combination of nonspecular conductors and dulled towers would be used where a route would pass within 1 mile (refer to Table 3-3). These mitigation measures would reduce the visual contrasts from dispersed viewpoints within the boundaries of WSAs or wilderness areas and are expected to result in residual visual impacts from low to moderate.

The results of the visual impact assessment for each of the alternative routes are described, from north to south, in the following sections. For detailed descriptions of the potential impacts, refer to the technical reports (locations where technical reports can be reviewed are listed in Appendix H).

Alternative Routes - Midpoint to Dry Lake

Route A

From Midpoint Substation to Jackpot, Nevada, Route A would result in high residual visual impacts to views from residences located within 1/2 mile of the assumed centerline. These impacts would occur for 1.5 miles adjacent to the communities of Hansen and Eden in Idaho (Links 20, 41), 0.9 miles near rural residences north of Hansen (Link 10), 4.7 miles occur in the Rock Creek Area (Link 41), and 0.5 miles near Jackpot (Link 70).

Other high residual visual impacts are expected to occur for 0.4 miles where the route would cross the access road to the Minidoka Relocation Center (Link 20) and for another 0.4 miles (Link 20) from the Minidoka Relocation Center historic interpretive site. The route would not comply with VRM Class II for about 0.8 miles where the route would cross the Snake River Canyon southwest of Murtaugh.

A total of approximately 1.7 miles of high residual impacts are expected to occur where the route would cross access roads to recreation sites in the Salmon Falls Reservoir SRMA northwest of Jackpot. Route A would not comply with VRM Class I where the route passes through the Salmon Falls Creek Reservoir SRMA east of Browns Bench (Link 70).

Between Jackpot and the North Steptoe substation site, the route would result in 0.2 miles of high residual visual impacts to views from residences located near Contact, Nevada (Links 101, 102, 110). In the Contact area, the route would not comply with VRM Class II for about 3.0 miles, where the route would pass through the Granite Mountains (Link 102). The route would also not comply with VRM Class II for 1.0 miles where the route would cross Bishops Creek and pass along the northern toe of the Windermere Hills (Link 1612). In addition, the route would not comply with VRM Class II for about 2.0 miles where the route would be within the low visibility corridor designated along Interstate 80 by BLM.

From the North Steptoe substation site to the Dry Lake substation site, Route A would result in about 0.1 miles of high residual impacts to views from an isolated residence in the Steptoe Valley (Link 270) near Cherry Creek Station. In Jakes Valley, the route would result in about 0.5 miles high residual impacts to views from access roads (Link 669) that access recreation destinations in the Humboldt National Forest.

Where the route would cross U.S. Highway 93, a portion of designated scenic highway (Link 675), at the southern end of Dry Lake Valley, high residual impacts to views from travelers would occur for about 0.6 miles. Similarly, this route would result in about another 0.6 mile of high impacts where it would cross the Kane Springs Backcountry Byway (Links 690, 700) east of its junction with U.S. Highway 93.

Route A would result in moderate residual impacts to views from U.S. Highway 93 for about 11.5 miles where the route would parallel UNTP adjacent to the highway through Pahranagat Wash. Though this highway is a moderate sensitivity viewpoint, the extended duration of view would result in significant impacts. In addition, visual contrasts within one-half mile of the portion of Route A that would parallel U.S. Highway 93 and Pahranagat Wash would also result in moderate visual impacts to dispersed views from backcountry users in the Delamar Mountain and Evergreen WSAs. The route would result in 0.5 mile of high residual impacts where it would cross U.S. Highway 93 adjacent to the highway historic marker and roadside turnout. Also refer to the cross sections in the Map Volume.

Visual contrasts along Route A would not comply with the VRM Class II designation in the area east of the Pahranagat National Wildlife Refuge (Link 690) for approximately 1.5 miles. In addition, visual contrasts would not comply with the VRM Class II designation in the area of the low pass between Coyote Spring Valley and Hidden Valley (Link 720) for about 1.3 miles.

Route B

From the Midpoint Substation to Jackpot, Nevada, the descriptions for visual impacts to residences, scenic highways, parks and recreation viewpoints, and compliance with VRM designations for Route B would be the same as those described for Route A, above.

