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Background Information on High Voltage Fields

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The increased demand for power has led to higher voltages for overhead transmission lines. Environmentalists, governmental agencies, and some members of the scientific community have questioned if past biological effects research and experience with lower voltage lines provide adequate bases for predicting the possible health and environmental effects of the higher voltage lines. Only a small amount of work has been done to explore the possible effects, especially long term effects, of the exposure of biological systems to electric fields from transmission lines. Research in Western Europe and the United States has not identified any prompt or acute effects other than spark and electric discharge and no permanent effects. Contrasted with this are the studies of workers in Soviet and Spanish high voltage switchyards that report effects, such as excitability, headaches, drowsiness, fatique, and nausea, that are not found in Soviet line maintenance workers. The results of current and planned research, supported by both U. S. Government agencies and the private sector, should resolve a number of the present uncertainties and provide answers for the many questions concerning potential effects.

Introduction

The high-voltage fields that are of current environmental interest are the fields associated with the transmission of electricity. Since electricity is often generated at sites that are remote from the points of consumption, some means of electrical transmission is required. Most of this transmission is accomplished with overhead transmission lines. The increase in the demand for power and the economies that can be realized when electricity is transmitted at high voltage have led to higher and higher transmission voltages. Extra-high-voltage (EHV) is the term applied to transmission of electricity at or above 345 kV. The highest transmission voltage in use in North America was 10 kV in 1892. Transmission at 345 kV began in the mid-1950's, followed by 500 and 765 kV in the late 1960's. In 1971, 22% of the U. S. transmission capability was at 500 kV, and it is estimated that by 1980 15% of the transmission capability will be on 765 kV lines (*1*). Voltages as high as 2000 kV have been considered, with 1500 kV as the highest level at which extensive research has been done (*1*). The Bonneville Power Administration completed a prototype 1100 kV line in 1976 (*2*).

Environmentalists, governmental agencies, and some members of the scientific community have questioned whether past biological effects research and experience with lower voltage lines provide an adequate basis for predicting the possible health and environmental effects of the higher voltage lines (*3–5*). The state of current knowledge and the need for additional research is being critically examined. The New York State Public Service Commission is currently holding hearings on the health and environmental impact of 765 kV transmission lines (*6, 7*). A considerable amount of expert testimony from the scientific community has been incorporated into the hearing record. In March 1976, the Environmental Protection Agency (EPA) requested data and information on the health and environmental effects associated with the operation of extremely high voltage transmission lines (*8*). Over 50 responses exceeding 6,000 pages of material have been received. A request for proposals to analyze the submitted material to determine if there are subtle effects and if concerns have been adequately addressed by past research efforts has been issued with joint support from EPA and the Energy Research and Development Administration (ERDA). ERDA has established an Interagency Advisory Committee on Electric Field Effects from

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High Voltage Lines. The Committee's objective is to coordinate all research efforts in the Government relating to the environmental effects of electric fields from high voltage transmission lines. Nine Federal agencies are participating in the Committee's deliberations.

Public Health Impact

The effects of transmission lines fall into two categories, electric and magnetic field effects and corona effects. Field effects have been discussed in depth (*9–13*) and corona effects were the subject of a recent study at the Illinois Institute of Technology Research Institute that was sponsored by ERDA (*14*).

As with any current carrying device, an electromagnetic field exists about a transmission line. For practical purposes, the electric and magnetic fields can be discussed separately. The electric field at or near the ground depends principally on the line voltage and the conductor height. At certain locations on the transmission line right-of-way ground level electric field strengths can approach appreciable values, 10 kV/m for a 46-ft-high 765 kV line (*15*). The earth's DC electric field is about 0.13 kV/m and can be as high as 3 kV/m under thunderclouds, even in the absence of local lightning (*16*). A typical electric field profile for a 765 kV transmission line is shown in Figure 1 (*15*). Typical profiles for 345 and 500 kV lines (*15*) and a profile for a 1100 kV line (*17*) have been given elsewhere.

