LIKELY TO OCCUR?

A. Corona activity depends on a number of factors: altitude, line voltage, conductor size, conductor geometry, and weather conditions. The breakdown strength of air is 30 kV/cm at sea level and decreases with increasing altitude. For a particular altitude, conductor size and line voltage are taken into consideration when designing a transmission line so that the electric fields at the conductor surface do not exceed the breakdown potential of air. However, for lines with a voltage greater or equal to 345-kV, any irregularities on the conductor surface (e.g., nicks, water droplets, or debris) may create points where the electric field is intensified sufficiently to produce corona. In foul weather, raindrops or snowflakes accumulating on the conductor surface will also act as points for corona inception. Corona activity is, therefore, most likely near transmission lines at higher altitudes, and is most pronounced during foul weather.

Q. WHAT ABOUT AUDIBLE NOISE?

A. The corona caused by large electric fields at the surface of a transmission line conductor is accompanied by an audible snapping sound. If there is sufficient corona activity on a high voltage line, many small snaps from corona sources

along a conductor may be sufficient, in combination, to produce discernable audible noise or crackle at the edge of the right-of-way. At lower system voltages (voltages below 230-kV), audible noise from the transmission-line conductors are typically not formally evaluated because of the low levels of corona activity and correspondingly low occurrence of corona effects. For lines at higher voltages (345-kV and above) with higher conductor-surface gradients, corona activity is more likely and audible noise more frequent, particularly in foul weather, and is therefore taken into account in the design of the transmission line.

Q. HOW IS AUDIBLE NOISE MEASURED?

A. Sound intensity is measured in decibels ("dB") referenced to 20 micropascals, which is approximately the pressure threshold of human hearing at 1 kilohertz ("kHz"). The range of audible frequencies for the human ear is from approximately 20 Hz to 20 kHz, with peak sensitivity near 1 kHz. The change in sensitivity of the human ear with frequency is reflected in measurements by weighting the contribution of sound at different frequencies. The weighting of sound over the frequency spectrum to account for the sensitivity of the human ear is called the *A-weighted sound level*. When the A-weighting scale is applied to a sound-pressure measurement, the level is often reported as dBA, referenced to the audible pressure threshold.

Q. WHAT ARE TYPICAL AUDIBLE NOISE LEVELS?

A. The sound intensity of typical human speech is approximately 60 dBA, and background levels of noise in rural and urban environments are about 30 to 40 dBA. Specific identifiable noises such as birdcalls, neighborhood activity, and traffic can produce audible noise levels of 50 to 60 dBA or greater.

Q. FOR WHAT CONDITIONS WAS AUDIBLE NOISE FROM THE TRAIL PROJECT CALCULATED?

A. The levels of audible noise for the proposed line were calculated at a height of 5 ft from the ground for fair-weather and foul-weather conditions. The lowest anticipated conductor heights were considered to place an upper bound on the predicted audible noise level.

Q. WHAT AUDIBLE-NOISE LEVELS DID YOU CALCULATE?

A. The calculated A-weighted audible noise level at the edge of the 500-kV right-of-way is less than 42 dBA in fair-weather conditions and less than 52 dBA in foul-weather conditions. These audible noise levels are below 55 dBA, the annual average level outdoor target value published by the Environmental Protection Agency (EPA, 1974). The triple-conductor bundles of the 500-kV line will reduce the audible-noise level below that of a less expensive design with fewer conductors. Audible noise below 26 dBA was calculated in the vicinity of the 138-kV lines.

Q. WHAT IS RADIO NOISE?

A. Impulsive corona currents cause wide-band electric and magnetic "noise" fields. This radio noise spans the frequency spectrum from below 100 kHz to approximately 1,000 megahertz MHz. Foul weather and high altitude increase radio noise levels. This noise from transmission lines can produce interference to an amplitude-modulated ("AM") signal such as a commercial AM radio audio signal (i.e., radio noise) or the video portion of a TV station (i.e., TV noise). Frequency modulated ("FM") radio stations and the audio portion of a TV station signal (which is also frequency modulated) are generally not affected by noise from a transmission line.

Q. HOW IS RADIO NOISE MEASURED?

A. Radio noise is measured in units of dB based on its field strength referenced to a signal level of 1 microvolt/meter ("ˇ V/m") (IEEE Standard 430-1986).

Q. UNDER WHAT CONDITIONS WAS RADIO NOISE CALCULATED FOR THIS PROJECT?

A. The levels of radio noise for the proposed line were calculated at 1 MHz and a height of 3 ft from the ground for fair-weather and foul-weather conditions. The lowest anticipated conductor heights were considered to place an upper bound on the predicted radio-noise levels.

Q. WHAT ARE THE CALCULATED RADIO-NOISE LEVELS?

A. At the edge of the 500-kV right-of-way, radio noise is less than 37 dBˇ V/m in fair-weather conditions and less than 58 dBˇ V/m in foul-weather conditions. The triple-conductor bundles of the 500-kV line reduce the radio-noise level below that of a less expensive design with fewer conductors. Along the 138-kV corridors running east and west from Prexy substation, radio noise is below 36 dBˇ V/m at the edge of the right-of-way in foul-weather conditions.

Q. ARE THERE LIMITS FOR RADIO NOISE?

A. TrAILCo will comply with good design practices to minimize radio noise (IEEE, 1971) and with applicable Federal Communication Rules and Regulations, Part 15, Section 15.25. Even though there are no state limits in Pennsylvania on radio noise, the proposed line has been designed in a manner consistent with the IEEE Radio Noise Design Guide for High-Voltage Transmission Lines. Fair-weather radio-interference levels at a 100-foot lateral distance from the outside conductor of the proposed 500-kV line are less than the IEEE level of 40 dBˇ V/m.

Q. WHAT RELEVANT ENGINEERING STANDARDS WILL TRAILCO MEET WITH REGARD TO HEALTH AND SAFETY RISKS?

A. The proposed line is designed to meet the safety requirements of the National Electric Safety Code (NESC, 2007).

Q. DOES COMPLIANCE WITH THE NATIONAL ELECTRIC SAFETY CODE PROTECT THE PUBLIC AGAINST HARMFUL SHOCKS?

A. Compliance with the NESC protects the public against harmful shocks from vehicles, equipment, and buildings near the high-voltage power line. Shocks and currents may still be perceived, but they will be less than the current limit set in the NESC for safety concerns.

Q. DOES THIS CONCLUDE YOUR TESTIMONY?

A. Yes. However, I reserve the right to file such additional testimony as may be necessary or appropriate.

Gary B. Johnson, Ph.D.
Senior Managing Engineer

Professional Profile

Dr. Gary Johnson is a Senior Managing Engineer in Exponent's Electrical and Semiconductors practice. He specializes in issues pertaining to electrical engineering particularly as they relate to the electrical environment of power systems. Dr. Johnson has extensive experience with the electric and magnetic fields of transmission and distribution systems as well as the audible noise, radio noise, and ozone that may be produced by high voltage power systems. His work has involved the measurement, modeling, and mitigation of the electrical environment of transmission lines, transformer vaults, and underground cables. His power system experience includes issues dealing with lightning, electrical transients, ground currents, and stray voltage.

Dr. Johnson has testified on the corona and field effects of DC and AC transmission lines and been a lecturer at the EPRI Transmission Line Design Seminars. He has given numerous presentations and led several workshops on power line design and the electrical environment. As part of his investigations of the electrical environment, Dr. Johnson developed an instrumentation system to measure the charge-size distribution of aerosols.

Dr. Johnson has also performed engineering studies related to power system fields, audible noise, radio noise, induced currents, and ground currents for clients including state and federal agencies, utilities, and site developers. He was a principal investigator in the EPRI research on magnetic field sources and methods of shielding.

Other areas of expertise include investigations of electrically-related fires in devices ranging from consumer appliances to industrial equipment, electrical injury, electrical faults, electronic component failure, code compliance, and facility wiring systems. Prior to joining Exponent, Dr. Johnson was the President of Power Research Engineering, where he worked on engineering issues related to the electrical environment and power quality.

Credentials and Professional Honors

Ph.D., Electrical Engineering, University of Illinois, 1979
M.S., Physics, University of Illinois, 1976
B.S., Engineering Physics (Highest Honors), University of Illinois, 1974
Tau Beta Pi; Phi Kappa Phi
Institute of Electrical and Electronic Engineers, Corona and Field Effects Subcommittee; American Association for the Advancement of Science; American Physical Society; BioElectroMagnetics Society

Publications

"Design Considerations For Consumer Products Utilizing High Voltage," Presentation and Conference Proceedings, 2006 IEEE Symposium on Product Safety & Compliance Engineering, IEEE Product Safety Engineering Society, (PSES), Irvine, CA, October 23–24, 2006 (with J. Martens and P. So).

"Charging and Transport of Aerosols near AC Transmission Lines: A Literature Review," EPRI Report 1008148, Palo Alto, CA, December 2003 (with T.D. Bracken and W. Bailey).

"Measurement Instrumentation for Transient Magnetic Fields and Currents," Proceedings, 2001 IEEE Electromagnetic Compatibility Symposium, Montreal, Canada, August 2001 (with J.L. Guttman, J. Niple, and R. Kavet).

"Transient Magnetic Fields and Currents in Residences," Proceedings, 2001 IEEE Electromagnetic Compatibility Symposium, Montreal, Canada, August 2001 (with J.L. Guttman and R. Kavet).

"Determinants of Power-Frequency Magnetic Fields in Residences Located Away from Overhead Power Lines," Bioelectromagnetics, Vol. 20, No. 5, May 1999, pp 306–318, (with R. Kavet, R.M. Ulrich, W.T. Kaune, and T. Powers).

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"Low Field Transmission Lines: Design Concepts," Proceedings, 1995 CIGRE Study Committee 36 Colloquium, Foz do Aquacu, Brazil, May 1995 (with B.A. Clairmont).

"Study on the Human Perception of Hybrid Fields," Proceedings, 1995 CIGRE Study Committee 36 Colloquium, Foz do Aquacu, Brazil, May 1995 (with B.A. Clairmont and S. Zelingher).

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"Residential Field Sources: EPRI EMF Survey," Proceedings, Pennsylvania Electric Association Transmission and Distribution Meeting, Metamoras, Pennsylvania, May 12, 1994.

"EPRI Magnetic Field Technical Information Center," Proceedings, American Power Conference, Chicago, Illinois, April 26, 1994 (with R.J. Lordan).

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"Magnetic Field Management for Transmission Lines," Proceedings, 1994 Missouri Valley Electric Association Engineering Conference, Kansas City, MO, March 23, 1994 (with R. Lordan, B. Clairmont, K. King, and V. Rashkes).

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"Survey of Residential Magnetic Field Sources: Interim Report," Proceedings, 1993 American Power Conference, Chicago, IL, April 1993, pp. 1669–1673 (with J.H. Dunlap and L.E. Zaffanella).

"Measurements of Magnetic Field Sources in Schools," Proceedings, 1992 American Power Conference, Chicago, IL, April 1992.

"Transmission Line Magnetic Fields: Measurements and Calculations," Proceedings, 1992 American Power Conference, Chicago, IL, April 1992 (with B. Clairmont and J. Dunlap).

"Magnetic Field Sources in Nonresidential Settings" Proceedings, 1991 EPRI Science and Communication Seminar, San Jose, CA, October 1991.

"Magnetic Field Management: Residential Low-Voltage Grounding," Proceedings, 1991 EPRI Science and Communication Seminar, San Jose, CA, October 1991.

"A Comparison of International Grounding Practices and Associated Magnetic Fields," Proceedings, 1991 IEEE T&D Conference, Dallas, TX, September 1991 and, IEEE Transaction on Power Delivery, Vol. 7, pp. 934–939, April 1992 (with G.B. Rauch, P. Johnson, A. Stamm, S. Tomita, and J. Swanson).

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"The Effect of HVAC – HVDC Line Separation in a Hybrid Corridor," IEEE Transactions on Power Delivery, PWRD-4, No. 2, pp. 1338–1350, April 1989 (with B.A. Clairmont, L.E. Zaffanella, and S. Zelingher).

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"Measurement of Space Charge Density Using a Faraday Cage," Proceedings, 6th International Symposium on High Voltage Engineering, Paper 42.32, New Orleans, LA, August 1989.

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"Electric Field and Ion Density in Proximity of HVDC Transmission Lines: Measurements and Calculations," CIGRE Study Committee Montreal Colloquium, Montreal, Canada, June 1987.

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"Techniques for Measurements of the Electrical Environment Created by HVDC Transmission Lines," Proceedings, 4th International Symposium on High Voltage Engineering, Paper 13.05, Athens, Greece, September 1983 (with L.E. Zaffanella).

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Workshops/Seminars

"Method for Measuring Charge on Aerosol Particles Near AC Transmission Lines," Joint Meeting of the Biolectromagnetics Society and the European BioElectromagnetics Association, Dublin Ireland, June 2005 (with T.D. Bracken and W.H. Bailey).

"Proposed IEEE Standard – 1556: Public Impacts," Panel Session: Electric and Magnetic Field Exposure Standards for the Public and Workers: 0 – 3 kHz, IEEE Power Engineering Society Summer Meeting, Vancouver, Canada, 2001.

"Power System Magnetic Fields," GPU Workshop, EPRI Power Delivery Center-Lenox, MA 1997.

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"Measurement of Residential Magnetic Fields," Yankee Conference, Massachusetts Environmental Health Association, Westborough, MA, 1995.

"Residential Sources and Exposure," EMF Health Research: State of the Science, Harvard School of Public Health, Boston, MA, 1995

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"End Use Magnetic Field R&D Workshop," EPRI Workshop, Raleigh, NC, 1992.

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"Magnetic Field Considerations: Low Voltage Grounding," EPRI Workshop, Colorado Springs, CO, 1991.

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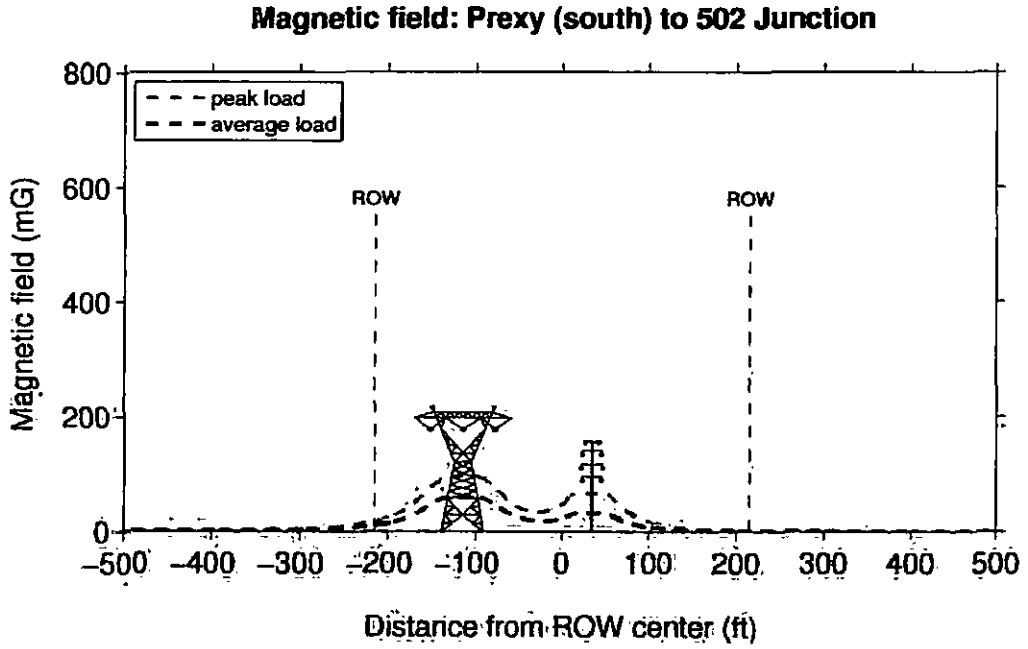

Figure 1. Peak and average load magnetic field profiles for TrAIL (left structure) and 138-kV line (right structure) between Prexy substation and 502 Junction. View looking south.

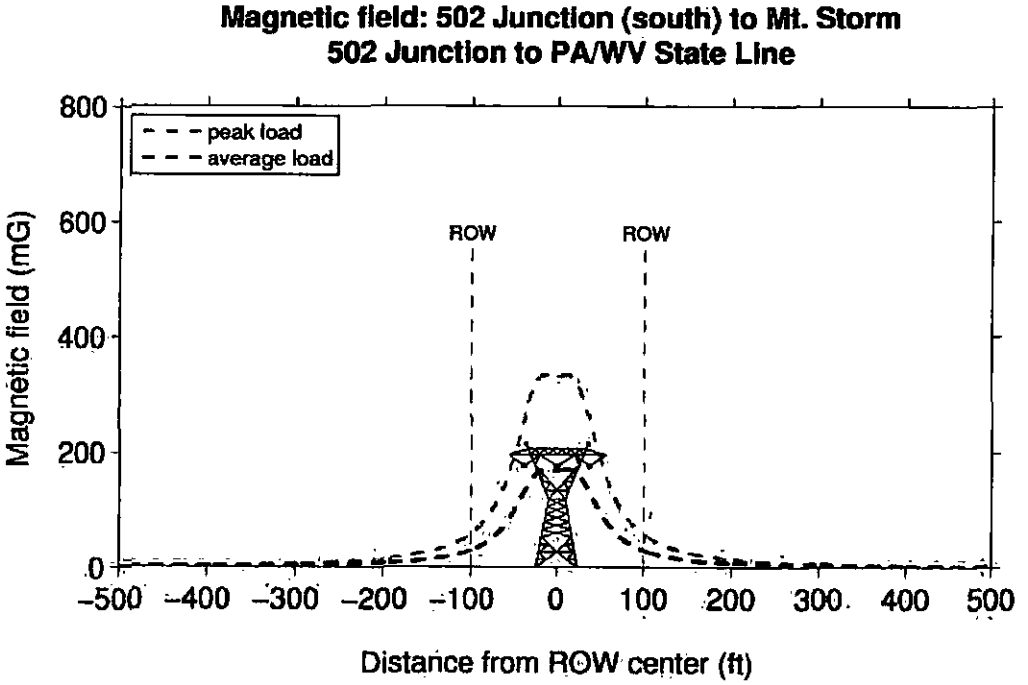

Figure 2. Peak and average load magnetic field profiles for TrAIL between 502 Junction and the PA/WV state line. View looking south.