From Jackpot to the North Steptoe substation site, the route would result in 0.5 miles of high residual impacts to views from the crossing of the California Trail Scenic Backcountry Byway (Link 91). In Trout Creek the route would result in about 0.4 miles of high residual impacts to views from a rural residence. The route would not comply with VRM Class II for about 1.0 mile where it would cross Salmon Falls Creek toward Trout Creek (Link 91). Further south in the Thousand Springs Valley, the route would cause about 0.7 miles of high residual impacts at a crossing of the California Trail Scenic Backcountry Byway (Link 140). The route would not comply with VRM Class II through Toano Draw into Goshute Valley for about 13.0 miles where the route would be within the low visibility corridor BLM has designated along Interstate 80 (Link 222) and for another 4.0 miles along the toe of the Goshute Mountains (Link 226).

From the North Steptoe substation site to the Dry Lake substation site, the descriptions of visual impacts for Route B would be the same as those described above for Route A.

Route C

From Midpoint Substation to Toano Draw north of Interstate 80, the high residual impacts to views from residences, scenic highways, parks and recreation and compliance with VRM designation for Route C would be the same as those described for Route A.

From the vicinity of Interstate 80 to the Dry Lake substation site, the high residual impacts to views from residences, scenic highways, parks and recreation viewpoints, and compliance with VRM designation for Route C would be the same as those described for Route B.

Route D

From the Midpoint Substation to Jackpot, Nevada, the high residual impacts to views from residences, scenic highways, parks and recreation viewpoints, and compliance with VRM designations for Route D would be the same as those described for Route A, above.

North of Wells, the route would not comply with VRM Class II for about 5.5 miles where it would pass along the west side of Bishop Creek. East of Wells, the route would cross about 5.0 miles of the BLM's Interstate 80 low visibility corridor (Link 180) and would not comply with its VRM Class II designation.

In the Independence Valley, the route would result in about 0.4 miles of high residual impacts to views from a ranch residence (Link 180).

From North Steptoe substation site to the Dry Lake substation site, high residual impacts to views from residences, scenic highways, and parks and recreation viewpoints and compliance with VRM designations for Route D would be the same as those described for Route A.

Route E

From the Midpoint Substation to the crossing of Interstate 80, the high residual impacts to views from residences, scenic highways, parks and recreation viewpoints and compliance with VRM designations for Route E would be the same as those described for Route B.

From the crossing of Interstate 80 to the Dry Lake substation site, the high residual impacts to views from residences, scenic highways, and parks and recreation viewpoints and compliance with VRM designations for Route E would be the same as those described for Route B.

Route F

From Midpoint Substation and Jackpot, the route would result in a total of about 5.3 miles of high residual impacts to views from rural residences near the community of Hagerman and on the bluff above (Links 61, 62). Where the route would cross the Hagerman Valley and the Snake River, it would result in about 0.6 miles of high residual impacts to views from U.S. Highway 30, the Thousand Springs Scenic Route (Link 61).

Route F would result in about 0.3 miles of high residual impacts where the route crosses a proposed access road into the Hagerman Fossil Beds National Monument (Link 62). For about 1.0 mile where this route would cross the Snake River (Link 61) and about 2.0 miles adjacent to the Fossil Beds National Monument (Link 64), this route would not comply with VRM Class I designations.

The route would result in a total of 5.8 miles of high residual impacts to views from roads that provide access to the Salmon Falls Creek WSA (Link 64) and the Salmon Falls Reservoir SRMA from U.S. Highway 93. This route would not comply with VRM Class II for about 3.0 miles where it would parallel the Salmon Falls Creek Canyon.

In the vicinity of Castleford, Idaho along the eastern rim of the Salmon Falls Creek Canyon (Link 64), this route would result in about 3.5 miles of high residual impacts to views from rural residences. Also, the route would not comply with VRM Class II for about 0.7 miles where it would cross Salmon Falls Creek within the Salmon Falls Creek SRMA west of Jackpot (Link 711).

In Thousand Springs Valley, Route F would result in about 0.7 miles of high residual impacts to views where it would cross the California Trail Scenic Back Country Byway (Link 140). Further south, the route would not comply with VRM Class II for 5.0 miles where it would cross the BLM's Interstate 80 designated low visibility corridor (Link 211).