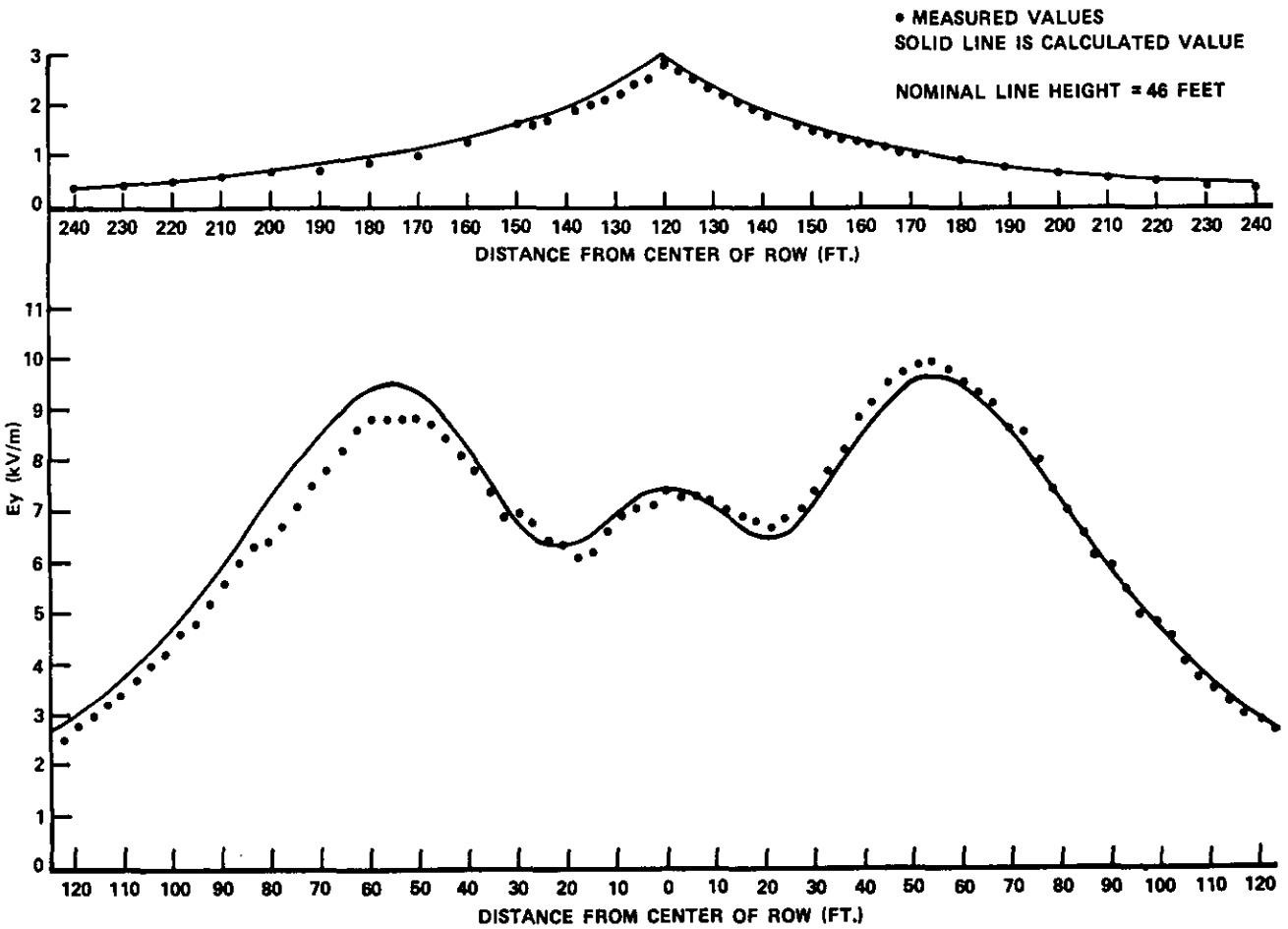

FIGURE 1. Measured and calculated vertical electric field strength E_y at 1 m above ground for a typical 765 kV line. Minimum line height about 46 ft, nominal phase to neutral voltage 440 kV, average phase-to-phase voltage 766 kV. Note upper curve gives values for field strength beginning at 120 ft from the center line of the right-of-way (ROW), the lower curve gives values from the center line to 120 ft.