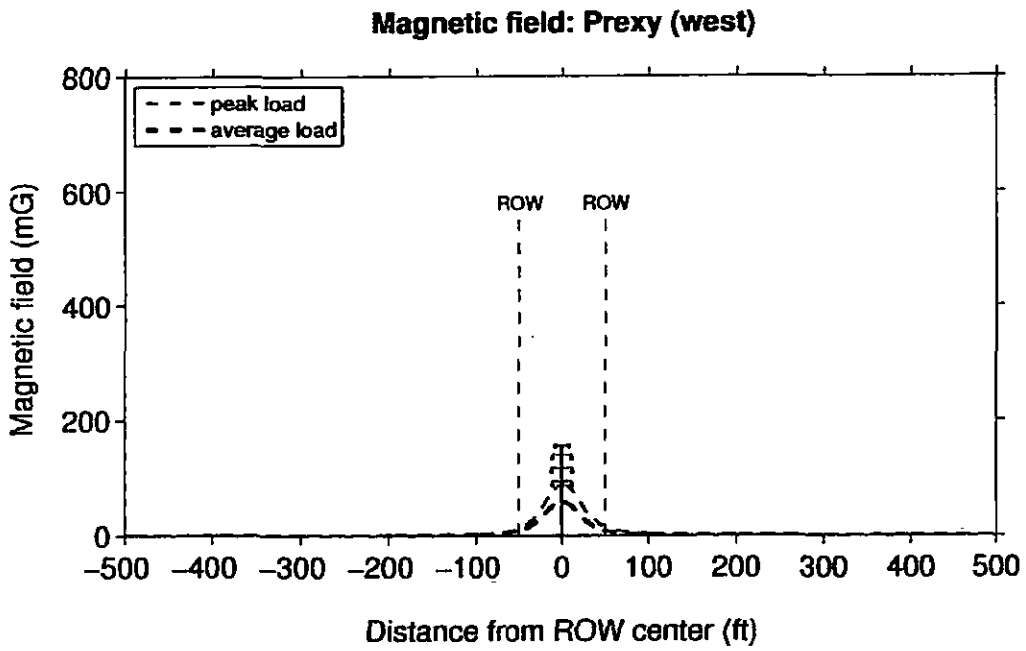

Figure 3. Magnetic field profile for 138-kV line running west from Prexy substation. View looking west.

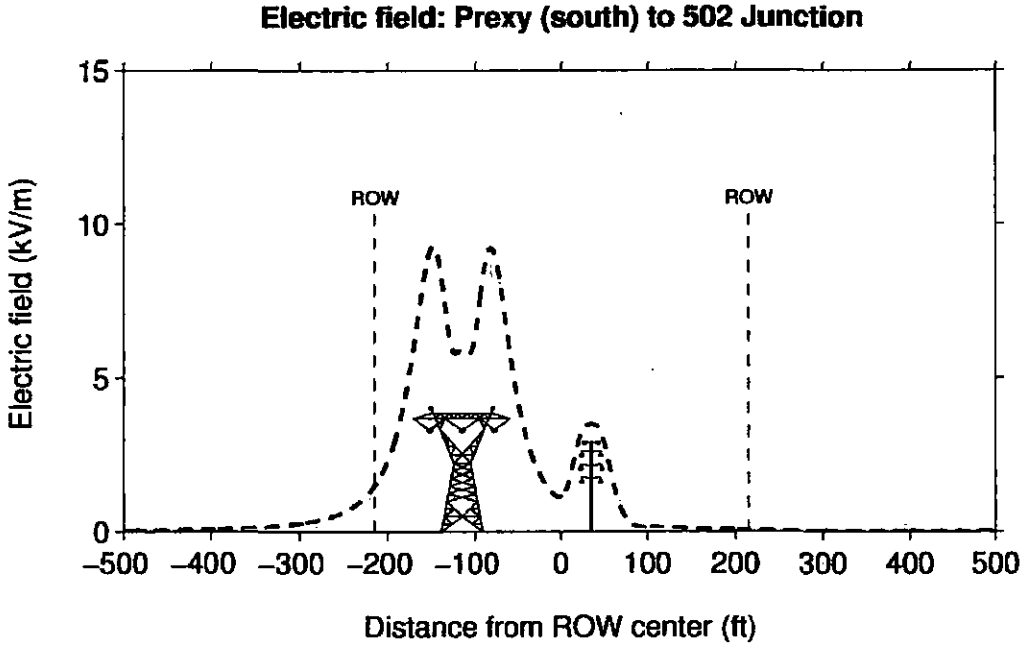

Figure 4. Electric field profile for TrAIL (left structure) and 138-kV line (right structure) between Prexy substation and 502 Junction. View looking south.

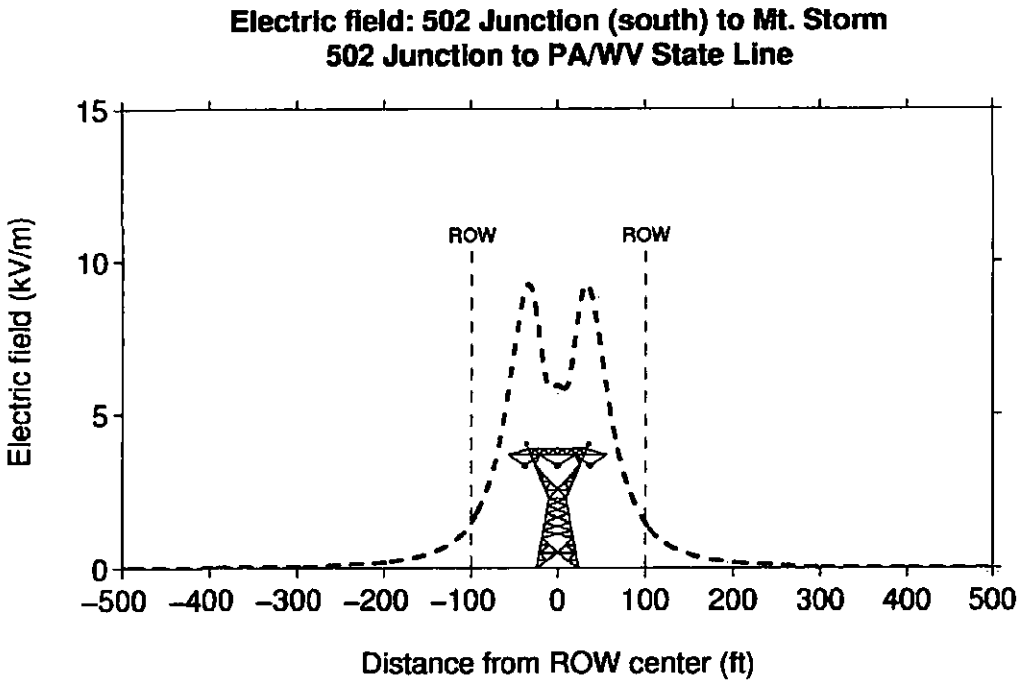

Figure 5. Electric field profile for TrAIL between 502 Junction and the PA/WV state line. View looking south.

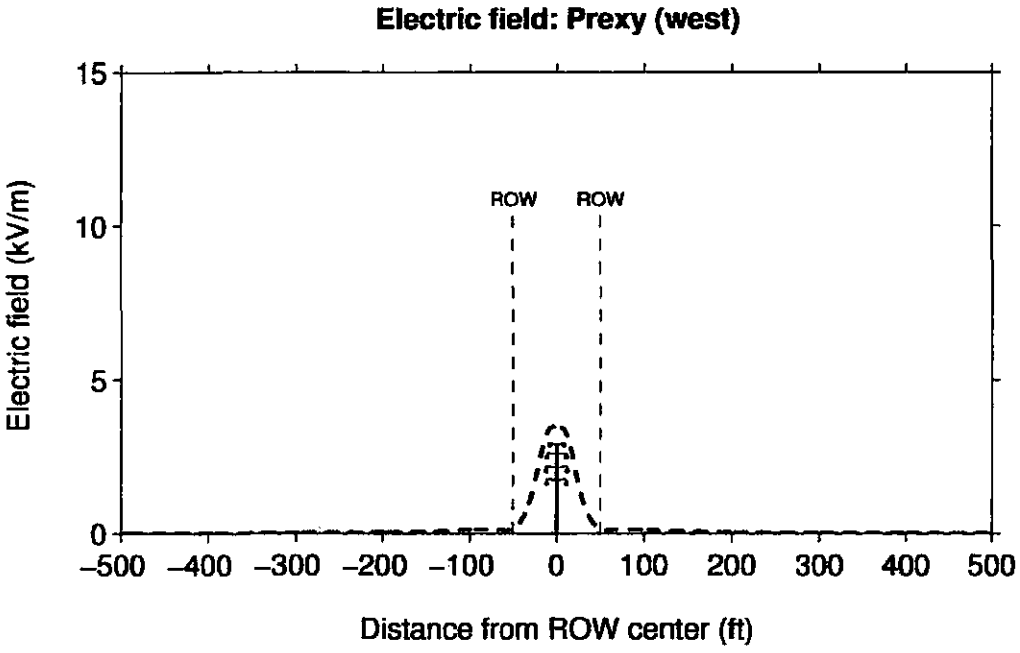

Figure 6. Electric field profile for 138-kV line running west from Prexy substation. View looking west.

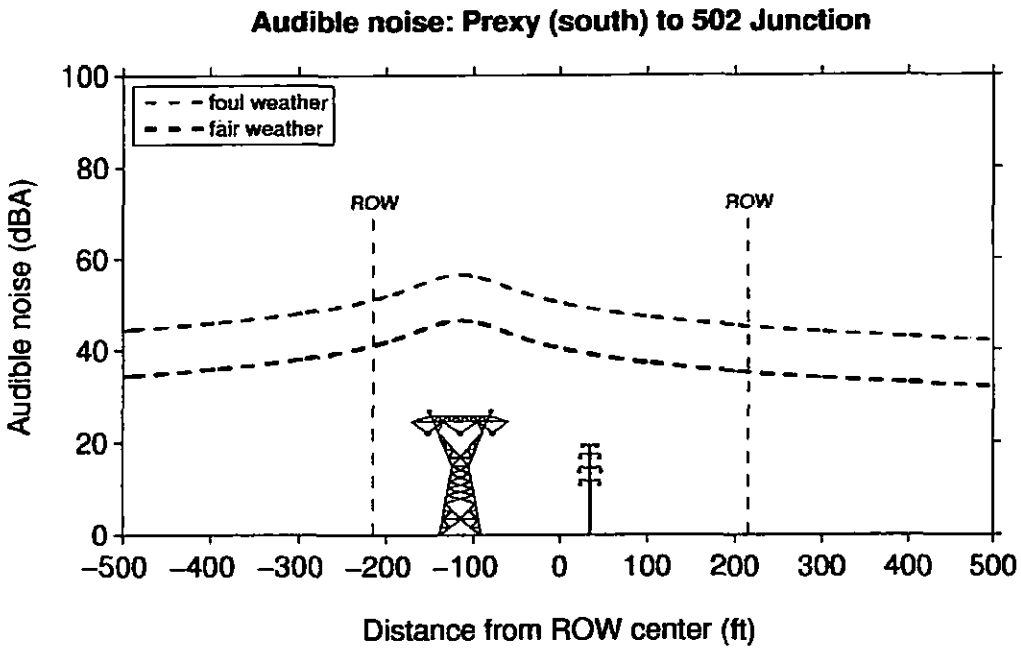

Figure 7. Foul weather/fair weather audible noise profiles for TrAIL (left structure) and 138-kV line between Prexy substation and 502 Junction. View looking south.

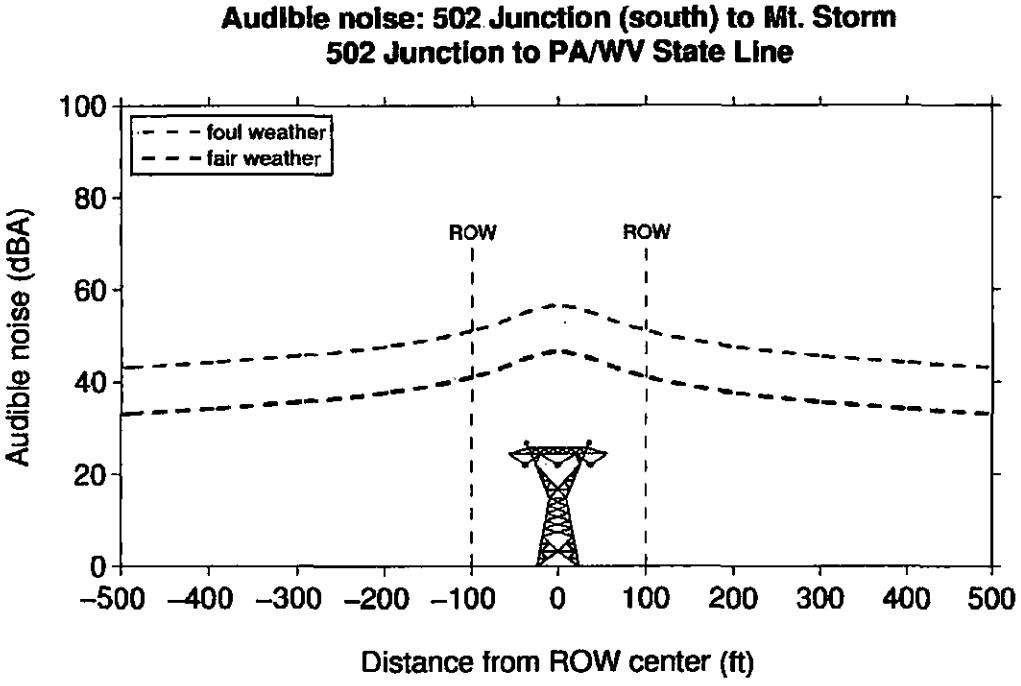

Figure 8. Foul weather/fair weather audible noise profiles for TrAIL between 502 Junction and the PA/WV state line. View looking south.

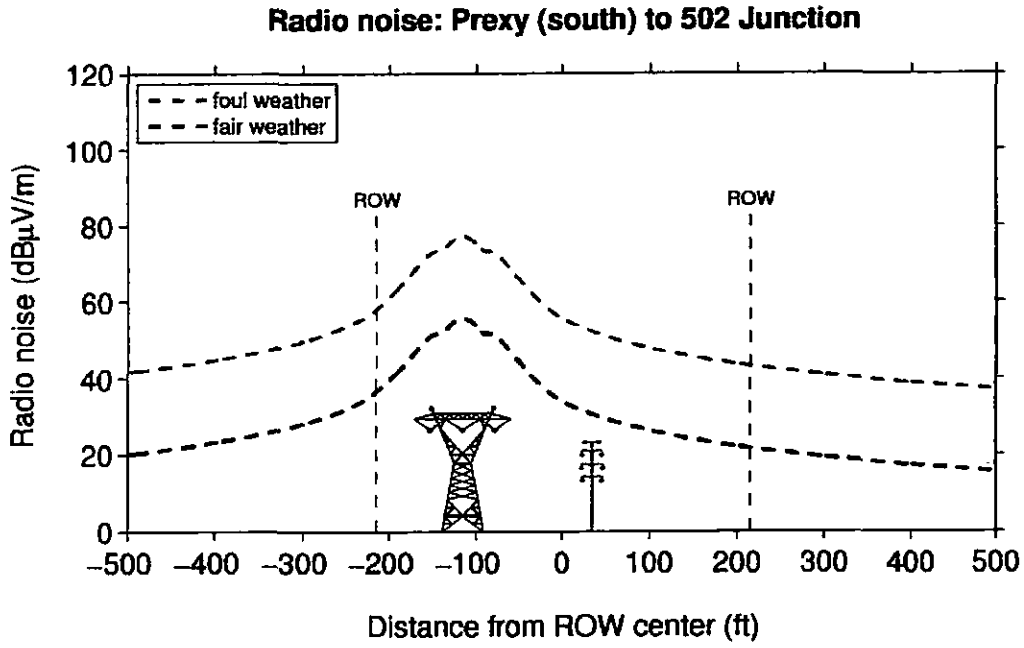

Figure 9. Foul weather/fair weather radio noise profiles for TrAIL (left structure) and 138-kV line between Prexy substation and 502 Junction. View looking south.

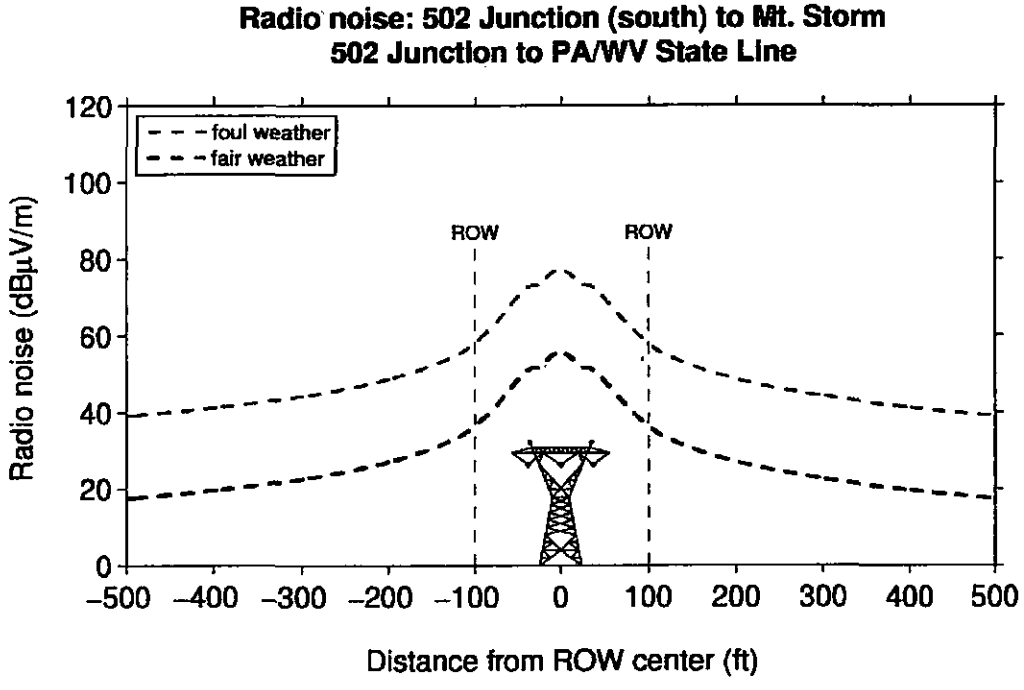

Figure 10. Foul weather/fair weather radio noise profiles for TrAIL between 502 Junction and the PA/WV state line. View looking south.