From the North Steptoe substation site to the Dry Lake substation site, the high residual impacts to views from residences, scenic highways, and parks and recreation viewpoints and compliance with VRM designations from Route F would be the same as those described for Route A.

Route G

From the Midpoint Substation to Jackpot, high residual impacts to views from residences, scenic highways, parks and recreation viewpoints, and compliance with VRM designations for Route G would be the same as those described for Route A.

From Jackpot to the North Steptoe substation site, Route G would result in about 0.5 miles of high residual impacts to views from residences in the Contact area (Links 713, 715). This route would not comply with VRM Class II for about 1.0 mile where it would cross Salmon Falls Creek within the Salmon Falls Creek SRMA west of Jackpot (Link 711).

In Thousand Springs Valley, the route would result in about 0.5 miles of high residual impacts to views from several residences at the Winecup Ranch (Link 151). The route would also result in about 0.7 miles of high residual impacts to views from the California Trail Scenic Back Country Byway. The route would cross the BLM's designated low visibility corridor of Interstate 80 further south (Link 211), and would not comply with VRM Class II for about 5.0 miles.

From the North Steptoe substation site alternative to the Dry Lake substation site alternative, the significant visual impacts to residences, scenic highways, parks and recreation viewpoints, and compliance with VRM guidelines that would result from Route G would be the same as those described for Route B.

Alternative Routes - Ely to Delta

Direct Route

East of the North Steptoe substation site this route would result in about 0.2 miles of moderate to high residual impacts to views from a ranch residence located on the western toe of the Schell Creek Range (Link 262). It would result in about 0.4 miles of high residual impacts to views from the Pony Express Trail, at the north end of Spring Valley.

The remainder of the route would pass through remote and undisturbed landscapes with low impacts to scenic quality and to views from parks and recreation and travel routes viewpoints. The impacts created by construction of the proposed transmission line would result in adverse visual impacts on scenic values and would reduce the scenic quality in these remote areas. However, these impacts would comply with the VRM Class IV designations crossed by the route.

Cutoff Route

East of the North Steptoe substation site, this route would result in about 0.2 miles of moderate to high residual impacts to views from a ranch residence on the western toe of the Schell Creek Range (Link 262). It would also result in about 0.4 miles of high residual impacts to views from the Pony Express Trail at the north end of Spring Valley. In addition, this route would pass within three miles of the Mount Moriah Wilderness. However, no high residual impacts are expected to occur to dispersed viewers in this wilderness area.

This route would result in 0.6 miles of high residual impacts to views from a road that provides recreation access to the Howell Peak WSA (Link 470). Further east, the route would pass adjacent to an isolated residence near the Red Knolls in Whirlwind Valley (Link 470) resulting in about 0.25 mile of moderate residual impacts.

230kV Corridor Route

Originating from the Robinson Summit substation site, this route would result in about 1.2 miles of high residual impacts to views from rural residences in Smith Valley and in Steptoe Valley north of Ely (Link 351).

About 0.5 miles of high residual impacts would occur to views from the entrance road into Cave Lake State Park, which is also part of the Success Loop scenic route (Link 380). It would result in about 1.2 miles of high residual impacts to views from an area proposed for development as a primitive camping site in Weaver Creek (Link 460) east of Sacramento Pass. Further east, the route would pass between two isolated farms on Silver Creek and would result in about 0.9 miles of high residual impacts to views from residences.

Because of the level of concern expressed during project scoping and the national significance of Great Basin National Park (GBNP), the SWIP visual analysis assessed the potential impacts to views from several existing and planned overlooks and facilities sites within the park. Further, the assessment included four proposed interpretive road wayside sites. The locations of the wayside sites identified in the Draft General Management Plan for the GBNP are preliminary. The proposed transmission line would be visible for many miles across Snake Valley (Links 461, 462) from several of the viewpoints within GBNP due to unique visibility conditions that allow clear views for up to 20 miles or more across this valley. However, because of the great distance between the proposed transmission line and these viewpoints and the presence of two existing 230kV transmission lines, visual impacts are expected to be low under most viewing circumstances. Somewhat stronger visual contrasts could be expected under specific lighting conditions (e.g., sunrise or sunset). The use of nonspecular conductors for the portion of the SWIP that would cross Spring Valley would effectively minimize this effect.