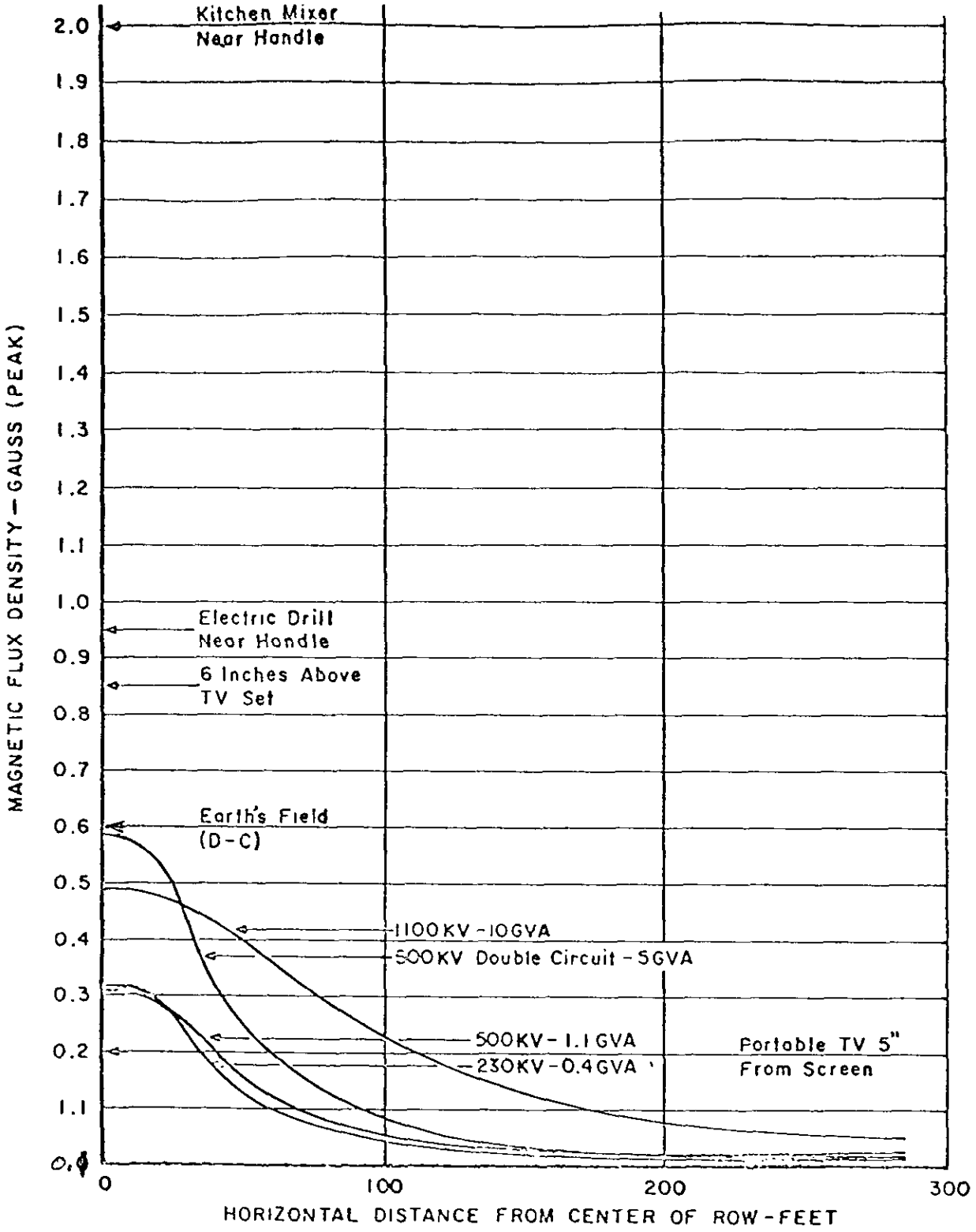

FIGURE 2. Profile of calculated magnetic flux density (60 Hz) at 1.5 m above ground for transmission lines compared with localized fields from household appliances reproduced with permission from Bonneville Power Administration data (17).

The electric-field capacitively couples to objects under the line and induces a displacement current. Questions have been raised about the resultant effects of this displacement current on biological systems. Voltages are also induced on objects that are insulated from ground. Electrical discharges, similar to the discharge experienced by people walking across a rug and touching a grounded doorknob, can be experienced by a person insulated from ground touching a grounded object such as a metal fence pole or conversely a grounded person touching a vehicle isolated from ground on nonconducting tires.

Magnetic field strengths at ground level depend on the line current and conductor height. Calculated values fall in the range of 0.3–0.6 gauss, a range which includes the Earth's DC field, 0.6 gauss. Comparative values, reproduced from Bonneville Power Administration data (*17*), are shown in Figure 2. Currents can also be produced in conductors near the line through magnetic coupling.

Corona discharge occurs when the electric field strength reaches values sufficient to cause air ionization. Transmission lines are designed not to go into corona under normal operating conditions. However, local inhomogenities, nicks, scrapes, insects, raindrops, etc. on the conductor surface can increase local field strength sufficiently to produce corona. The phenomena associated with corona discharge include audible noise, radio and television interference, and ozone production.