TrAILCo Rebuttal Statement No. 15
Witness: Jay Williams

4/1/08
Pbg JK

BEFORE THE
PENNSYLVANIA PUBLIC UTILITY COMMISSION

IN RE: APPLICATION OF TRANS-ALLEGHENY INTERSTATE LINE COMPANY FOR (I) A CERTIFICATE OF PUBLIC CONVENIENCE TO OFFER, RENDER, FURNISH AND/OR SUPPLY TRANSMISSION SERVICE IN THE COMMONWEALTH OF PENNSYLVANIA; (II) AUTHORIZATION AND CERTIFICATION TO LOCATE, CONSTRUCT, OPERATE AND MAINTAIN CERTAIN HIGH VOLTAGE ELECTRIC TRANSMISSION LINES AND RELATED ELECTRIC SUBSTATION FACILITIES; (III) AUTHORITY TO EXERCISE THE POWER OF EMINENT DOMAIN FOR THE CONSTRUCTION AND INSTALLATION OF AERIAL ELECTRIC TRANSMISSION FACILITIES ALONG THE PROPOSED TRANSMISSION LINE ROUTES IN PENNSYLVANIA; (IV) APPROVAL OF AN EXEMPTION FROM MUNICIPAL ZONING REGULATION WITH RESPECT TO THE CONSTRUCTION OF BUILDINGS; AND (V) APPROVAL OF CERTAIN RELATED AFFILIATED INTEREST ARRANGEMENTS	:	Docket Nos. A-110172 A-110172F0002 A-110172F0003 A-110172F0004 G-000721229

REBUTTAL TESTIMONY OF JAY WILLIAMS

Re: Feasibility of Placing TrAIL Underground

December 10, 2007

REBUTTAL TESTIMONY OF JAY WILLIAMS

Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.

A. My name is Jay Williams and my business address is 28 Lundy Lane, Ballston Lake, New York 12019.

Q. BY WHOM ARE YOU EMPLOYED AND IN WHAT CAPACITY?

A. I am employed by and a principal engineer with Power Delivery Consultants, Inc. ("PDC"). PDC provides engineering and consulting services to electric utilities, research organizations, merchant power producers, and manufacturers. Our practice areas include overhead line and underground cable design, power transformer ratings, and transmission and distribution-related engineering support for circuit uprates, operating and maintenance, failure investigation, and training.

Q. HAVE YOU PREVIOUSLY SUBMITTED DIRECT TESTIMONY IN THIS PROCEEDING ON BEHALF OF THE TRANS-ALLEGHENY INTERSTATE LINE COMPANY ("TrAILCo")?

A. No, I have not.

Q. PLEASE DESCRIBE YOUR EDUCATIONAL BACKGROUND AND PROFESSIONAL EXPERIENCE.

A. I earned a Bachelor of Science degree in engineering from Brown University and an MBA from New York University. I worked as a cable engineer at Consolidated Edison Company of New York, Inc. ("Con Edison") from 1965

until 1973, and was in charge of the transmission cable group when Con Edison was installing major amounts of 345-kV cable. I worked at Power Technologies, Inc. from 1973 until 1992 and was in charge of the cable group when I left in 1992 to form PDC with another cable specialist. At PDC, I head a group of engineering professionals, including five engineers whose entire collective workload is spent on transmission cable systems. I have developed and present several courses each year on underground power transmission, and have written more than fifty technical papers, articles, and book sections on underground transmission cables. I am a Fellow of the Institute of Electrical and Electronics Engineers, Inc. ("IEEE") and a registered Professional Engineer in New York and Ohio. My resume is attached to this testimony as TrAILCo Rebuttal Exhibit JW-1.

Q. HAVE YOU PREVIOUSLY APPEARED AS A WITNESS BEFORE ANY REGULATORY AGENCIES?

A. Yes. I testified as an expert witness on behalf of the Vermont Department of Public Service for the cable crossing at Grand Isle as part of the PV-20 line application and regarding an application by the Vermont Electric Power Company, Inc. and Green Mountain Power Company for authority to construct the Northwest Vermont Reliability Project. I have also testified as a cable expert for several utilities evaluating underground transmission lines. I am currently assisting Northeast Utilities as their expert witness on cable systems for major 345

kilovolt ("kV") installations as part of the Southwest Connecticut Reliability Project.

Q. WILL THE USE OF VARIOUS TERMS IN YOUR REBUTTAL TESTIMONY BE CONSISTENT WITH THE DEFINITIONS ASSIGNED TO THOSE TERMS IN THE TABLE OF NOMENCLATURE ATTACHED TO TrAILCo WITNESS FLITMAN'S DIRECT TESTIMONY AS TrAILCo EXHIBIT DEF-1?

A. Yes. In addition, I may define other specific terms in my rebuttal testimony.

Q. PLEASE DESCRIBE THE TOPIC AND PURPOSE FOR YOUR REBUTTAL TESTIMONY.

A. My rebuttal testimony will address and respond to the various suggestions or comments that were offered during the public input hearings in Pennsylvania regarding whether the proposed TrAIL project or any portion thereof can be placed underground.

Q. IS IT POSSIBLE TO PLACE ALL OR ANY PORTION OF TRAIL UNDERGROUND?

A. I cannot state that it would be impossible to place portions of the TrAIL project underground. However, there are numerous impediments to placing 500 kV cables underground and the disadvantages of such an installation, for all practical purposes, make the placement of any portion of the TrAIL project underground infeasible for the transmission grid reliability purposes intended for TrAIL.

Q. ARE YOU AWARE OF ANY CIRCUMSTANCES IN THE UNITED STATES OR ELSEWHERE IN WHICH 500 KV CABLES HAVE BEEN PLACED UNDERGROUND?

A. There are no current examples of the installation of 500 kV cables of any appreciable length in the United States and certainly none at the length of the route proposed for TrAIL. In fact, the only instance of cables of this voltage being placed underground of which I am aware in this country is a short length less than two miles long of 500 kV underground cables that were installed within the property of Grand Coulee Dam in the 1970s, from the generator transformers to a switchyard. Following a catastrophic failure and fire soon after installation, the replacement cables have operated satisfactorily. During that same period, a 500 kV gas-insulated line a few hundred feet long was installed on the West Coast, but it has since been abandoned. Outside of the United States, 500 kV cables have been installed underground on a limited basis in utility tunnels or under bridges for lengths of less than twenty five miles in Japan and Canada. In addition, 500 kV submarine cables of lengths limited to about 25 miles or less have been installed between Vancouver, British Columbia and Vancouver Island.

Q. WHAT ARE SOME OF THE DISADVANTAGES OF PLACING 500 KV CABLES IN A PROJECT SUCH AS TRAIL UNDERGROUND?

A. Beginning with construction-related disadvantages, placing electric cables underground requires a massive excavation of the entire length of the segments of right-of-way planned for underground installation, as compared to excavating

material only at tower locations for an overhead line. To accommodate a 500 kV project with the power transfer capacity required of TrAIL, such an excavation would be particularly large in width. For example, as I explain below in my rebuttal testimony, several sets of cables would be required to provide the power transfer capability of the three-phase overhead circuit planned for TrAIL. These cables would be spliced together in fifteen hundred foot sections and would be placed into individual plastic conduits. Each set of cables could require cement vaults approximately every fifteen hundred feet, at the points of splicing, that would be approximately 35 feet long by 8 feet in width and height. The extensive excavation required to place cables underground could also severely affect streams, wetlands, and other environmentally sensitive areas along a proposed right-of-way. Finally, as compared to a relatively limited number of access roads that would be required for subsequent maintenance and repair operations along an overhead right-of-way, permanent roads would be required along the entire lengths of any underground segments for the line.

Q. ARE THERE DISADVANTAGES TO PLACING 500 KV CABLES UNDERGROUND FROM AN ELECTRICAL AND OPERATIONAL PERSPECTIVE?

A. Yes, there are several. Because they cannot dissipate heat as effectively as conductors in an above-ground open air configuration, an underground cable is able to carry far less power than a similarly-sized overhead line. Consequently, perhaps as many as four to six sets of 500 kV cables (twelve to eighteen

individual cables) could be required to provide the power transfer capacity that will be required for TrAIL. As I stated above, these multiple sets of cables, and required conduit and vaults, would be a significant contributing factor to the larger excavation that would be required along the selected right-of-way segment. Additionally, the electrical capacitance for underground transmission lines is significantly higher as compared to overhead lines.

Q. WOULD YOU BRIEFLY EXPLAIN CAPACITANCE AND WHY IT IS SIGNIFICANT TO THE ISSUE OF UNDERGROUND TRANSMISSION LINES?

A. Yes. Cable capacitance is an inherent property of all cable systems, and results from the placing of insulation material between two cylindrical electrodes – the internal cable conductor and outer cable shielding. Capacitance may cause a significant increase in steady-state voltages throughout a power system as the charging current – the amount of current required to charge and discharge the cable capacitance at a frequency of 60 times per second – flows through inductive impedances such as transformers. Even without the presence of these transformers, a phenomenon known as the "Ferranti effect" causes voltage increases when the cable charging current flows through the power system itself. The flow of charging current generates heat, reducing the amount of through-current the cable is capable of carrying. This means that the charging current required for 500 kV underground cables would consume the entire power transfer capabilities of the cables beyond segment lengths of sixty miles or less, depending

upon the type of cable. Finally, the cable capacitance challenges I just described could also cause unacceptably high transient over-voltage conditions on substation equipment during switching operations.

Q. DO UNDERGROUND TRANSMISSION LINES PRESENT ANY RELIABILITY DISADVANTAGES?

A. Yes. A significant example is simply the additional time required for unforeseen events and repairs to an underground facility as compared to overhead lines. A problem on a 500 kV line placed underground could require as long as a month or more to locate and repair; such emergencies on an overhead facility can be located and repaired much more quickly. There is no experience with 500-kV polyethylene-insulated cables in the duct-and-manhole system used by U.S. utilities, and no experience with 500-kV fluid-filled cables whatsoever. Researchers have expressed concern that there could be a common failure mode such as thermo-mechanical movement that could result in multiple outages on these systems. Prolonged outages of the longer durations that could be experienced with an underground facility would be counterproductive to PJM's designation of the TrAIL project as a transmission expansion necessary to maintain grid reliability.

Q. ARE THERE CABLES AVAILABLE TO THE ELECTRIC INDUSTRY THAT COULD BE PLACED UNDERGROUND AT THE VOLTAGE LEVEL AND LENGTH PLANNED FOR TRAIL?

A. Three cable types could be considered; again, however, none have been installed at 500 kV beyond the limited lengths of the installations I described above. The three possible cable types would be (i) high-pressure fluid-filled ("HPFF") cables; (ii) extruded dielectric, cross-linked polyethylene ("XLPE") cables; and, (iii) self-contained fluid-filled ("SCFF") cables. For installation at 500 kV, however, the HPFF or the XLPE cables would be the most likely candidates. Both types, however, would present significant construction and operational issues that would be disadvantageous. SCFF cables are seldom used for installations on land; they are primarily installed on long alternating current submarine crossings.

Q. PLEASE DESCRIBE HPFF CABLES AND ISSUES THIS CABLE TYPE WOULD PRESENT.

A. HPFF cable accounts for most of the limited amount of underground 345 kV transmission facilities currently in commercial service in the United States, the longest of which is a seventeen mile line. Industry-sponsored tests in this country have demonstrated the technical feasibility of these cables in a 500 kV application, but there have been no commercial installations of HPFF cables in the United States at this higher voltage. A previous short, trial installation of HPFF at 500 kV in Japan is not currently in commercial service. HPFF conductors are insulated with wrapped layers of a laminated paper/plastic tape that are factory impregnated with a dielectric liquid and shipped to the installation site on large reels. The three separate phases are then pulled at one time into a previously installed 8.625-inch (for 345 kV cables) outside diameter, coated and

cathodically-protected steel pipe. 500 kV cables would probably require at least a 10.75 outside diameter pipe. The line is filled with a dielectric liquid that is pressurized to 200-250 pounds per square inch gauge ("psig"). At a minimum, a large pressurizing plant is installed at each end of the line segment to maintain this pressure while accepting fluid expansion and contraction. Assuming level terrain along the right-of-way, a pressurizing plant is installed at each end of the underground line segment to maintain pressure while accepting fluid expansion and contractions. For a right-of-way with significant terrain changes such as the preferred route for TrAIL, however, an HPFF cable system would also be segregated into multiple hydraulic (pressurizing) sections wherever elevation changes of greater than 300 feet occur along the right-of-way. The large volumes of dielectric fluids in the cable pipe (approximately 100,000 gallons for each line of a four to six line installation of a ten-mile segment) presents the potential for a large release of this fluid into the environment in the event of a major leak on even one of the cables. The entire 100,000 gallons of fluid could leak from the pipe, in the hypothetical ten-mile segment described above, depending upon the location of a leak and the time required for utility crews to find and reach that location to plug the leak. HPFF cables present the issues of reduced power transfer capability, higher electrical capacitance, and high transient over-voltages I mentioned above, and are susceptible to outages for both hydraulic and electrical problems. Finally, the installation of HPFF cables requires special training and, while there are foreign suppliers, there is only one domestic supplier for these

cables, and none of these foreign or domestic suppliers have ever manufactured commercially-feasible lengths of 500 kV cables.

Q. LIKEWISE, WOULD YOU PLEASE DESCRIBE XLPE CABLE AND IDENTIFY ANY ISSUES THE POSSIBLE USE OF THIS TYPE OF CABLE WOULD PRESENT?

A. XLPE cables are conductors insulated with polyethylene, which is extruded over the conductors and then cross-linked at high temperatures. A lead, aluminum, or copper sheath is applied, and the individual conductors are configured as three XLPE-insulated cables that are pulled into individual plastic ducts in a concrete-encased duct bank or tunnel. There are only short, splice-free 345-kV XLPE lines in commercial service in this country for longer than a year (a 2.1 mile long circuit with splices that was energized in 2007), but there are significant lengths totaling more than 100 miles installed at 330-kV and higher voltages including 500 kV overseas. There are lengths totaling more than 150 miles installed at 230 kV in the United States, as well.

However, no XLPE cable has been installed at 500 kV in the United States and the limited experience elsewhere has been in utility tunnels and not in an underground installation. The manufacture and installation of XLPE cable requires extremely high levels of quality control due to the high sensitivity of dielectric materials to contaminants and voids. XLPE cables above 230 kV are available only from foreign suppliers and these cables also require special skills

and equipment for splicing during installation or for repairs. The lack of domestic suppliers and the special skill requirements, while not necessarily prohibitive to the initial installation of an underground facility, are factors that can contribute to the relatively longer duration of outage repairs on underground cables if replacement cables must be shipped from overseas locations and the necessary skilled labor must be located and brought to the outage site.

Q. PLEASE DESCRIBE THE CONFIGURATION OF FACILITIES THAT WOULD BE REQUIRED TO PLACE EVEN A SEGMENT OF TRAIL UNDERGROUND.

A. First, a dead-end type transmission structure would be required at each end of an underground line segment. Transition stations would also be required at each end of the underground segment; one station to transition the overhead facility into underground and the other station to transition back to an overhead facility. The transition stations would be fenced areas, much like a traditional substation, with dimensions of approximately 160 by 320 feet. Each station would have three cable terminations for each line – 12 to 18 terminations in total, each ten or so feet tall, on substation-type structures with bases ten feet or more above the ground. Flexible conductors would be required to drop down from the overhead conductors to the cable terminations. Additional equipment within each transition station would include switches, surge arrestors, equipment for communicating with transmission control rooms, including relaying and alarms, and any circuit breakers determined to be necessary. This would be repeated at each end of each

segment of the line to be placed underground. For HPPF cable systems, pressurizing plants with pumps, controls, alarms, and a large storage tank would be required at each end of an underground segment.

Q. YOU INDICATED ABOVE THAT THE CABLES REQUIRE SPECIAL SPLICING. WOULD YOU PLEASE PROVIDE SOME ADDITIONAL DETAIL ABOUT THIS PROCESS?

A. Yes. The individual cables would be provided in lengths of no more than approximately 1,500 feet for XLPE-insulated cables, and perhaps 2,000 feet for HPFF cables, on large reels that may weigh as much as 60,000 pounds or more. Consequently, splicing by factory or factory-trained splicing crews is a significant component of the construction of an underground transmission line. This splicing process requires a "clean room" environment and can take up to ten days for each individual splice. Because between four and six three-conductor lines would be required, this would mean between 12 and 18 splicing procedures would be necessary for every fifteen hundred foot length of the planned underground segment and would require the cement vaults I described earlier. This complex process not only adds significantly to the length of time for constructing underground facilities, it is the principal contributing factor to the relatively long outage periods that would result during an unforeseen event on an underground line segment. As a comparison, bare overhead transmission conductors are typically shipped in reel lengths of between 16,000 to 30,000 feet, depending on

the size of conductor, and an overhead conductor splice typically takes one worker less than an hour to complete.

Q. WOULD YOU PLEASE SUMMARIZE WHY, IN YOUR PROFESSIONAL OPINION, IT WOULD BE INFEASIBLE TO PLACE ANY PORTION OF THE TRAIL PROJECT UNDERGROUND?

A. I indicated at the start of my rebuttal testimony that, while it may be technically possible to place segments of TrAIL underground, the significant construction and operational challenges I have detailed above, in my opinion, make the placement of any portion of TrAIL underground infeasible. The significantly longer time periods that would be required to respond to unforeseen outages on an underground segment would largely, if not completely, negate TrAIL's intended purpose for transmission grid reinforcement and reliability enhancement. Because there is no commercial service experience with HPFF cables at voltage levels of 500 kV or with XLPE cables in an underground environment such as for TrAIL, any segment of the line placed underground would, for all intents and purposes, be the equivalent of a research and development demonstration project for the commercial feasibility of 500 kV underground transmission facilities. In my professional opinion, such an outcome would be particularly imprudent for a new high-voltage transmission facility that is intended to maintain transmission grid reliability.

Q. DOES THIS CONCLUDE YOUR REBUTTAL TESTIMONY?

A. Yes. I reserve the right, however, to file such additional testimony as may become necessary or appropriate.

PDC

Power Delivery Consultants, Inc.

- 110172
Pbg. JK 4/14/08

JAY A. WILLIAMS - PRINCIPAL ENGINEER

Jay A. Williams received a BS in Engineering from Brown University in 1965 and a Master of Business Administration from New York University in 1972. He joined the Consolidated Edison Company of New York in 1965, and held engineering positions in several groups at Con Edison until he joined Power Technologies, Inc. in 1973. He served in the U.S. Air Force, Base Civil Engineers, in the 1960's. He and John Cooper founded Power Delivery Consultants, Inc in 1992.