The public health impact of EHV transmission can only be discussed in a qualitative way. Corona-related phenomena, i.e., audible noise and radio and television interference, decrease with increasing distance from the line and for the most part are intermittent; for a well constructed line they occur only during and immediately after periods of rain, snow, or fog. Studies to date indicate that contributions to environmental ozone levels are negligible (*18–20*). Thus the impact of corona related phenomena is related to average meteorological conditions, specific line configurations, and the population density near power line corridors. Population density figures for current and proposed power line corridors are not available to us. Thus, though the number of people that are intermittently influenced by phenomena related to corona may be large, it is essentially unknown. Similarly the number of people influenced by the electric and magnetic fields from power lines is also unknown. These fields also drop off rapidly with distance from the line. The risk, if any, from exposure to existing fields is not well established. Thus any quantitative estimate of public health impact is, of necessity, speculative.

Summary of the State of the Art of Effects Data

Reviews of the biological effects of high voltage electric fields have been published by Kaufman and Michaelson (9) and Bridges (*10–13*). Kaufman and Michaelson (*9*) conclude, "research to date has failed to provide convincing evidence that human exposure to stationary or low-frequency electric fields has any harmful biological effect." In his more recent review, Bridges (*10*) concludes, "although the great bulk of evidence suggests that there are no significant effects of electric fields as encountered under extra-high voltage lines, further research is needed." The need for further research is treated in the next section. For a concise review of research on biological effects the reader is referred oo Bridges' article (*13*) which summarizes his earlier work, and a review prepared by the Bonneville Power Administration (*17*).

Only a small amount of work has been done to explore the possible effects of electric fields from transmission lines on biological systems. Bridges lists seven American and Western European studies that relate to effects on humans (*12, 13*). Four of these studies are on effects of short term exposures to electrical fields, one examines the medical treatment experience of people living within 25m of a transmission line, another examines the experience of farm workers on 18 farms traversed by a 765 kV line, and the final study investigates the physiological state of transmission line workers intermittently exposed to intense electric fields during maintenance work. No prompt, acute, or permanent effects were noted in any of these studies, which is reassuring. However only two of these studies look at long-term exposure.

Contrasted with the above studies are the results of studies on workers in Soviet and Spanish high voltage switchyards (*21–23*). These studies report effects such as excitability, headaches, drowsiness, fatigue, and nausea in switchyard workers exposed to electric fields. Bridges (*12, 13*) argues that there are other factors in the switchyard environment such as acoustical noise which may be more significant than electric fields in producing the observed effects. The argument is developed in detail by Bridges and will not be repeated here except to note that one of the Soviet investigators has stated that "the staff maintaining 500 and 750 kV lines in the USSR in contradiction to the staff maintaining substations of the same voltages do not complain of their health changing for the worse under the influence of the field (*24*).

Bridges (*12, 13*) lists eight American and Western

European studies on the effects of electric fields on agricultural or laboratory animals. Two of these are abstracts and one other is not generally available. As in the human studies, no prompt or acute effects are noted. A small reduction in weight gain was reported for progeny of mice exposed to intense fields (160 kV/m), and transitory changes in the electrical activity, reaction time, and blood composition were reported for rodents exposed to intense fields in the range from 50 to 100 kV/m. In summarizing these data, Bridges states, "some of the findings, however, are not definitive, owing to possible problems in biological methods or laboratory environments." For example the design of animal exposure apparatus presents the problem of simulating the electric field environment of EHV lines without inadvertently electrifying support apparatus such as water bottles or feeding dishes. Mini-shocks from a feeding dish could well lead to diminished weight gain which could be erroneously attributed to a direct rather than indirect effect of the electric field.

In summary, the amount of biological effects data is small. Specific prompt or acute adverse effects have not been found in humans or animals due to exposure to electric fields of the form and magnitude likely to be encountered around power transmission lines. The observation of effects in Soviet switchyard workers after long duration exposure to relatively intense fields raises two questions. First, are the existing data on effects adequate to determine whether or not there are effects due to long exposure durations? Second, are there collateral factors that interact with electric fields to produce effects and if so are these factors widespread in the environment as well as the workplace?

Recommendations for Future Research

Sponsored by the Electric Power Research Institute, the Illinois Institute of Technology Research Institute (IITRI) has prepared a recommended biological effects research program (*10*). The bases of the recommended program include: a Workshop, an *ad hoc* meeting of experts, and a "state-of-the-art" review of past and ongoing programs (*10*). Four categories of studies were recommended: studies using existing electric field environments, studies in controlled simulated environments, studies on medical devices, and dosimetry studies.

Under ERDA sponsorship, the IITRI group has also prepared a research plan for investigating coupling and corona effects from EHV lines (*14*). Three areas where additional work is needed have been identified: "let-go" and capacitive discharge effects as related to power line environmental situations, flammable mixture ignition hazards, and psychoelectrical response of annoyance, perception, and pain. As in the earlier IITRI study, the recommended research was based on: a review of past and present research programs, a special workshop, and steering committee meetings.