As a Senior Engineer in charge of Con Edison's Transmission Cable Group, Mr. Williams' responsibilities included system design and preparation of specifications for 138-kV and 345-kV underground transmission lines and accessory equipment; economic studies of proposed underground transmission systems; field supervision for nonstandard construction operations; and fault analysis and repair. He had responsibility for detailed design of cable bays for the Waltz Mill Cable Test Facility. He was Project Engineer for installation of the world's first underground 345-kV SF_6 - insulated transmission line, and supervised the construction of the line in 1971.

After joining PTI, Mr. Williams was responsible for experimental projects for the forced cooling of high-pressure, fluid-filled cable circuits. These projects were the first ones to undertake the installation, instrumentation, and analysis of a full-scale cable system. He was also project engineer for an EPRI-sponsored study to develop rapid and accurate leak location systems for buried cables.

Mr. Williams has conducted technical and economic studies of alternate underground systems, for voltages from 138 kV to 500 kV ac, as well as HVDC. He has prepared testimony and represented utilities and commissions in hearings. He designed and supervised the construction of an extensive uprating project for existing pipe-type cables, and has been responsible for engineering analysis, specifications, bid review, and field supervision for many underground and submarine cable projects for both utilities and architect-engineers.

In addition to utility design/installation projects, he was project engineer for the EPRI – funded development of the ACE program to perform technical and economic analyses of cable systems. He was in charge of the EPRI project to prepare the 1992 edition of the Underground Transmission Systems Reference Book; he wrote the Cable Ampacity chapter plus several other chapters of the book. He was also project engineer for the EPRI Underground Transmission Workstation project, as well as several other EPRI-funded projects — including the Distributed Fiber Optic Temperature Monitoring development. He has taught many courses and seminars for underground transmission cables, from system planning to field operation & maintenance.

Mr. Williams is a Fellow of the IEEE, and member of the Power Engineering Society and Electrical Insulation Society. He is a Voting Member of the IEEE Insulated Conductors Committee and served as Chairman of the Insulations Subcommittee. Mr. Williams has authored more than fifty technical articles and papers, and was co-author of the Underground Transmission Systems section of the McGraw-Hill Standard Handbook for Electrical Engineers. He is a registered Professional Engineer in the States of New York and Ohio.

TrAILCo Rebuttal Statement No. 16
Witness: Wayne A. Knoblauch Ph.D.

BEFORE THE

PENNSYLVANIA PUBLIC UTILITY COMMISSION

IN RE: APPLICATION OF TRANS-ALLEGHENY INTERSTATE LINE COMPANY FOR (I) A CERTIFICATE OF PUBLIC CONVENIENCE TO OFFER, RENDER, FURNISH AND/OR SUPPLY TRANSMISSION SERVICE IN THE COMMONWEALTH OF PENNSYLVANIA; (II) AUTHORIZATION AND CERTIFICATION TO LOCATE, CONSTRUCT, OPERATE AND MAINTAIN CERTAIN HIGH VOLTAGE ELECTRIC	:	Docket Nos. A-110172
TRANSMISSION LINES AND RELATED ELECTRIC	:	A-110172F0002
SUBSTATION FACILITIES; (III) AUTHORITY TO EXERCISE THE POWER OF EMINENT DOMAIN FOR THE CONSTRUCTION AND INSTALLATION OF AERIAL ELECTRIC TRANSMISSION FACILITIES ALONG THE PROPOSED TRANSMISSION LINE ROUTES IN PENNSYLVANIA; (IV) APPROVAL OF AN EXEMPTION FROM MUNICIPAL ZONING REGULATION WITH RESPECT TO THE CONSTRUCTION OF BUILDINGS; AND (V) APPROVAL OF CERTAIN RELATED AFFILIATED INTEREST ARRANGEMENTS	:	A-110172F0003
	:	A-110172F0004
	:	G-000721229

REBUTTAL TESTIMONY OF WAYNE A. KNOBLAUCH, Ph.D.

Re: Impacts of TrAIL on Farming and Agricultural Operations

December 10, 2007

REBUTTAL TESTIMONY OF WAYNE A. KNOBLAUCH, Ph.D.

Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.

A. My name is Wayne A. Knoblauch. I am a Professor in the Department of Applied Economics and Management ("AEM") at Cornell University, with a business address at Cornell University, 359 Warren Hall, Ithaca, New York 14853.

Q. HAVE YOU PREVIOUSLY SUBMITTED DIRECT TESTIMONY IN THIS PROCEEDING ON BEHALF OF THE TRANS-ALLEGHENY INTERSTATE LINE COMPANY ("TrAILCo")?

A. No, I have not.

Q. PLEASE DESCRIBE YOUR CURRENT RESPONSIBILITIES AND PROFESSIONAL EXPERIENCE.

A. I have been a full Professor in the College of Agriculture and Life Sciences at Cornell University since 1989. I began my academic career there as an Assistant Professor in 1976 and was promoted to an Associate Professor in 1982. My primary departmental program area is farm business management. I teach courses in farm management, conduct research on farm management topics and advise undergraduate and graduate students. I also currently serve as Faculty Director of the NY FarmNet and NY FarmLink Programs, the NY Dairy Farm Business Summary Program, and the Pro-Dairy Farm Business Management Programs in the AEM Department.

Q. PLEASE SUMMARIZE YOUR EDUCATION AND YOUR ACADEMIC AND RESEARCH EXPERIENCE.

A. I earned a Ph.D. in Agricultural Economics from Michigan State University in 1976. I also earned B.S with Honors and M.S. degrees in Agricultural Economics from Michigan State University in 1971 and 1972, respectively. TrAILCo Rebuttal Exhibit WAK-1 is my curriculum vitae, which provides the details of my academic honors, research experience, and my research and extension publications.

Q. ARE YOU A MEMBER OF ANY PROFESSIONAL ORGANIZATIONS?

A. Yes. I am a member of the American Agricultural Economics Association; the American Dairy Science Association; and the Northeastern Agricultural and Resource Economics Association.

Q. WILL THE USE OF VARIOUS TERMS IN YOUR REBUTTAL TESTIMONY BE CONSISTENT WITH THE DEFINITIONS ASSIGNED TO THOSE TERMS IN THE TABLE OF NOMENCLATURE ATTACHED TO TRAILCO WITNESS FLITMAN'S DIRECT TESTIMONY AS TRAILCO EXHIBIT DEF-1?

A. Yes. In addition, I may define other specific terms in my rebuttal testimony.

Q. PLEASE DESCRIBE THE TOPIC AND PURPOSE FOR YOUR REBUTTAL TESTIMONY.

A. My rebuttal testimony will address and respond to the various comments and concerns that were raised during the public input hearings in Pennsylvania about the possibility that the proposed TrAIL project will negatively affect or prohibit the current agricultural uses of farms over which the TrAIL right-of-way may pass.

Q. BASED ON YOUR PROFESSIONAL OBSERVATION AND EXPERIENCE, WILL THE PLACEMENT OF AN ELECTRIC TRANSMISSION LINE ON A NEW RIGHT-OF-WAY OVER AN OPERATING FARM, IN AND OF ITSELF, NEGATIVELY AFFECT THE EXISTING AGRICULTURAL USES OF THAT PROPERTY OR RENDER CONTINUED FARMING OPERATIONS INFEASIBLE OR IMPOSSIBLE?

A. No, it does not. I have been extensively involved in the agricultural industries in many states throughout my academic and professional career, whether performing academic research based on the hundreds of operating farms from which I have gathered data, provided consultation services regarding agricultural economics, management, and operations, or supervising the research of my under- and post-graduate students and, based on those experiences, I have never seen an operating farm unable to continue existing agricultural uses on land within an electric transmission line right-of-way that was used for such purposes before the transmission line was constructed.

While the farm operator may lose the benefit of the use of any acreage upon which the footprint (or base) of a transmission tower structure is placed, the cumulative area of those tower footprints on a single landowner's farm is typically very small compared to the entire acreage, and the landowner's existing agricultural operations, whether tilling crops or pasturing livestock, can be continued unabated on the balance of their land over which a right-of-way may pass.

Q. TO WHAT EXTENT DOES THE PREFERRED TRAIL ROUTE CROSS OVER EXISTING AGRICULTURAL OPERATIONS IN WASHINGTON AND GREENE COUNTIES IN PENNSYLVANIA?

A. Based upon my review of the Route Evaluation Report and Environmental Report ("LRE") for both the Prexy Segment facilities and the 502 Junction Segment facilities, TrAILCo Exhibit JH-1, it appears that the preferred route passes over land currently used for agricultural purposes, but not to a large degree as compared to the total line mileage of the Prexy Segment and the 502 Junction segment combined. Based on the LRE, approximately 9,650 lineal feet of the preferred route from the 502 Junction Substation site to Prexy will pass over cropland and 38,700 lineal feet of preferred route from the West Virginia-Pennsylvania state line to Prexy will pass over pasture and hayland; the two agricultural use categories identified in the LRE at page 72. These distances equate to an area of approximately 44 acres of cropland and 178 acres of pasture/hayland from the West Virginia State line to the Prexy

substation. This translates to about a half acre of cropland and two acres of pasture/hayland that would be lost to tower structure bases. Approximately 1,950 lineal feet of the Prexy-Manifold/Houston 138 kV Lines will pass over cropland, or an area equivalent of 4 to 5 acres (page 119 of the LRE), of which tower structure bases would take less than a tenth of an acre. The Prexy-Manifold/Houston 138 kV Lines will also pass over 6,900 lineal feet of pasture/hayland, or about 16 acres, with a loss of about a tenth of an acre to the tower structure bases. The Prexy-Union Junction/Peters 138kv Line crosses 2,250 lineal feet of cropland (page 150 of the LRE), which equates to about 5 acres of area with a loss of less than a tenth of an acre of crop production to tower structure bases. The Prexy-Union/Peters 138 kV Line also passes over 7,450 feet of pasture/hayland, encompassing 17 total acres with a loss of a tenth of an acre of hay production to tower structure bases. Finally, the Prexy-Washington/Charleroi 138 kV Line passes over 3,600 lineal feet of cropland, or about 8 acres (page 180 of the LRE), which translates to less than a tenth of an acre lost to tower structure bases. The Prexy-Washington/Charleroi 138 kV Line also crosses 6,700 lineal feet of pasture/hayland, or an estimated 15 acres, with about a tenth of an acre lost to tower structure bases.

Q. OF THE TWO AGRICULTURAL CATEGORIES DESCRIBED IN THE LRE, IS THERE A MORE PREVALENT AGRICULTURAL ACTIVITY ALONG THE TRAIL RIGHT-OF-WAY?

A. Yes. Based on my review of the LRE, current agricultural activity along the preferred TrAIL right-of-way appears to be primarily livestock grazing on pasture land and hay production.

Q. WILL FARM OWNERS BE ABLE TO CONTINUE THEIR CURRENT AGRICULTURAL OPERATIONS AND USES ON THE PORTIONS OF THEIR PROPERTIES THAT WOULD BE CROSSED BY THE PREFERRED ROUTE?

A. Yes. Current farming operations, whether cultivation or pasturing, could be continued without interruption. The most obvious impact to the typical farm owner would be the relatively small area footprint (or base) of each transmission tower structure that might be placed on the right-of-way. Per the direct testimony of TrAILCo witness John Bodenschatz and the LRE, the typical span length between tower structures is expected to be approximately 1,200 feet. Considering this information and the relatively small cumulative area for all transmission tower bases along the entire preferred route that is estimated in the LRE, it is unlikely that any single landowner would have a significant number of towers placed on their property. The presence of a tower structure will remove only the area occupied by the transmission tower base from production, for both cultivation and grazing uses, and would result in a minimal reduction in field efficiency of the operator's machinery. In light of the small number of tower structures that will likely be placed directly on current agricultural properties, the cumulative impact of the area under those

structures on right-of-way, currently under cultivation or being utilized for livestock grazing, will be very small. Based on the LRE, the entire preferred TrAIL route in Pennsylvania is estimated to cross over 61 acres of cropland and 226 acres of pasture/hayland, with all tower structure bases occupying less than one acre of cropland and about 2.3 acres of pasture/hayland.

Q. ASIDE FROM ANY TRANSMISSION TOWER STRUCTURE THAT MIGHT BE PLACED ON THE RIGHT-OF-WAY, DOES THE PLACEMENT OF NEW OVERHEAD LINES OVER EXISTING PASTURE OR TILLED ACREAGE PROHIBIT, OR OTHERWISE IMPEDE THE CONTINUED AGRICULTURAL USES OF THAT LAND?

A. No. The presence of new overhead lines over an existing farm operation would not, in any way, prohibit or impede any continuing agricultural operation. Livestock grazing can continue unabated, as well as any crop tillage or haying activities.

Q. SOME WITNESSES AT THE PUBLIC INPUT HEARINGS DESCRIBED CONCERNS WITH THE EFFECTS OF ELECTRIC AND MAGNETIC FIELDS ("EMFs") ON LIVESTOCK THAT WOULD BE UNDER OR IN CLOSE PROXIMITY TO THE TRAIL RIGHT-OF-WAY. ARE YOU AWARE OF ANY RECENT STUDIES WHICH EXAMINED THE POSSIBLE EFFECTS OF EMFs ON FARM ANIMALS?

A. Yes, I am. However, there are no credible studies which have indicated a danger or damage to farm animals. In a February 2005 study entitled "Electromagnetic Fields and Public Health, Effects of EMF on the Environment," the World Health Organization ("WHO"), a respected scientific body, reported that "[f]ield studies of 50-60 Hz exposure to plants and crops have shown no effects at the levels normally found in the environment, nor even at field levels directly under power lines up to 765 kV." In that report, the WHO stated that "[i]n particular, there were no adverse effects found on cattle grazing below power lines."

TrAILCo witness Dr. William Bailey in TrAILCo Statement No. 8-R addresses in more detail the negligible effects of EMFs on farm animals.

Q. DOES THIS CONCLUDE YOUR REBUTTAL TESTIMONY?

A. Yes. However, I reserve the right to file such additional testimony as may become necessary or appropriate.

WAYNE A. KNOBLAUCH, Ph.D.
CURRICULUM VITAE

NAME: WAYNE A. KNOBLAUCH, Ph.D.

TITLE: Professor, Department of Applied Economics & Management

CAMPUS ADDRESS: 359 Warren Hall, Cornell University, Ithaca, NY 14853

PHONE: (607) 255-1599

E-MAIL: WAK4@Cornell.edu

BACKGROUND

EDUCATION:

Year	Degree	Institution
1976	Ph.D., Agricultural Economics	Michigan State University
1972	M.S., Agricultural Economics	Michigan State University
1971	B.S. with Honor, Agricultural Economics	Michigan State University

ACADEMIC RANKS AT CORNELL & YEAR ACHIEVED:

Professor: 1989
Associate Professor: 1982
Assistant Professor: 1976

PRIMARY DEPARTMENTAL PROGRAM AREA: Farm Business Management

AREAS OF EXPERTISE: Accounting, Business Analysis, Economic Decision Making, Business Organization, Strategic Planning & Economic Analysis

PROFESSIONAL EXPERIENCE:

Year	Experience
June 1970 - September 1970	Michigan State University. Field Enumerator. Surveying dairy farmers under supervision of Professor C. Raymond Hoglund
September 1971 - December 1972	Michigan State University. Graduate Research Assistant. Agricultural Economics

January 1973 - December 1975	Michigan State University. Instructor and Academic Advisor, Institute of Agricultural Technology
January 1976 - June 1976	Michigan State University. Instructor, Agricultural Economics
1984, 1985, and 1986	Trustee - Village of Lansing
1987 – 1992	Member - Board of Zoning Appeals, Village of Lansing
1987-88, 1988-89	Faculty Advisor - Phi Kappa Psi
1990-91	Faculty Advisor - Alpha Zeta
2002-07	Faculty Advisor - Cornell Baseball Club

SABBATICALS AND STUDY LEAVES:

2006 – Cargill Financial Services; Minneapolis, Minnesota

1994 - Consumers Power Company; Jackson, Michigan

HONORS AND AWARDS:

Alpha Zeta, Agricultural Honorary, 1969.

Outstanding MS Thesis for 1972, Agricultural Economics, Michigan State University.

American Agricultural Economics Association, Outstanding Extension Program Team Award, "The Dairy Diversion Program", 1984.

American Agricultural Economics Association, Outstanding Extension Program Team Award, "The Dairy Buyout Program", 1987.

American Society of Agricultural Engineers, Blue Ribbon For Quality of Publication, "Farming Alternatives Guidebook", 1989.

Community and Rural Development Institute, Innovator Award, Farming Alternatives Program, 1993.

Community and Rural Development Institute, Innovator Award, New York City Watershed Project, 1997.

American Agricultural Economics Association, Outstanding Extension Program Team Award, "Managing Risk & Profits in Dairy", 2000.

Outstanding New Extension Publication Award, New York Association of County Agriculture Agents, "The Organic Decision: Transitioning to Organic Dairy Production", 2002.

Outstanding Extension Publication Award, New York Association of County Agriculture Agents, "Dairy Farm Business Summary", 2004.

Outstanding Accomplishments in Extension, College of Agriculture and Life Sciences, Cornell University, November, 2006.

ACADEMIC RESPONSIBILITIES

CURRENT ADMINISTRATIVE RESPONSIBILITIES:

Faculty Director, NY FarmNet and NY FarmLink Programs

Faculty Director, NY Dairy Farm Business Summary Program

Faculty Supervisor, Pro-Dairy Farm Business Management Programs in AEM

TEACHING AND ADVISING RESPONSIBILITIES

- **Active Grants/Contracts/Gifts**
  Farm Management Study Trip, Principal - Knoblauch, Term 5/06 to 5/07
  Warren Teaching Endowment, $25,800, Percent Effort - 5%
  Project Title - AEM 403 Farm Management Study Trip to Texas

- **Pending Grants/Contracts/Gifts**
  Farm Management Study Trip, Principal - Knoblauch, Term 5/07 to 5/08
  Warren Teaching Endowment, $15,000, Percent Effort - 5%
  Project Title - AEM 403 Farm Management Study Trip to Arizona

- **Administrative Leadership**
  Dean's Committee to Design an Undergraduate Agricultural Science Curriculum
  Farm Credit Fellows Committee
  Department Undergraduate Program Committee

- **Courses Taught**
  AEM 302, Farm Business Management
  AEM 403, Farm Management Study Trip

EXTENSION RESPONSIBILITIES

- **Active Grants/Contracts/Gifts**

  Project No. 8619, Principal Investigators – Staehr/Knoblauch, 4/1/06 to 3/31/07
  Source: NYS Department of Agriculture & Markets, $300,000, Percent Effort - 20%
  Title of Project - NY FarmNet & NY FarmLink, Farm Family Assistance

  Project No. 8623, Principal Investigators – Mastronardi/Knoblauch, 7/1/06 to 6/30/07
  Source: NYS Department of Mental Health, $200,000, Percent Effort - 5%

Title of Project - NY FarmNet Mental Health Project

Project No. ARP – 05 - 002, Principal Investigator – Knoblauch, 1/1/06 to 12/31/07
Source: New York Farm Viability Institute, $100,000 plus $50,000 from Dean's Funds,
Title of Project – Dairy Farm Business Summary Project – Improving the Profitability of New York Dairy Farms, Percent Effort -20%

Project No. 8112-950, Principal Investigators – Staehr/Knoblauch, 5/06 to 5/07
Source: Warren Teaching Endowment, $13,500
Title of Project – Management Training for Educators and Consultants

Project No. 8611, Principal Investigators – Staehr/Knoblauch, 2/1/06 to 1/31/08
Source: New York Farm Viability Institute, $200,000
Title of Project – Farm Business Planning

Project No. TBD, Principal Investigator – Knoblauch, 3/3/07 to 6/30/08
Source: New York Farm Viability Institute, $140,000
Title of Project – Dairy Farm Business Summary Enhancements

PROFESSIONAL ACTIVITIES

PROFESSIONAL SOCIETIES:

American Agricultural Economics Association
American Dairy Science Association
Northeastern Agricultural and Resource Economics Association

CONFERENCES/WORKSHOPS/IN-SERVICE PARTICIPATION

Extension Programs:

NY FarmNet

Provide supervision and leadership to the program, interact with the FarmNet Board of Directors and serve as the liaison to the Department and Cornell Cooperative Extension. Guide the strategy formulation and forge productive linkages to other extension and research activities. FarmNet responds to financial and family requests for assistance by using an 800 number. Services range from assistance in strengthening the profitability of the farm business, improving family relationships to the extreme of suicide intervention. Duration, 2000 to 2007.

NYFarmLink

Provide supervision and leadership to the program, interact with the FarmNet Board of Directors and serve as the liaison to the Department and Cornell Cooperative extension. Guide the strategy formulation and forge productive linkages to other extension and research activities. The program improves the process and effectiveness of farm transfers by providing entering and

exiting farmers with essential networking, consulting and educational support. Duration, 2000 to 2007.

Dairy Farm Business Summary

Provide faculty leadership for the survey and computer analysis of production and financial records from New York dairy farms. Prepare extension and research publications, work with agents and farmers on data collection and conduct regional meetings on topics of current interest. Work with DFBS Board of Directors. Leadership from 1996 to 2007.

Currently enhancing a web-based data base and interface program to enter and analyze dairy farm production and financial data. Plans are being developed to expand the use of the new program beyond New York.

Pro-Dairy Project

Work jointly with a Sr. Extension Associates in the planning, development and implementation of extension programming in farm management and human resource management for the dairy industry. Activities range from program planning to joint authorship of articles and publications. Also working with an extension associate on the development of a web-based, monthly herd monitor. Duration, 1988 to 2007.

Developed a proposed staffing plan for dairy, field crops & business management programs under the Agricultural Initiative, May 2001.

Developed a program of work and position description for a redefined Senior Extension Associate position to work with me on Farm Business Management topics, 1997. Continue to work with and act as joint supervisor for Sr. Extension Associate.

Member of the "Managing With Finances" Committee which developed educational materials for dairy farming, 1989-90.

Member of the "Managing For Success" and "Forage Crop Production and Feeding" Committees, 1988.

CWT Program

Developed worksheets and a web program to assist farmers in determining if herd termination was of benefit to them. The worksheets assisted in the development of a specific bid to be submitted to CWT. Duration, 2003 and 2004.

French Creek Watershed

Developed questionnaire and analyzed results of a survey to evaluate the impacts of nutrient management planning on dairy farms in the French Creek Watershed, Chautauqua County, New York. Joint project with David Gross, Natural Resources. Funding provided by The Nature Conservancy. Duration, 2001 and 2002.

Developed questionnaire and analyzed results of a survey to evaluate farmers' opinions of stream bank protection programs in the French Creek Watershed, Chautauqua County, New

York. Joint project with David Gross, Natural Resources. Funding provided by The Nature Conservancy. Duration, 2002 and 2003.

Farm Unit Study

Coordinate with Thomas R. Maloney and Robert A. Milligan to develop an integrated, in-depth experience for farm management, dairy and field crops agents in farm problem identification, decision-making and farm family counseling, 1997, 1998, 1999, 2000, 2001 and 2003.

Top US Dairy Financial Performance

Worked jointly with Mark Stephenson to develop a survey instrument to collect financial data on "Top" US dairy farms. Presented results at Orlando, Florida conference, August 1997. Improved the survey form and expand questions asked for 1999 data. Presented results at a conference in Orlando, Florida, November 2000.

Web Site Development

Coordinate Agricultural Finance and Management Web Site development in relationship to total department, 1999-00.

New York City Watershed Project

Jointly developed, with faculty in other Cornell departments, the procedures to construct "whole farm plans" for farms in the New York City Watershed to improve water quality and maintain or enhance farm profitability.

Empire Managers Program, 1988 and 1989

Organized a three workshop series for managers of large farms and agriculturally related businesses on:

1. Information Systems and Economic Decision Making,
2. Strategic Planning in an Uncertain Environment, and
3. Management Organization and Personnel Management.

Program was attended by invitation only, with a wide variety of commodities represented. Program was conducted jointly with Gerald B. White. Reunion meetings for the group were held in 1989 and 1990.

Large Dairy Herd Management Conference

Co-chaired with Charles Sniffen, Department of Animal Science, a three-day conference on management tactics and strategies to improve the efficiency and profitability of large dairy farms. Also presented a workshop on setting goals for labor efficiency.

Farming Alternatives Project

Served as the Co-Director and then as Director of the Farming Alternatives Project. Was responsible for working with a staff of three on the identification, planning, development and

implementation of programs to help farmers assess the possibilities of starting or adding new enterprises to existing farm businesses.

Presentation at Northeast Farm Management Committee Meeting on "Results of Farming Entrepreneur Survey", Bangor, Maine, June 1988.

Presentation at the kick-off session of the Farm Family Opportunity Program on "Developing Farming Alternatives", Oneonta, New York, February 1988.

Jointly conducted with Farming Alternatives Project Directors and Staff a "Farming Alternatives Conference", March 1988. Presentation at the conference on a description of the Farming Alternatives Project and Moderated the Extension/Technical Assistance Workshop.

Development of a workbook to assist persons interested in farming alternatives to evaluate the enterprise before investing capital, in process.

Presentation at the Field Test In-service Program for Agents on using the draft workbook to evaluate profit potential and financial feasibility. Cornell University, January 1988.

Presentation at the Pennsylvania, Delaware, and New Jersey Conference on "Marketing Alternative Enterprises" for growers and a more detailed presentation and discussion with Cooperative Extension personnel following the conference. Reading, Pennsylvania, November 1987.

Presentation to W.I. Myers Advisory Committee on progress and plans for the future of the Farming Alternatives Project, October 1987.

Presentation on "Steps in the Management Process of Evaluating Farming Alternatives", Hudson Valley, February 28; Western New York, March 14; Central New York, March 28; and Northern New York, April 11, 1987.

Presentation to Agents and Specialists attending "1986 Production Agriculture Training School" on Objectives and Goals of the Farming Alternatives Project, November 1986.

Alternative Agricultural Opportunities Task Force

Co-chair with John Brake of a Task Force appointed by the Office of Research and Director of Extension to determine if a policy statement which specifies the appropriate focus and priorities in the area of alternative agricultural opportunities is needed by the College, 1988-89.

Farm Financial Crisis

Special Presentation to FarmNet Financial Counselors, "Constructing and Interpreting the Farm Balance Sheet", Department of Agricultural Economics, Cornell University, June and October 1986.

Presentation to Extension Agent In-depth Training Class on Working with Farm Families Under Stress, "Identifying and Prioritizing Extension Clientele for 1986/87", March 1986.

Presentation to FarmNet Counselors Training Session on "Analysis and Use of The Balance Sheet When Working With Farmers Under Financial Stress" and "Using The Dairy Farm Business Summary as a Diagnostic Tool", March 1986.

Presentation to Broome and Chenango County Young Farmers on "Farm Machinery Management", January 1986.

Dairy Herd Buyout

Jointly developed and appeared in a videotape describing "The Dairy Buyout" and how farmers should evaluate the programs impacts on their business. The videotape was distributed to 27 states as well as 33 copies being distributed within New York.

As part of a three location series for farm lenders, agribusiness, and Extension personnel, presented "Calculating Your Breakeven Bid" in Albany, New York, February 1986.

Presentation at organizational meeting of National Dairy Herd Buyout Extension Program Committee on "Worksheets for Dairy Farmers to Calculate Bread-even Bids", Ohio State University, Columbus, Ohio, November 1985.

Dairy Diversion Program

Jointly developed and appeared in a 60-minute television program entitled, "The New Dairy Bill: What Can Farmers Do?" The program was broadcast in New York and also by 43 television stations in 15 states from Maine to California and Georgia to Minnesota.

Presentation to Cortland County farmers and agribusiness personnel on the characteristics of The Dairy Stabilization Act and how farmers could analyze whether or not to participate in the diversion program, January 1984.

Presentation to Eastern Milk Producers Cooperative Board of Directors on how farmers could analyze whether or not to participate in the dairy diversion program, Owego, New York, January 1984.

Computer Use

Development and use of computerized decision aids that serve as education tools in working with farmers, extension agents and specialists, and industry leaders.

Remote Access Computers:

NEWPLAN Program 65 "Profitable Organization of Dairy Farm Enterprises". Selecting and combining enterprises given the dairy farmer's unique resources to maximize profit. Testing consequences of differing management strategies and production coefficients.

Jointly presented with Robert A. Milligan at ECOP Conference on Computer Use in Extension a session entitled "Use of Forward Planning Computer Models in Farm Management Extension", Pittsburgh, PA, March 1979.

Presented a paper entitled "User Evaluation of Remote Access Computing" at Outstate Forward Planning System Users Conference, University of Illinois, September 1978.

Jointly conducted with Robert A. Milligan and Marylouise van Lieshout three 3-session sequential schools for dairy farmers:

Oneida and Herkimer Counties; March 1980
Tompkins, Chemung, Tioga, and Schuyler Counties; January 1979
Erie and Wyoming Counties; February 1979

Jointly conducted with Robert A. Milligan, eight 3-day sequential schools for dairy farmers:

Cortland and Seneca Counties; January 1982
Jefferson and Lewis Counties; January 1981
Cattaraugus-Chautauqua Counties; November 1978
Genesee, Niagara, Orleans, Monroe Counties; February 1978
Cortland and Chenango Counties; February 1978
Wayne, Ontario, Seneca, Yates Counties; March 1978
Cayuga and Madison Counties; January 1978

Jointly conducted with Robert A. Milligan a two-day agent training session on use of the remote access computer and NEWPLAN program, September 1977.

Presentations to Ag Ec 302 and 402 farm management classes on the use of remote access computers in extension, April 1977 and April 1978.

Analyzed a dairy farm business using remote access computer programs for the Western Plains Dairy Team's Large Herd Dairy Tour, August 1977.

Jointly conducted with Robert A. Milligan two pilot sequential schools on use of the remote access computer and NEWPLAN program for Delaware, Otsego, and Chenango Counties in Oneonta in January 1976.

Presentation to Extension Lay Leaders Tour on Use of Computers in Farm Management and Finance, April 1978.

Presentation to College of Agriculture and Life Sciences Advisory committee on Use of Computers in Farm Management and Finance Extension Programs, May 1978.

Jointly conducted with Robert A. Milligan an Introduction to Enterprise Analysis for county agents during the Production Agriculture School in November 1976.

NEWPLAN Program 31 "Least-Cost Balanced Dairy Rations". Selecting and combining feeds into rations which meet all nutrient requirements of the animal for the least cost.

Jointly conducted with Robert A. Milligan, Charles Sniffen, and Larry Chase a two-day school on "Use of the New NEWPLAN Program 31 - Least-Cost Balanced Dairy Rations" for Cooperation Extension specialists and agents, October 1980.

Jointly conducted with Larry E. Chase a workshop for dairy farmers on "Economical Dairy Cattle Feeding in Limited Forage Situations", St. Lawrence County, February 1978.

Jointly conducted with Robert A. Milligan and Larry E. Chase a two day Agent Training Session on the use of the remote access computer and NEWPLAN program "Least-Cost Balanced Dairy Rations", December 1977.

NEWPLAN Program 18 "Profitable Combination of Cash Crop Enterprises". Selecting and combining cash crop enterprises given the machinery capacity, labor availability, and

acreage that will maximize profit for each individual farm. Economic returns from increased machinery capacity and changes in returns with product prices/input costs are analyzed.

Jointly conducted with Robert A. Milligan a three-day sequential school for farmers in Genesee, Monroe, Niagara, and Orleans Counties, January 1981.

Jointly conducted with Robert A. Milligan and Philip R. Sprague a three-day sequential school for farmers in Seneca, Wayne, Ontario, and Yates Counties, February 1979.

NEWPLAN Program 50 "Analysis of Major Capital Investments". Through estimation of cash inflows, capital outflows, and their terminal values an after tax assessment of the desirability of a major expansion and financial feasibility are determined.

Jointly conducted with Eddy LaDue and Stuart Smith a four-day sequential school for dairy farmers in Erie, Wyoming, Genesee, Niagara, Monroe, and Orleans Counties, March 1980.

Jointly conducted with Eddy LaDue, Robert Milligan, and Stuart Smith a training session during Agriculture Production School on "Analysis of Major Capital Investments for Dairy Herd Expansion and Use of NEWPLAN Program 50", November 1979.

Micro/Minicomputers:

Presentation at Production Agriculture School, "Analyzing Equipment Replacement Decisions Using a Microcomputer", November 1987.

Presentation at Vermont Computer Conference, "Is a Computer for Your Farm?" Barre, Vermont, November 1983.

Organized and moderated a "Contributed Software Symposia", Postconference meeting, American Agricultural Economics Association, August 1983.

Presentation to Graduate Bankers Seminar, "Futuristic View of Computer Use on Farms", August 1983.

Presentation to Extension Service County Coordinators, "Update on Kellogg Project and Challenges to Extension on Computer Use", June 1983.

Presentation to Eastern Milk Producers, Board of Directors, "Use of Computers on Farms, The Kellogg Project Experience", May 1983.

Presentation to College of Agriculture and Life Sciences Advisory Committee, "Computer Uses in Farm Management, Policy Issues for The Future", Geneva, November 1983.

Presentation to New York Farm Bureau, Young Farmers and Ranchers, "Future of Computer Use on Farms", Syracuse, February 1983.

Presentation at Farm Computing and Trade Show, "Goals of The Kellogg Project", Syracuse, January 1983.

Presentation to New York State Farm Bureau Board of Directors on "Computer Use in Agriculture", February 1981.

Presentation at College of Agriculture and Life Sciences, Symposium on "Computer Utilization - The Cornell Minicomputer Dairy Management Project", January 1981.

Jointly presented with Robert A. Milligan at Production Agriculture School "Small Computers - Potential and Pitfalls", November 1980.

Presentation at Dairymen's Seminar on "On-Farm Microcomputer Selection", Cornell Campus, November 1979.

Programmable Calculators:

Development and use of programs for use by farmers and extension personnel to assist in farm management decision making.

Two programs have been developed. Documentation is contained in:

Knoblauch, Wayne A. and Gary D. Rice, Economic Value of Cropland, Northeast Agricultural Engineering Service, No. 5.23, April 1979.

Knoblauch, Wayne A. and Gary D. Rice, Financial Feasibility of Cropland Purchase, Northeast Agricultural Engineering Service, No. 5.24, April 1979.

Agribusiness Seminars and Schools

Presented "Analyzing a Dairy Farm Business" to Farm Service Agency Loan Officers, Ithaca, New York, December, 2003

Moderator of Northeast Agribusiness Seminar, Cornell University, 1996, 1997, 1998, 1999 and 2001.

Presented "US Top Dairies Financial Performance" at the Agribusiness Economics Outlook, and Agribusiness Outlook Conference, December 1997.

"New York Dairy Situation" presented at the Annual and Mid-Year Agent Outlook, and Agribusiness Outlook Conferences, December 1978-93 and 1994-97.

Presentation at New York Tax Assessors School, "Sustainable Agriculture in the 1990's", July 1990.

Presentation at New York Tax Assessors School, "Farming Alternatives in New York", July 1989.

Presentation at Graduate Bankers Seminar, "The Farming Alternatives Project", August 1988.

Presentation at Graduate Bankers Seminar, "New York's Farm Financial Situation", August 1985.

Presentation at Graduate Bankers Seminar, "Dairy Farm Cash Flow Situation and Outlook", August 1984.

Presentation at Northeast Dairy Conference, "The Impact of the Dairy Production Stabilization Act of 1983 on New York Producers", Syracuse, NY, April 1984.

Presentation at Agribusiness Outlook Conference, "Steps for Evaluating the Paid Diversion Participation Decision", December 1983.

Presentation to FmHA personnel, "Farm Machinery Economics", June 1983.

Presentation at Key Bankers Meetings, "Managing a Dairy Farm in 1983", Syracuse and Batavia, October 1982.

Presentation to FmHA personnel on "Agricultural Information Sources", July 1982.

Taught a portion of Agribusiness Executives School, "Using Computers on Farms, What's Possible?" June 1982.

Taught a weeklong course in the Bankers School of Agriculture on "Farm Machinery Economics", August, 1980-1989.

Jointly coordinated with C. Arthur Bratton and Stuart F. Smith a two-day seminar for Agway Farm Consultants and Credit Managers, May 1978.

Taught a weeklong course in the Bankers School of Agriculture on "Capital Management Decisions in the Farm Business", August 1977, 1978, and 1979.

Presented a discussion of "Enterprise Analysis" to Graduate Bankers Seminar, August 1977.

Dairy Days Programs:

Presentation to Western New York Dairy Farmers on changes in 1996 with an eye to managing in 1997. Also, economics of leasing versus purchasing machinery. Wyoming County, February 1997.

Presentation on Economics of Dairy in the Future, Delaware County, April 1997.

Presentation at Western New York Dairy Congress, "Cost of Producing Milk in New York and Ontario, What's the Difference?" Batavia and Waterloo, February 1993.

Presentation at Agriculture Education Days, "Should I Repair or Replace Machinery?" Ulysses, PA and Rushford, NY, January 1993.