Insulated metal objects, such as vehicles or fences, near overhead transmission lines can become electrified. Additional work is needed to relate existnng biological current, voltage, shock, or let-go criteria more adequately to the overhead power line situation with emphasis on possible effects on children.

Under contrived conditions, it is possible to demonstrate the ignition of fuels and other flammable mixtures underneath power lines. Additional work is needed to develop statistical data on the incidence of fuel ignition and related liquids beneath power lines.

The responses to currents and discharges range from simple perception through annoyance to possible long-term or prompt hazards. Catastrophic effects are well understood. Annoyance and perception levels of arc discharges and leakage currents associated with power lines need to be further explored and compared to those of non-power-line sources.

A number of questions which have been asked are being addressed in current and planned research. In Fiscal Year 1975 Federal Agencies, principally ERDA, earmarked about $2.3 million for work related to the biological effects of electric fields. Most of the funds went into two and three year programs. The titles of these projects are given in Table 1. The Electric Power Research Institute is also sponsoring a considerable amount of biological effects research. These projects are listed in Table 2.

Summary

Some have questioned whether our knowledge of the biological effects of electric fields and operating experience with lower voltage lines are adequate for predicting the possible health and environmental effects of extra-high voltage lines. Research in Western Europe and the United States has not identified any acute or prompt effects other than spark and electric discharge and no permanent effects. Effects such as excitability, headaches, drowsiness, fatigue, and nausea have been reported for workers in Soviet and Spanish high voltage switchyards. However, these effects are not seen in workers who perform maintenance on Soviet extra-high-voltage

Table 1. U. S. Government-sponsored research on health and environmental effects of electric power transmission lines.

Project title	Contractor	Sponsor
Electric Field Instrumentation and Calibration	National Bureau of Standards	ERDA
State-of-the-Art Review and Research Plan for Corona and Corona Induced Effects from HV Transmission	Illinois Institute of Technology Research Institute	ERDA
Psycho-Acoustic Response to Noise in the Audible Spectrum for HV Transmission Lines	National Bureau of Standards	ERDA
Biological Effects of High Strength Electric Fields on Small Laboratory Animals	Battelle Pacific Northwest Laboratories	ERDA
Effects of Electric Fields on Fruit Flies	Battelle Pacific Northwest Laboratories	ERDA/EPA
Synthesis of Data and Information Received in Response to EPA Federal Register Notice of March 18, 1975	Award in process	ERDA/EPA
Effects of 60 Hz Fields on Mammalian Central Nervous System	W. R. Adey UCLA	DHEW/EPA
Environmental Effects of Bonneville Power Administration (BPA) 1100 kV Test Transmission Line	Battelle Pacific Northwest Laboratories	BPA
Investigation Into Environmental Effects of HVDC Transmission	Western Interstate Commission for Higher Education	BPA
Investigation of Ground Level Electric Field and Ions from HVDC Lines	intramural	BPA
Effects of Electric Power Transmission on Reptors (Hawks, Eagles, Osprey)	Morlan Nelson Tundra Films	BPA

Table 2. Biological effects research programs sponsored by the Electric Power Research Institute.

Project Title	Number	Contractor
Ecological Influence of Electric Fields	RP 129	Westinghouse Electric Corporation
Effects of 60-Hertz Electric and Magnetic Fields on Patients with Implanted Cardiac Pacemakers	RP 679	IITRI[a]
Electric Field Effects on Large Animals	RP 799	Battelle Pacific Northwest Laboratories
Biological Effects of Electric Fields	RP 857	IITRI
Field Evaluation of Effects of HV Powerlines	RP 934	
Basic Introduction to Electrical Effects of HV Power Lines	SOA 76-323	IITRI
Feasibility Study—Epidemiology of Linemen and Switchyard Workers	TPS 76-639	Equitable Environmental Health, Inc.

[a]Illinois Institute of Technology Research Institute.

transmission lines, and hence may be due to a unique switchyard environment rather than exposure to intense electric fields. The research needed to resolve this and other questions is now underway or planned. Existing manpower resources should be adequate to cover present research needs unless subtle long-term effects at relatively low field strength are uncovered.

This material is drawn from a Background Document prepared by the author for the NIEHS Second Task Force for Research Planning in Environmental Health Science. The Report of the Task Force is an independent and collective report which has been published by the Government Printing Office under the title, "Human Health and the Environment—Some Research Needs." Copies of the original material for this Background Document, as well as others prepared for the report can be secured from the National Technical Information Service, U. S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161.

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