Presentation at Capital District Day Futurama, "What's Required to be Competitive in Dairying", Greenwich, New York, February 1991.

Presentation at Oneida/Herkimer County Agricultural Science Day, "Purchasing vs. Growing Forage", Herkimer, 1990.

Presentation at Sullivan County Dairy Days, "Managing Dairy Farms During Periods of Economic Stress", Youngsville, March 1983.

Presentation to clientele of Citizens Central Bank, "Managing Farms During Periods of Economic Stress", Wyoming County, March 1983.

Presentation on "Buying Decisions in 1981 and Beyond" at Money Management Seminar, Batavia, March 1981.

Presentation at New York-Pennsylvania Dairymen's Seminar on "Remote Access Computer Programs to Assist in Farm Business Management Decisions", February 1981.

Presentation at Madison County Dairy Days Program on "Economical Utilization of Forages for Milk Production", January 1981.

Presentation at Cattaraugus County Dairy Days Program on "Managing Your Dairy Farm in 1980 - Prospects for Profit", March 1980.

Presentation at Chautauqua County Dairy Days Program on "Managing Your Dairy Farm in 1980 - Prospects for Profit", March 1980.

Presentation at Sullivan County Dairy Days Program on "Managing Your Dairy Farms in The 80's", April 1979.

Presentation at Lewis County Dairy Days Program on "Debt Capacity Per Cow", March 1978.

Presentation at Cattaraugus County Dairy Days Program on "Debt Capacity Per Cow", March 1978.

Presentation at Chautauqua County Dairy Days Program on "Debt Capacity Per Cow", March 1978.

Presentation at Allegany County Dairy Days Program on "Forage Crops Cost of Production and Systems", February 1978.

Presentation at Western Plains and Erie-Wyoming Dairy Teams Futurama on "Debt Capacity per Cow", January 1978.

Presentation at Delaware County Dairy Days Program on "Economics of Forage Systems", January 1978.

Presentation at Cornell Dairy Days Program on "Debt Capacity Per Cow", January 1978.

Presentation at Schoharie, Fulton, and Montgomery Counties Dairy Days Program on "The Economics of Hay and Hay Crop Silage", February 1977.

CONSULTING

Consulting services have been provided on economic aspects in four major areas: new product development, product liability, personal injury, and impact assessment.

New Product Development

Research as to the feasibility of starting a dairy operation was done for Anheuser-Busch, Inc., St. Louis, Missouri. Research into an economic and nutritional evaluation of three whey products as feed for dairy cattle was done for Abcor, Inc., Wilmington, Massachusetts.

Economic and nutritional evaluation of the value of the by-products of snack food processing for dairy cattle was done for Frito-Lay, Inc., Dallas, Texas.

Product Liability

Analysis of economic loss, and where required disposition and trial testimony, has been provided to the following: Alfa-Laval, Inc., Kansas City, Missouri; Michigan Power Company, Kalamazoo, Michigan; Consumers Power Company, Jackson, Michigan; Columbus and Southern Ohio Electric Company, Columbus, Ohio; Wheeling Electric Company, Wheeling, West Virginia; Castle and Cooke, Inc., San Francisco, California; Calvin Brown, Seneca County, New York; Van Kempen Electric Company, Grand Rapids, Michigan; Oceana Electric Company, Hart, Michigan; Michigan Farm Bureau, Lansing, Michigan; Powell Farms, Freemont, Michigan; Germania Dairy Automation, Madison, Wisconsin; Potomac Edison, Baltimore, Maryland; Comanche Electric Co-op, Comanche, Texas; Rappahannock Electric Cooperative, Culpeper, Virginia; Abel Farms, Pennsylvania; Babson Brothers, Illinois; Peb-L-Brook Farms, Michigan; Indiana REMC; Erath County Electric Cooperative Association, Stephenville, Texas; Heater Farms, Millerton, Pennsylvania and Painter Farms, Westfield, Pennsylvania; Conrad Farms, Millerstown, Pennsylvania; Lake and Piepkow Farms, Michigan; Southwestern Public Service Company, New Mexico; O & A Electric Cooperative, Michigan; Tri-County Electric Cooperative, Michigan; Bangor Hydro Electric, Bangor, Maine; American Electric Power Company, Columbus, Ohio; Green Mountain Power, Burlington, Vermont; Central Maine Power, Augusta, Maine; New Hampshire Public Utility Company; Cable Service Company, Pennsylvania; Mullen Farms, New York; The Irrigation Company, Idaho; Allegany Power Company, West Virginia; American Electric Power Company, Virginia; Ohio Power Company, Ohio; Tincknell Farm, Pennsylvania; Staley Manufacturing Company, Michigan; West Farm, New York; Carney Farm, New York; Maine Potato Growers, Maine; Vermont Farm Bureau; Giezen Electric, Idaho; Den-Tex Dairy, Texas, Miller Dairy, Texas; Idaho Power Company, Idaho; Geitzen Electric Company, Idaho; Novartis Corporation, North Carolina; Wisconsin Public Service Corp, Wisconsin; Anheuser-Busch, Columbus, Ohio; J-Star Manufacturing, Minnesota; King and Polhamus Farms, New York; Idaho Dairy Supply Company, Idaho; United Vaccines, Minnesota and Wisconsin; Cabot Corporation, Pennsylvania; Spring Flower Dairy, Ohio; Peterson Construction, Idaho; Professional Engineering Consultants, Kansas; Johnson Air Services, Delaware; ABB, Inc, Delaware; Bentley Farm, New York; Cargill Financial Services, Minnesota; Brofee Dairy, Pennsylvania, Pennsylvania Electric Cooperative, Pennsylvania; Crone Farms, Ohio; Cutter Dairy, Ohio; Excel Energy, Wisconsin; Gulf South Pipeline Company, Louisiana; Fulwood and Bland, United Kingdom & California, Espisoto, Pennsylvania.

Personal Injury

Analysis of economic loss and where required deposition and trial testimony has been provided the following: City of Kalamazoo, Michigan; Burnley Corporation, Saginaw, Michigan; David Sharick, Wyoming County, New York; Bill Smith, Trumansburg, New York; Lucy Snell, Akron, New York; William Conrad, Ithaca, New York; Vliestra Farm, Wisconsin.

Impact Assessment

New York City Water Board; Assessment of the economic impact of proposed regulations on agriculture in the Delaware/Catskill and Croton Watersheds, conducted with Parsons, Brinckerhoff, Quade and Douglas, New York City; Batavia Turf Farms, New York; Heering Creek Farms, Massachusetts.

RESEARCH AND EXTENSION PUBLICATIONS – 2000 to 2007

Knoblauch, Wayne, George Conneman and Linda Putnam, Chapter 7, "Dairy Farm Management" in New York Economic Handbook 2007, E.B. 2006-20, Department of Applied Economics and Management, Cornell University, December 2006.

Knoblauch, Wayne A., Linda D. Putnam and Jason Karszes, Dairy Farm Business Summary, New York State, 2005, R.B. 2006-06, Department of Applied Economics and Management, Cornell University, October 2006.

Knoblauch, Wayne A. and Linda D. Putnam, Dairy Farm Business Summary, New York Dairy Renters, 2005, E.B. 2006-18, Department of Applied Economics and Management, Cornell University, October 2006.

Knoblauch, Wayne A., Charles Z. Radick, George Allhusen, Jason Karszes and Linda D. Putnam, Dairy Farm Business Summary, Central Valleys Region, 2005, E.B. 2006-13, Department of Applied Economics and Management, Cornell University, September 2006.

Knoblauch, Wayne A., Linda D. Putnam, Jason Karszes, Peggy Murray, Frans Vokey, Molly Ames, William Van Loo, Anita Deming, Carl Tillinghast, Julie Viveiros, Dairy Farm Business Summary, Northern New York, 2005, E.B. 2006-12, Department of Applied Economics and Management, Cornell University, August 2006.

Knoblauch, Wayne A., Linda D. Putnam, Mariane Kiraly, Jason Karszes, Dairy Farm Business Summary, New York Small Herd Farms, 80 Cows or Fewer, 2005, E.B. 2006-09, Department of Applied Economics and Management, Cornell University, August 2006.

Knoblauch, Wayne A., Linda D. Putnam, Jason Karszes, James W. Grace, David L. Munsee, Jacob Schuelke, Joan S. Petzen, Dairy Farm Business Summary, Western and Central Plateau Region, 2005, E.B. 2006-06, Department of Applied Economics and Management, Cornell University, July 2006.

Knoblauch, Wayne A., Linda D. Putnam, Mariane Kiraly, Joseph J. Walsh, Stephen E. Hadcock, Larry R. Hulle, Dairy Farm Business Summary, Southeastern New York, 2005, E.B. 2006-08, Department of Applied Economics and Management, Cornell University, July 2006.

Knoblauch, Wayne A., Linda D. Putnam, Jason Karszes, John Hanchar, Griffen Moag, Josh Sauter, Dairy Farm Business Summary, Western and Central Plain Region, 2005, E.B. 2006-05, Department of Applied Economics and Management, Cornell University, May 2006.

Karszes, Jason, Wayne A. Knoblauch and Linda D. Putnam, Dairy Farm Business Summary, New York Large Herd Farms, 300 Cows or Larger, 2005, E.B. 2006-03, Department of Applied Economics and Management, Cornell University, May 2006.

Knoblauch, Wayne A. and Linda D. Putnam, Dairy Farm Business Summary, New York Dairy Renters, 2004, E.B. 2005-16, Department of Applied Economics and Management, Cornell University, December 2005.

Knoblauch, Wayne, George Conneman and Linda Putnam, Chapter 7, "Dairy Farm Management" in New York Economic Handbook 2006, E.B. 2005-14, Department of Applied Economics and Management, Cornell University, December 2005.

Knoblauch, Wayne A., Linda D. Putnam, Mariane Kiraly, Jason Karszes, Dairy Farm Business Summary, New York Small Herd Farms, 80 Cows or Fewer, 2004, E.B. 2005-15, Department of Applied Economics and Management, Cornell University, November 2005.

Knoblauch, Wayne A., Linda D. Putnam and Jason Karszes, Dairy Farm Business Summary, New York State, 2004, R.B. 2005-03, Department of Applied Economics and Management, Cornell University, November 2005.

Knoblauch, Wayne A., Jason Karszes, Charles Z. Radick, Dan Welch and Linda D. Putnam , Dairy Farm Business Summary, Central Valleys Region, 2004, E.B. 2005-13, Department of Applied Economics and Management, Cornell University, October 2005.

Knoblauch, Wayne A., Linda D. Putnam, Jason Karszes, James W. Grace, David L. Munsee, Jacob Schuelke, Joan S. Petzen, Dairy Farm Business Summary, Western and Central Plateau Region, 2004, E.B. 2005-09, Department of Applied Economics and Management, Cornell University, September 2005.

Knoblauch, Wayne A., Linda D. Putnam, Mariane Kiraly, Joseph J. Walsh, Stephen E. Hadcock, Larry R. Hulle, Dairy Farm Business Summary, Southeastern New York, 2004, E.B. 2005-10, Department of Applied Economics and Management, Cornell University, September 2005.

Knoblauch, Wayne A., Linda D. Putnam, Jason Karszes, Peggy Murray, Frans Vokey, Molly Ames, William Van Loo, Dairy Farm Business Summary, Northern New York, 2004, E.B. 2005-07, Department of Applied Economics and Management, Cornell University, August 2005.

Karszes, Jason, Wayne A. Knoblauch and Linda D. Putnam, Dairy Farm Business Summary, New York Large Herd Farms, 300 Cows or Larger, 2004, E.B. 2005-05, Department of Applied Economics and Management, Cornell University, June 2005.

Knoblauch, Wayne A., Linda D. Putnam, Jason Karszes, John Hanchar, Jason Murphy, Dairy Farm Business Summary, Western and Central Plain, 2004, E.B. 2005-03, Department of Applied Economics and Management, Cornell University, May 2005.

Knoblauch, Wayne A., Linda D. Putnam and Jason Karszes, Dairy Farm Business Summary, New York State, 2003, R.B. 2004-13, Department of Applied Economics and Management, Cornell University, January 2005.

Knoblauch, Wayne A., Linda D. Putnam, Mariane Kiraly, Jason Karszes, Dairy Farm Business Summary, New York Small Herd Farms, 80 Cows or Fewer, 2003, E.B. 2004-21, Department of Applied Economics and Management, Cornell University, December 2004.

Knoblauch, Wayne A. and Linda D. Putnam, Chapter 7, "Dairy Farm Management" in New York Economic Handbook 2005, E.B. 2004-20, Department of Applied Economics and Management, Cornell University, December 2004.

Knoblauch, Wayne A., Linda D. Putnam, Jason Karszes, Peggy Murray, Frans Vokey, Molly Ames, William Van Loo, Chris Nobles, Anita Deming, Dairy Farm Business Summary, Northern New York, 2003, E.B. 2004-19, Department of Applied Economics and Management, Cornell University, November 2004.

Knoblauch, Wayne A., Linda D. Putnam, Jason Karszes, George Allhusen, James W. Grace, Joan S. Petzen, Andrew N. Dufresne, Dairy Farm Business Summary, Western and Central Plateau Region, 2003, E.B. 2004-18, Department of Applied Economics and Management, Cornell University, November 2004.

Knoblauch, Wayne A., Linda D. Putnam, Mariane Kiraly, Joseph J. Walsh, Stephen E. Hadcock, Larry R. Hulle, Dairy Farm Business Summary, Southeastern New York, 2003, E.B. 2004-16, Department of Applied Economics and Management, Cornell University, October 2004.

Knoblauch, Wayne A., Linda D. Putnam, Jason Karszes, John Hanchar, Jason Murphy, Judith Barry, Dairy Farm Business Summary, Western and Central Plain, 2003, E.B. 2004-011, Department of Applied Economics and Management, Cornell University, August 2004.

Karszes, Jason, Wayne A. Knoblauch and Linda D. Putnam, Dairy Farm Business Summary, New York Large Herd Farms, 300 Cows or Larger, 2003, E.B. 2004-09, Department of Applied Economics and Management, Cornell University, July 2004.

Knoblauch, Wayne A. and Linda D. Putnam, Chapter 7, "Dairy Farm Management" in New York Economic Handbook 2004, E.B. 2003-22, Department of Applied Economics and Management, Cornell University, December 2003.

Knoblauch, Wayne A., Linda D. Putnam and Jason Karszes, Dairy Farm Business Summary, New York State, 2002, R.B. 2003-03, Department of Applied Economics and Management, Cornell University, November 2003.

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Knoblauch, Wayne A., Linda D. Putnam, Jason Karszes, George Allhusen, James W. Grace, Joan S. Petzen, Andrew N. Dufresne, Dairy Farm Business Summary, Western and Central Plateau Region, 2002, E.B. 2003-20, Department of Applied Economics and Management, Cornell University, November 2003.

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Knoblauch, Wayne A., Linda D. Putnam, William Van Loo, Peggy Murray, Frans Vokey, Anita Demming, Chris Nobles, Molly Ames, Jason Karszes, Dairy Farm Business Summary, Northern New York, 2002, E.B. 2003-14, Department of Applied Economics and Management, Cornell University, September 2003.

Knoblauch, Wayne A., Linda D. Putnam, Stephen E. Hadcock, Larry R. Hulle, Mariane Kiraly, Joseph J. Walsh, Dairy Farm Business Summary, Southeastern New York, 2002, E.B. 2003-11, Department of Applied Economics and Management, Cornell University, August 2003.

Karszes, Jason, Wayne A. Knoblauch and Linda Putnam, Dairy Farm Business Summary, New York Large Herd Farms, 300 Cows or Larger, 2002, E.B. 2003-08, Department of Applied Economics and Management, Cornell University, July 2003.

Knoblauch, Wayne A., Linda D. Putnam, Jason Karszes, John Hanchar, Jason Murphy, Judith Barry, Steve Richards and George Allhusen, Dairy Farm Business Summary, Western and Central Plain, 2002, E.B. 2003-04, Department of Applied Economics and Management, Cornell University, June 2003.

Knoblauch, Wayne, Jason Karszes, Brad Hilty, "Dairy Expansion: Financial Planning for Success", NRAES-166, ISBN 0-935817-90-5, February 2003.

Knoblauch, Wayne A. and Linda D. Putnam, Chapter 8, "Dairy Farm Management" in New York Economic Handbook 2003, E.B. 2002-21, Department of Applied Economics and Management, Cornell University, December 2002.

Knoblauch, Wayne A, Linda D. Putnam and Jason Karszes, Dairy Farm Business Summary, New York State, 2001, R.B. 2002-11, Department of Applied Economics and Management, Cornell University, November 2002.

Knoblauch, Wayne A., Linda D. Putnam, Mariane Kiraly and Jason Karszes, Dairy Farm Business Summary New York Small Herd Farms, 70 Cows or Fewer, 2001, E.B. 2002-18, Department of Applied Economics and Management, Cornell University, October 2002.

Knoblauch, Wayne A. and Linda D. Putnam, Dairy Farm Business Summary Eastern New York Renter Summary, 2001, E.B. 2002-19, Department of Applied Economics and Management, Cornell University, October 2002.

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Knoblauch, Wayne A., Linda D. Putnam, Jason Karszes, George Allhusen, James W. Grace, Joan S. Petzen, Andrew N. Dufresne and Janet Allard, E.B. 2002-14, Dairy Farm Business Summary Western and Central Plateau, 2001, Department of Applied Economics and Management, Cornell University, September 2002.

Knoblauch, Wayne A., Linda D. Putnam, Jason Karszes, Steven Richards, John Hanchar, Judith Barry, Kathleen English, Tim Terry and George Allhusen, E.B. 2002-09, Dairy Farm Business Summary Western and Central Plain, 2001, Department of Applied Economics and Management, Cornell University, July 2002.

Karszes, Jason, Wayne A. Knoblauch and Linda D. Putnam, Dairy Farm Business Summary New York Large Herd Farms, 300 Cows or Larger, 2001, E.B. 2002-08, Department of Applied Economics and Management, Cornell University, June 2002.

Richards, Steve, Steve Bulkley, Craig Alexander, Janice Degni, Wayne Knoblauch and Dan Demaine, E.B. 2002-02, The Organic Decision: Transitioning to Organic Dairy Production, Department of Applied Economics and Management, Cornell University, January 2002.

Knoblauch, Wayne A. and Linda D. Putnam, Chapter 8, "Dairy Farm Management" in New York Economic Handbook 2002, E.B. 2001-16, Department of Applied Economics and Management, Cornell University, December 2001.

Knoblauch, Wayne A, Linda D. Putnam and Jason Karszes, Dairy Farm Business Summary, New York State 2000, R.B. 2001-06, Department of Applied Economics and Management, Cornell University, October 2001.

Knoblauch, Wayne A., Linda D. Putnam, Mariane Kiraly and Jason Karszes, Dairy Farm Business Summary New York Small Herd Farms, 70 Cows or Fewer, 2000, E.B. 2001-10, Department of Applied Economics and Management, Cornell University, August 2001.

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TrAILCo Rebuttal Statement No. 18
Witness: Kevin T. McLoughlin

4/1/08 Pbg. SK

BEFORE THE

PENNSYLVANIA PUBLIC UTILITY COMMISSION

IN RE: APPLICATION OF TRANS-ALLEGHENY INTERSTATE LINE COMPANY FOR (I) A CERTIFICATE OF PUBLIC CONVENIENCE TO OFFER, RENDER, FURNISH AND/OR SUPPLY TRANSMISSION SERVICE IN THE COMMONWEALTH OF PENNSYLVANIA; (II) AUTHORIZATION AND CERTIFICATION TO LOCATE, CONSTRUCT, OPERATE AND MAINTAIN CERTAIN HIGH VOLTAGE ELECTRIC TRANSMISSION LINES AND RELATED ELECTRIC SUBSTATION FACILITIES; (III) AUTHORITY TO EXERCISE THE POWER OF EMINENT DOMAIN FOR THE CONSTRUCTION AND INSTALLATION OF AERIAL ELECTRIC TRANSMISSION FACILITIES ALONG THE PROPOSED TRANSMISSION LINE ROUTES IN PENNSYLVANIA; (IV) APPROVAL OF AN EXEMPTION FROM MUNICIPAL ZONING REGULATION WITH RESPECT TO THE CONSTRUCTION OF BUILDINGS; AND (V) APPROVAL OF CERTAIN RELATED AFFILIATED INTEREST ARRANGEMENTS	:	Docket Nos. A-110172 A-110172F0002 A-110172F0003 A-110172F0004 G-000721229

REBUTTAL TESTIMONY OF KEVIN T. MCLOUGHLIN

Re: Vegetation Management Practices and The Use of Herbicides

December 10, 2007

REBUTTAL TESTIMONY OF KEVIN T. MCLOUGHLIN

Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.

A. My name is Kevin T. McLoughlin. My business address is 520 Business Park Circle, Stoughton, Wisconsin 53589.

Q. BY WHOM ARE YOU EMPLOYED AND IN WHAT CAPACITY?

A. I am employed by Environmental Consultants, Inc. ("ECI") as a Senior Consultant. ECI is a consulting firm engaged in a broad spectrum of activities in environmentally-related science.

Q. HAVE YOU PREVIOUSLY SUBMITTED DIRECT TESTIMONY IN THIS PROCEEDING ON BEHALF OF THE TRANS-ALLEGHENY INTERSTATE LINE COMPANY ("TrAILCo")?

A. No, I have not.

Q. PLEASE DESCRIBE YOUR CURRENT RESPONSIBILITIES AND PROFESSIONAL EXPERIENCE.

A. As a Senior Consultant, my practice primarily focuses on electric transmission rights-of-way ("ROW") vegetation management issues and strategy.

EDUCATION AND EXPERIENCE

Q. PLEASE SUMMARIZE YOUR EDUCATION.

A. I earned a B.S. in Natural Resource Management from the State University of New York ("SUNY") College of Environmental Science and Forestry at Syracuse in 1971. My education also includes an M.S. in Environmental Management from the SUNY College of Environmental Science and Forestry in 1975.

Q. PLEASE SUMMARIZE YOUR PREVIOUS PROFESSIONAL EXPERIENCE.

A. Prior to joining ECI, I served as a System Forester with the New York Power Authority ("NYPA"), where I was responsible for vegetation management along 1,500 miles of 765, 345, 230, and 115 kilovolt ("kV") electric transmission ROW, comprising approximately 20,000 acres. I developed comprehensive ROW vegetation management plans and instituted a geographic information system ("GIS") application for vegetation management. In 2004, the NYPA was awarded the EPA's Pesticide Environmental Stewardship Award for its ROW Vegetation Management Program. In previous roles at the NYPA, I served as an environmental engineer with oversight of the environmental-related aspects of routing, ROW preparation, facility construction, clean-up, restoration and mitigation for various transmission line projects (i.e., 765kV, 345kV and 230kV) under the jurisdiction of the New York Public Service Commission and the Federal

Energy Regulatory Commission. For approximately 19 years beginning in 1979, I was the Research Project Manager with the Empire State Electric Energy Research Corporation ("ESEERCO"), where I managed over 20 ROW management research projects while also concurrently under an assignment to the New York Power Pool ("NYPP"). During this time period, I was the Administrator – Land Use and Industrial Waste Management Programs on behalf of the NYPP. In this capacity, I was responsible for regulatory affairs concerning a range of transmission-related environmental issues, including wetlands, endangered species, pesticides, herbicides & wood preservatives, non-point sources of pollution, and all aspects of integrated ROW vegetation management ("IVM").

Q. PLEASE OUTLINE YOUR SCIENTIFIC RESEARCH EXPERIENCE CONCERNING VEGETATION MANAGEMENT INVOLVING THE USE OF HERBICIDES.

A. During my employment with ESEERCO, we conceived and funded a number of ROW vegetation management research studies that involved the use of herbicides. I was specifically responsible for overseeing the engagement with each of the consulting groups who conducted these studies. TrAILCo Rebuttal Exhibit KTM-1 lists the nine different studies that were prepared under my supervision while employed by ESEERCO.

Q. HAVE YOU PRESENTED OR PUBLISHED THE RESULTS OF YOUR OWN RESEARCH OR OTHER WORK IN THIS AND OTHER AREAS?

A. Yes. I have published or presented four scientific papers on this and related subjects, which are listed on TrAILCo Rebuttal Exhibit KTM-1.

Q. ARE YOU A MEMBER OF ANY PROFESSIONAL ORGANIZATIONS?

A. Yes. I am a member of the International Society of Arboriculture and the Utility Arborist Association. I am also a member of the Society of American Foresters and the American Forestry Association. In 2004, I chaired the Environmental Concerns in Rights-of-Way Management 8th International Symposium.

Q. HAVE YOU PREVIOUSLY APPEARED AS A WITNESS BEFORE ANY OTHER REGULATORY AGENCIES?

A. Yes. I have testified in various regulatory and legal proceedings on behalf of member systems of the NYPP and/or ESEERCO, as well as for transmission project applications for the NYPA.

Q. WILL THE USE OF VARIOUS TERMS IN YOUR REBUTTAL TESTIMONY BE CONSISTENT WITH THE DEFINITIONS ASSIGNED TO THOSE TERMS IN THE TABLE OF NOMENCLATURE ATTACHED TO TRAILCO WITNESS FLITMAN'S DIRECT TESTIMONY AS TRAILCO EXHIBIT DEF-1?

A. Yes. In addition, I may define other specific terms in my rebuttal testimony, as necessary.

Q. PLEASE DESCRIBE THE TOPIC AND PURPOSE FOR YOUR REBUTTAL TESTIMONY.

A. The topics of my rebuttal testimony are vegetation management along transmission line ROW, in general, and the TrAIL project, in particular. In my rebuttal testimony I will also explain why the selective use of herbicides to control and manage vegetation is environmentally compatible and effective. The purpose of my rebuttal testimony is to respond to the direct testimonies of the Office of Trial Staff ("OTS") witness Gary L. Yocca and the Pennsylvania Office of Consumer Advocate ("OCA") witness Peter J. Lanzalotta. My rebuttal testimony will also respond to various concerns raised or allegations that were made during the public input hearings in Pennsylvania regarding the use of herbicides along the proposed TrAIL ROW.

Q. YOU UTILIZED THE TERM "INTEGRATED ROW VEGETATION MANAGEMENT" OR "IVM" IN YOUR TESTIMONY, ABOVE. WOULD YOU BRIEFLY DESCRIBE AN IVM PROGRAM?

A. Yes. IVM programs are actually a subset of the more widely known and practiced, particularly in agriculture, IPM or integrated pest management. IPM is the sustainable approach to managing pests by combining biological, cultural, physical, and chemical tools in a way that minimizes economic,

health, and environmental risks. IVM takes this basic framework further by defining it as a system of managing plant communities in which managers set objectives, identify compatible and incompatible vegetation, consider action thresholds, and evaluate, select and implement the most appropriate control method or methods to achieve set objectives. The choice of control method or methods is based on their environmental impact and anticipated effectiveness, along with site characteristics, security, economics, current land use and other factors. The key elements in the application of an IVM program for high voltage power line ROW are the twin interconnected objectives of selecting one set of plants (e.g., tall growing trees) to be discouraged, i.e., selectively removed, while concurrently encouraging the growth and development of all the other low growing compatible vegetation (e.g., shrubs, forbs and grasses) that are incapable of reaching heights that would interfere with the overhead conductors. One of the important components of the IVM process is the selective use of herbicides to curtail the growth of undesirable tall growing species while preserving, to the extent practical, the lower growing vegetation on the ROW to act as a biological deterrent to the future re-establishment of trees. Hence, the attentive implementation of a cost-effective IVM program on high voltage power line ROW meets the objectives of safe and reliable transmission of electric energy in an environmentally compatible manner.

Q. PLEASE DESCRIBE THE KEY COMPONENTS OF AN IVM PROGRAM.

A. After a forested landscape is initially cleared, the natural vegetation type that will ultimately re-occupy the site and dominate the area will be once again tall growing trees. When the cleared area is an electric utility ROW, these resurgent trees can grow too close to the overhead high voltage electric conductors. When this occurs, there is the potential for an electrical discharge from the electric line through the air to the tree and then to the ground. This is known as a "flash-over" or "line to ground fault." The result of a line to ground fault is a line outage, i.e., an instantaneous break in electric service, and a potentially very dangerous situation on the ground in the immediate vicinity of the high voltage discharge. As a matter of public safety and system reliability, therefore, utility ROW vegetation managers have a continuing need to preclude the establishment and subsequent growth of those tree species that are capable of growing into or even close to the electrical lines. Utilities ensure that tall growing species do not interfere with electric lines by committing to a long-term IVM program. The principle components of such a plan are: (1) understanding pest and ecosystem dynamics; (2) setting management objectives and tolerance levels; (3) compiling treatment options; (4) accounting for economic and ecological effects of treatments; (5) site-specific implementation of treatments; and (6) adaptive management, research and monitoring.

Q. WHY ARE HERBICIDES AN IMPORTANT COMPONENT OF AN IVM?

A. The appropriate and selective use of herbicides avoids some significant disadvantages that flow from the removal of trees and vegetation by mechanical means. Mechanical methods (e.g., mowing or hand cutting with a chain saw) of tree removal, alone, will physically clear the ROW of tree stems temporarily. These mechanical methods, however, allow trees to physiologically respond by regenerating quickly from the energy reserves contained in their undisturbed root systems. This tree regrowth occurs through such mechanisms as "stump sprouting" and/or in some species "root suckering." This regenerative capacity is characteristic of virtually all hardwood trees, e.g., maple, beech, birch, aspen, oak, ash, cherry, etc., and is particularly pronounced in the juvenile or sapling stage of tree maturation resulting in the eventual production of many more stems than were originally cut. By drawing upon the food reserves in their undisturbed root systems and through a series of complex compensatory physiological plant responses, the resurgent growth from the remaining portions of the tree (i.e., stump and/or roots) is actually enhanced when a tree stem is severed. It is through the production within the plant of naturally occurring stimulatory substances, together with the loss of growth inhibitors (caused by the removal of the above ground growth centers), which then exert their influence on the remaining vegetative structure to promote excessive new tree growth. These new, more numerous stems, growing much faster than when left uncut, (e.g., five to ten

feet or more the first year after cutting) makes subsequent tree removal from the ROW more frequent, laborious, hazardous and costly.

Q. WHAT ARE THE ADVANTAGES OF UTILIZING HERBICIDES WHERE APPROPRIATE?

A. The selective application of herbicides to only the tall growing target tree species can, in most instances, eliminate the resurgent tree growth problem because the herbicide when properly deposited on the target species will be translocated throughout the tree (including the root system) and will arrest all future growth and development, i.e., killing the entire target plant and not just temporarily removing the above ground portion. Just as importantly, selectively applying herbicides to the targeted tall-growing species allows the retention of nearly all the desirable low-growing vegetation that will naturally occur on the ROW. The elimination of the tall-growing trees from the ROW will also further encourage the establishment and foster the additional growth and development of all the indigenous low-growing woody shrubs, herbs (e.g., forbs and grasses), ferns, etc., by removing the trees that would otherwise begin to directly compete with and eventually "crowd out" the low-growing species over time. With effective and minimally disruptive tree removal, these lower growing desirable plant species will expand their presence into the ROW areas formerly occupied by trees and produce a thick dense plant cover that will discourage the invasion of new tree seedlings and/or the future growth of any remaining tree seedlings. These desirable low-growing plant communities

act as the "biological control" in this IPM/IVM scenario by thwarting future tree growth through their collective competition for the available site resources (i.e., sunlight, water, and nutrients) as well as through their sheer physical presence and overwhelming numbers.

Q. IN ADDITION TO THE BENEFITS OF REDUCING THE NEED FOR FUTURE APPLICATIONS OF HERBICIDES OR MECHANICAL METHODS, ARE THERE ANY OTHER INDIRECT BENEFITS OF A SELECTIVE USE OF HERBICIDES?

A. Yes. There may even be some indirect biochemical interactions, called allelopathy, occurring among various plants that result in a chemical competition of sorts between certain lower growing desirable ROW species and some of the undesirable tall growing tree species. Allelopathy has been defined as the influence of one plant on another via the production of natural growth inhibitors. Currently there exists only a limited understanding of this ability of plants to produce and release phytotoxic substances that can then be translocated to other plants and used to curtail certain critical physiological plant functions such as growth and reproduction. These naturally occurring "herbicides" offer yet another potential beneficial aspect of the biological controls in assisting the ROW vegetation manager to curb the spread of the undesirable tall growing trees.

Q. ARE THERE SPECIFIC BENEFITS TO UTILIZING HERBICIDES FOR SELECTED VEGETATION MANAGEMENT AND CONTROL?

A. Yes. In addition to their immediate benefits to the utility of reducing the undesirable tree population, the low-growing plant communities that are encouraged by the use of herbicides on competing vegetation offer an assemblage of plant species that provide diverse and productive habitat conditions for a wide variety of wildlife, e.g., birds, reptiles, amphibians, insects, and mammals. Managed ROW creates habitats that provide wildlife food and cover values that are remarkably different, and often times surpassing, those of the neighboring forest. Also, this juxtaposition of two different, but complementary plant communities (one perpetually kept in a low-growing condition and the other usually a forest) produces what is known as the "edge effect." This effect enhances wildlife profusion, i.e., abundance and diversity, in the boundary area transition zone (ecotone) between these two distinct habitat types. Some of the new and more numerous wildlife species attracted to these enhanced ROW created habitats provide yet another beneficial function of further reducing tree establishment and growth through their collective herbivory, e.g., browsing by deer and rabbits on young trees, girdling of tree seedlings by voles, and tree seed predation by mice. The establishment, fostering and preservation of these low growing plant communities on the ROW also serve to reduce, over time, the amount of work required and cost incurred by the utility to maintain the ROW (i.e., reduction in the number of tree stems to treat) each treatment cycle while coincidentally

diminishing the amount of herbicide necessary for adequate coverage of the reduced numbers of target species. As a professional vegetation control project manager, it was my experience that the owners of property under and along transmission ROW also saw significant advantages to these reductions in the occurrences and durations of the utility's maintenance activities along those ROW.

Q. IS THE USE OF HERBICIDES FOR VEGETATION MANAGEMENT SAFE FOR LANDOWNERS AND FARM ANIMALS WITHIN OR ADJACENT TO A TRANSMISSION LINE ROW, AND FOR THE GENERAL PUBLIC?

A. Yes. First, the use of all pesticides (including herbicides) by Allegheny Power and/or TrAILCo is subject to regulation under the Federal Insecticide, Fungicide, and Rodenticide Act ("FIFRA"), which is administered by the U.S. Environmental Protection Agency ("EPA"), and various state statutes. Pursuant to FIFRA regulations, no herbicide may be marketed, distributed, sold or advertised until the EPA registers it. After many years of product development, advanced toxicology studies and extensive field testing, the pesticide manufacturers submit to the EPA thousands of pages of research data that are compiled into a registration application. From this voluminous registration package, the manufacturer, in cooperation with the EPA, develops a proposed product label that identifies the pest or pests that the product will be effective in controlling and provides complete instructions for the correct use,

handling, and disposal of the product as well as other precautionary information required by FIFRA. As stated by the EPA: "[b]y their nature, many pesticides may pose some risk to humans, animals, or the environment because they are designed to kill or otherwise adversely affect living organisms. At the same time, pesticides are often useful because of their ability to control disease-causing organisms, insects, weeds, or other pests. The pesticide label is your guide to using pesticides safely and effectively. It contains pertinent information that you should read and understand before you use a pesticide product." The EPA-approved pesticide label becomes, in effect, the law concerning the application and use of that substance and when it is followed astutely with additional precautionary measures taken as needed, risks from the use of herbicides in an IVM program are significantly minimized. Moreover, in an IVM program, the specific choice of treatment method (including the exact selection of herbicide mix rates) can take into account and accommodate specific land uses on and adjacent to the targeted ROW. Hence, the ROW treatment method selected can be modified to accommodate the concerns of the underlying fee owners, adjacent landowners and other third-party users of the ROW. The type of application selected can be quite minimally intrusive, e.g., hand cut and stump treatment, whereby the tall growing trees are individually physically cut down by a chain saw operator and, immediately after the severing of the stem occurs, a small deposit of a herbicide is placed by a hand held applicator along just the outside perimeter of the cut stem, i.e., covering the cambium layer, containing the xylem and

phloem, the plants water and nutrient transfer vessels. Such a timely and focused spot application minimizes any chance for exposure to both the general public and others living closer to the ROW.

Yet, another technique commonly used by utilities to further reduce any risk and/or potential for exposure is to require prior notification of the underlying fee owners or those adjacent to the ROW in advance of scheduled ROW vegetation management work operations. Also, buffer zones between certain sensitive land uses (e.g., organic farms) and environmental features (e.g., streams and other water bodies) can also be employed to further reduce any potential for inadvertent exposure.

Q. IS THE APPLICATION OF HERBICIDES VIA AERIAL SPRAYING CONSIDERED AN IVM TREATMENT TECHNIQUE?

A. Yes, under certain circumstances and in specific ROW areas with the appropriate choice of selective herbicides, the aerial application of herbicides via helicopter is an accepted ROW vegetation management tool for the implementation of an IVM program. One example where aerial spraying can play a positive role in the inauguration of an IVM program on a newly cleared ROW, is as a reclamation method. Here the initial aerial spraying can quickly promote the conversion of the ROW from a crowded tree-filled thicket (i.e., many thousands of stems per acre) to a ROW condition with a much lower density of tree stems (i.e., a few hundreds per acre) and an abundance of

grasses. After initially clearing forested areas during ROW preparation, the resurgence of new tree growth, (propagating both from the former trees as stump sprouts or in some cases root suckers as well as from the residual soil bank and from airborne seeds of pioneer tree species coming in from the surrounding forest area) can sometimes result in the newly created ROW becoming virtually completely filled with trees, e.g., often more than 10,000 stems per acre. In such ROW situations, the desirable lower-growing species are quickly crowded out by the fast growing trees and only a few grasses are usually able to continue to grow under the thickening canopy cover of tree saplings. A ROW reclamation type program is required in these situations, whereby the entire undesirable tree stems need to be treated and/or removed at once in order to give the ROW another chance at naturally developing lower-growing plant communities. Under these circumstances, aerial or ground broadcast treatments with herbicides targeted for specific species must often be done to control those sections of ROW covered entirely by the target tree species. When selective herbicides are used, i.e., those that do not overtly harm grasses, sedges, and other monocots such as orchids, the targeted trees are effectively controlled and the remaining grasses are able to flourish and other species of plants are able to propagate (seed) into the now more open ROW.

Q ARE THERE OTHER CIRCUMSTANCES IN WHICH AERIAL APPLICATIONS OF HERBICIDES ARE AN EFFECTIVE TECHNIQUE IN IVM?

A. Yes. For example, another type of ROW situation that is appropriate for aerial spraying is where sections of ROW are so remote and in such rough terrain that ground access is very limited. In these nearly inaccessible ROW locations aerial spraying may also serve the purpose of reducing the target tree numbers so that the area becomes more amenable to selective treatment applications with hand held equipment such as cutting with follow-up stump treatment.

Q. IN YOUR EXPERT OPINION, DOES ALLEGHENY POWER'S CURRENT VEGETATION MANAGEMENT PRACTICE FOR ELECTRIC TRANSMISSION LINES REPRESENT A VALID APPROACH TO IVM?

A. Yes. After reviewing its standards and practices for vegetation management and meeting with relevant Forestry personnel, Allegheny Power, in my opinion, conducts its overall electric transmission ROW vegetation management activities under an effective IVM approach.

Q. WILL TRAILCO UTILIZE AN IVM APPROACH FOR VEGETATION CONTROL ALONG THE PROPOSED TRAIL ROW?

A. Yes. It is my understanding that TrAILCo will adopt and carry out all current or future Allegheny Power practices and standards for vegetation management along the TrAIL ROW.

Q. WOULD YOU SUMMARIZE THE CONCERNS RAISED BY WITNESSES AT THE PUBLIC INPUT HEARINGS REGARDING THE USE OF HERBICIDES FOR VEGETATION CONTROL AND MANAGEMENT ALONG THE PREFERRED TRAIL ROW?

A. Yes. The concerns raised during the public input hearings included, among other things, the perceived toxicity of herbicides, where and by what means TrAILCo might apply herbicides along the preferred TrAIL route, whether herbicides would be applied around water sources, residences, or on pasture or croplands, and how often herbicides would be applied.

Q. EARLIER IN YOUR TESTIMONY, YOU DESCRIBED THE REGULATION AND TESTING OF HERBICIDES AND ALSO EXPLAINED WHY THE APPROPRIATE USE OF HERBICIDES IS SAFE FOR LANDOWNERS, FARM ANIMALS AND THE GENERAL PUBLIC. WOULD YOU BRIEFLY EXPAND ON THAT ANSWER AND ADDRESS THE CONCERNS THAT WERE EXPRESSED AT THE PUBLIC INPUT HEARINGS REGARDING THE PERCEIVED TOXICITY OF THESE SUBSTANCES?

A. As I described in my rebuttal testimony above, all herbicides that are available to the public and to licensed commercial and industrial applicators such as Allegheny Power and TrAILCo have been rigorously researched and tested prior to being made available for public and commercial use. The manufacturers' labels, which also provide the required framework for safely

applying the herbicides, are derived from the rigorous research and testing upon which regulatory approvals are based. One of the EPA's fundamental testing standards and conditions for approval of an herbicide is that a labeled use must be demonstrated in laboratory testing to result in exposures too small to have any measurable effect on test animals. These standards are also substantially conservative. In approving a labeled usage, regulators typically require a one hundred- to several hundred-fold safety margin. For example, if the least measurable effect in the most sensitive test subject species is "x," then regulators will typically register the herbicide as having acceptable exposure amounts of 100 to perhaps 1,000 times less than the least measurable test amount. Careful application procedures, as practiced by Allegheny Power and TrAILCo and which include the significant dilution of selected herbicides before their applications, consistent with manufacturers' labels and instructions, will further minimize the potential for members of the public and farm animals to be exposed to these approved herbicides.

Q. CAN DIFFERENT TYPES OF HERBICIDES BE MIXED FOR A SINGLE APPLICATION AND, IF SO, DOES THIS RESULT IN A MIXTURE WITH INCREASED TOXICITY?

A. As I testified above, among the advantages of herbicides is the ability to target specific unwanted species with substances designed for those species, and where two or more unwanted types of vegetation are present on a ROW segment, it is economical and less intrusive to combine the necessary

substances. Again, any combinations would be done only where allowed and according to the instructions of the manufacturers' label. It is my understanding that manufacturer research and testing of various combinations of the limited group of herbicides currently utilized by Allegheny Power show no decrease in the margins of safety from toxic exposure that are already built in to the underlying approvals and registered usages and application requirements for each of these herbicides.

Q. WOULD YOU PLEASE EXPLAIN HOW ALLEGHENY POWER/TRAILCO'S GUIDELINES AND PRACTICES FOR APPLYING HERBICIDES WILL ENSURE THAT THESE SUBSTANCES ARE USED SAFELY?

A. Allegheny Power's guidelines and practices for applying herbicides are extensive. These guidelines not only strictly limit where herbicides are to be utilized, but also under what weather and other conditions herbicides will be applied. In addition to the buffer zones around ponds, lakes, and flowing water as I discussed above, buffer zones are also provided for all known sources for domestic or commercial water wells. Buffer zones are required for residences, barns, gardens and farm crops, and a variety of ornamental and cultivated trees. Herbicides are not applied to pasture land or land under cultivation. Moreover, TrAILCo will also work with landowners or other affected third-parties to ensure that additional specific buffer zones are established where the owners of

property under the ROW have specific concerns. TrAILCo will also attempt to accommodate specific requests that herbicides not be utilized over a property.

Q. PLEASE DESCRIBE THE SPECIFIC GUIDELINES FOR AERIAL APPLICATIONS.

A. The aerial application of herbicides, which appeared to be of most concern to witnesses at the public input hearings, are performed under a strict and comprehensive set of specifications, terms, and conditions which must be followed by the applying contractor. First, aerial applications may not take place along ROW segments that traverse through more heavily developed areas. Next, the specifications I just referenced include, among other things, minimum helicopter crew sizes, a pre-spray flight with Allegheny Power personnel over each line scheduled for aerial spraying, a defined set of approved helicopter types that may be used, and the use of only an approved set of spraying equipment.

Q. WHAT STEPS ARE TAKEN TO ENSURE THAT HERBICIDES APPLIED AERIALLY DO NOT AFFECT PEOPLE, ANIMALS, OR PLANTS OUTSIDE OF THE TARGETED ROW?

A. Allegheny Power's guidelines for when, where, and how herbicides are to be applied ensure that herbicides reach the ground only where they are directed. Herbicides are not applied when wind conditions exceed five miles per hour. ROW corridors are not sprayed under any conditions at locations where ground

clearances are 150 feet or more below the conductors (typically where the line would cross over a ravine or gully). Helicopters are required to maintain a steady ground speed during operations – approximately twenty five miles per hour – so as to allow the released herbicides to fall to the ground without being unduly dispersed by the downdraft of helicopter blades. In addition to these application specifications, substances such as drift control agents are often mixed with the herbicide to further ensure that the herbicides fall directly on the targeted ROW segments in droplet sizes that are designed to maximize effectiveness and control.

Q. DOES THE APPLICATION OF HERBICIDES POSE A RISK TO GROUNDWATER SOURCES ALONG THE PREFERRED TRAIL ROW?

A. No. First, the application of herbicides in the diluted forms required and in accordance with the strict conditions (regarding location and application methods) followed by Allegheny Power, will protect groundwater sources. Moreover, since ROW terrain in Western Pennsylvania is typically quite dense in groundcover, very nearly all of any application of herbicides will fall on the targeted vegetation rather than falling through to any bare ground. Allegheny Power's application guideline also limit the use of herbicides in bare ground areas to those within its substations and power stations and only selected areas along a transmission ROW where there is no risk of the inadvertent movement of the herbicide away from the targeted terrain. Finally, the types of soil present in most of the Allegheny Power service areas are not highly permeable,

which would limit the passage through the soil of any diluted herbicides that might actually reach the ground.

Q. IN GENERAL TERMS, HOW OFTEN ARE HERBICIDES APPLIED TO A TARGETED SEGMENT OF TRANSMISSION ROW?

A. It is important to note that, contrary to some of the comments made at the public input hearings, herbicides are not applied to any one ROW segment on a regularly-occurring basis. Following the initial preparation of the ROW for a new electric transmission line, which will be performed by mechanical means, the time between any initial and subsequent applications of herbicides, whether aerially or by hand, will be measured in years and will increase in time as the re-growth of tall trees is discouraged or substantially reduced by the encouragement of the lower growing woody shrubs and other herbaceous vegetation I described above. Again, this is one of the most significant advantages of the appropriate and selected use of herbicides: it can actually result in the decreased need for herbicide applications and other methods of vegetation management over the long term by encouraging the growth of more desirable vegetation to naturally control unwanted trees. This minimal number of applications, e.g., a treatment cycle of once every four to five years or longer over a several year period, serves to further minimize the intrusion and any risk to landowners, farm animals and the general public.

Q. YOU JUST INDICATED THAT A PROPERTY OWNER ALONG THE ROW CAN ASK FOR SPECIFIC BUFFER ZONES BEYOND THOSE PROVIDED FOR IN THE GUIDELINES. ARE THERE OTHER AVENUES AVAILABLE TO A PROPERTY OWNER WHO HAS CONCERNS ABOUT VEGETATION CONTROL PRACTICES?

A. Yes. Allegheny Power currently permits, and TrAILCo will likewise, transmission ROW property owners to carry out vegetation control on their property according to the terms and conditions of a Landowner Maintenance Agreement ("LMA"). Under the LMA, the landowner conducts ROW vegetation management according to an agreed set of specifications for which TrAILCo reimburses the landowner based upon the cost TrAILCo would have incurred if TrAILCo had performed the same work using herbicides.

Q. TURNING YOUR ATTENTION TO THE PARTIES' DIRECT TESTIMONIES, WOULD YOU PLEASE ADDRESS THE DISCUSSION OF VEGETATION MAINTENANCE IN OTS WITNESS YOCCA'S DIRECT TESTIMONY?

A. Yes. Although he makes no specific criticisms of, or recommendations concerning, TrAILCo's planned vegetation control activities, Mr. Yocca characterized the testimony from the public input hearings as indicating that subsequent vegetation maintenance could have an adverse affect on domestic animals and natural water supplies used for livestock and crops. He also characterized citizens' concerns that herbicide applications could adversely

affect domestic water supplies and, if carried out near residences, could adversely affect human health. It is precisely these kinds of concerns, by both the public and Allegheny Power, to which its comprehensive standards and guidelines for selectively applying herbicides along carefully selected segments of its existing transmission rights-of-way are intended to respond. TrAILCo's practices will be no less cautious. It is those concerns that are the fundamental bases for the buffer zones around standing and running water and any identified water supplies for domestic, commercial, or agricultural use. The detailed specifications and guidelines I have described above as to when, where, and under what weather and other conditions TrAILCo will apply herbicides, whether by air or hand, fully respond to the concerns expressed at the public input hearings.

Q. OCA WITNESS LANZALOTTA PROPOSES THAT THE ALLEGHENY POWER/TRAILCO POLICIES FOR THE AERIAL APPLICATION SHOULD BE CONSIDERED ABSOLUTELY MANDATORY FOR USE ALONG THE PREFERRED TRAIL ROW IN PENNSYLVANIA. IS THIS PROPOSAL NECESSARY IN YOUR VIEW?

A. No, I do not believe it will further the public's or landowner's interests to include a rigid mandatory policy for aerial herbicide applications along the TrAIL ROW. Again, I have fully described the prudent Allegheny Power standards for the aerial and hand application of herbicides, all of which TrAILCo will adopt. No party has provided any indication that TrAILCo will

not continue to carefully and appropriately utilize herbicides for vegetation control in an IVM program. Nor has there been any indication that prior Allegheny Power vegetation management practices or specific activities have been improper or placed landowners or the general public at risk. It would be far more effective to continue to allow TrAILCo the discretion and flexibility to manage and carry out vegetation management along the TrAIL route, including the flexibility to adopt new technologies and practices as they become available.

Q. OCA WITNESS LANZALOTTA ALSO RECOMMENDS THAT TRAILCO BE PERMITTED TO UTILIZE AERIAL APPLICATIONS OF HERBICIDES ONLY ALONG PORTIONS OF THE TRAIL ROW WHERE GROUND ACCESS IS LIMITED BY TERRAIN CONTOURS OR IS OTHERWISE UNACCEPTABLY UNSAFE. SHOULD THIS RECOMMENDATION BE ADOPTED?

A. No, this recommendation would significantly and unnecessarily limit TrAILCo's already cautious and prudent use of aerial applications. Although the ROW areas to which Mr. Lanzalotta would limit the aerial applications of herbicides are the types of terrain and conditions that are particularly amenable to aerial spraying, his recommendation would prohibit TrAILCo from utilizing aerial spraying from other types of ROW way terrains and areas for which such applications continue to be safe and appropriate, given TrAILCo's standards and guidelines for doing so.

Q. PLEASE ADDRESS MR. LANZALOTTA'S RECOMMENDATION THAT TRAILCO'S PENALTY POINT ASSESSMENT SYSTEM FOR BUFFER ZONE VIOLATIONS BY CONTRACT HELICOPTER PILOTS WHO CONDUCT AERIAL APPLICATION OPERATIONS SHOULD BE AMENDED.

A. Mr. Lanzalotta recommends that the penalty point assessment system be modified to reflect a reduced tolerance by TrAILCo for buffer zone violations by contract pilots conducting spraying operations. Again, I believe this recommendation is unnecessary and would represent an intrusion into TrAILCo's discretion to manage its day-to-day operations. Mr. Lanzalotta did not allege or provide any other indication that contract vendor pilots have been violating buffer zones during applications. It is my understanding from Allegheny Power forestry personnel that there have been very few instances where penalty points have ever been assessed against a contract pilot for a spraying infraction within a buffer zone. Rather, as a result of caution on their part, it has been Allegheny Power's experience that contract pilots will leave buffer zones in excess of the areas outlined. As with the prior two OCA recommendations, this recommendation need not be adopted.

Q. DOES THIS CONCLUDE YOUR REBUTTAL TESTIMONY?

A. Yes. However, I reserve the right to file such additional testimony as may necessary or appropriate.

ESEERCO ROW HERBICIDES REPORTS

ESEERCO Research Report EP85-38, *Vegetation Dynamics Along Utility Rights-of-Way: Factors Affecting the Ability of Shrub and Herbaceous Communities to Resist Invasion by Trees*, prepared by the Institute of Ecosystem Studies, Millbrook, N.Y., December 1993.

ESEERCO Research Report EP84-8, *Herbicide Residue and Mobility Study: Existing* and *Simulation Model Review, Volume I & 2,* prepared by Arthur D. Little, Inc., December 1987.

ESEERCO Research Report EP83-15, *Long-Term Right-of-Way Effectiveness*, prepared by Environmental Consultants, Inc., Southampton, PA, October 1985.

ESEERCO Research Report 84-17, *Right-of-Way Treatment Cycles*, prepared by Environmental Consultants, Inc., Southampton, PA, 1985.

ESEERCO Research Report EP80-5, *Cost Comparison of Right-of-Way Treatment Methods*, prepared by Environmental Consultants, Inc., Fort Washington, PA, 1984.

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ECI TrAILCo Papers

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22. At page 9, lines 20 through 22 of your direct testimony, you testify that many residences are located very near the proposed transmission line and that many residents will be forced to live, play or work next to or under the line.

a. Identify the "many residences." by number and address, which you testify are located "very near" the power line;

b. Of those residences so identified in the response to subpart (a) above, identify, describe and explain which ones were built after any easements were placed of record in favor of West Penn Power Company. Provide copies of all documents relied upon or supporting your answer;

c. Explain, based on distance in feet, what you mean by "located very near" the proposed transmission line and identify the distance, in feet, each of the many residences that you testify are "located very near" each section of the proposed transmission line; and

d. Identify, describe and provide all documents you relied upon or supporting the aforesaid statement at page 9, lines 20-22 of your direct testimony.

ANSWER: TrAILCo has identified and applied for a 1200 foot corridor through Washington and Greene Counties, and has identified the proposed locations of the power lines on certain maps and/or drawings. TrAILCo claims it notified all property owners within the corridor of its Application. At the public input hearing, some of those property owners testified that their residences falls within the 1200 foot corridor.

I am also aware that a lawsuit has been filed against TrAILCo or related entities, alleging that valid easements "in favor of West Penn Power Company" within the right of way exist. I am not offerring an opinion, expert or otherwise, on the existence or validity of any so-called easement "in favor of West Penn Power Company."

TrAILCo Cross Examination
Exhibit 6

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10. [sic Interrogatory No. 7] Provide copies of any Line Route Evaluation Report or comparable analysis completed with in the last 5 years of which you are aware relating to the siting of a high voltage electric transmission line that addresses (i) "Construction Impacts"; (ii) "Maintenance Impacts"; (iii) "Cumulative Impacts"; and (iv) ("Secondary Impacts") as such terms are used on page 10, lines 14-17 of your direct testimony.

ANSWER: It is my opinion that an environmental report documenting potential impacts of a corridor construction project should address all impacts in detail, as defined above in my answer to Interrogatory No. 9 [sic Interrogatory No. 6].