Although U.S. Highway 6/50 was inventoried as a moderate sensitivity viewpoint, it provides primary access to GBNP. Approximately 0.5 mile of moderate to high residual impacts to views from travellers on U.S. Highway 6/50 are expected to occur where the route would cross the highway in the Sacramento Pass area. H-frame towers would be used at this highway crossing to minimize structure contrasts with the existing 230kV transmission lines.

This route would result in 0.6 miles of high residual impacts to views from a road that provides recreation access to the Howell Peak WSA (Link 470). Further east, the route would pass adjacent to an isolated residence near the Red Knolls in Whirlwind Valley (Link 470) and would result in about 0.25 miles of moderate residual impacts.

Southern Route

From the Robinson Summit substation site, the route would result in 3.2 miles of high impacts to views from the proposed Horse and Cattle Camp Backcountry Byway (Link 364) where this route would cross in the Steptoe Valley. Also in this area, the route would pass within one-half mile of the Mount Grafton WSA. Near Lake Valley Summit, the route would result in about 0.5 miles of significant visual impacts to views from a portion of U.S. Highway 93 that is a designated scenic highway (Link 420). Although there would be only about 0.3 miles of high impacts to views from residences (Link 560), the route would result in moderate impacts views from residences along much of Link 560.

Socioeconomics

Introduction

This section describes potential changes in existing socioeconomic characteristics within the study area that could result from the proposed project. The primary socioeconomic effects associated with transmission line projects are: (1) construction-period impacts within area communities, (2) social and economic impacts along the selected route, and (3) fiscal effects within local jurisdictions. These effects can be adverse or beneficial, and short-term or long-term in nature. They may be experienced by property owners along the transmission line routes, residents of nearby communities, and taxpayers in jurisdictions crossed by the route.

The influx of the construction labor force can have both adverse and beneficial impacts on area communities. Potential adverse affects include overburdening existing retail facilities, such as motels and restaurants, and public services and facilities, such as law enforcement and public roads. The project can also benefit local communities by increasing retail sales or generating employment. These impacts are short-term, lasting only for the duration of construction in the area.

Social and economic impacts may result where existing or planned land uses are displaced by the right-of-way or where the transmission line affects nearby properties. The effects of the selected route on agricultural production and recreation areas are of particular concern to the public in this study. Specific land-use impacts are addressed in the Land Use section.

Revenues from property taxes assessed on the project provide a long-term benefit to local taxpayers. This can be particularly important to small rural communities with declining tax bases. Additional revenues may be generated through local sales taxes on purchases by construction contractors and workers, but these revenues are generally small and transitory. In addition to payments to private property owners for fee purchases or for right-of-way leases, the FS and BLM receive right-of-way payments on federal lands crossed by the route.

Methods

The basic methodology for assessing socioeconomic impacts is to compare the pre-project environment, or no-action alternative with the projected condition of the socioeconomic parameters of interest with the project implemented.

The assessment of construction impacts involved evaluating whether the influx of construction workers would require additional community services or facilities, including accommodations. Potential economic benefits from the influx of workers were also considered. The assessment involved an analysis of data on the proposed construction schedule, size of the work force, project hiring procedures, population distribution, available campgrounds, and other accommodations within counties crossed by the alternative routes.

Data related to project construction were obtained from contacts with IPCo and LADWP, and the SWIP Preliminary Construction, Operation, and Maintenance Plan (May 1990).

According to IPCo, construction of the transmission line would require at least one construction contractor with a minimum of 105 workers. It is possible that an additional contractor may begin work simultaneously at the opposite end of the project. Typical personnel required from each contractor are shown in Table 2-3. Fenced construction yards would be placed approximately every 20-30 miles along the selected route. Construction is expected to begin in 1995 and be completed by the summer of 1998.

Because the construction work would be contracted, it is not possible to determine the geographic origin of the work force. Estimates from one construction company anticipate that 60 percent of the work force would be unskilled labor hired locally with the remaining 40 percent being skilled labor from out of town. Generally, more unskilled, local workers would be needed for steel lattice tower construction than for other structure types. Approximately 10 percent of the local hires are likely to stay with the project throughout its duration (West 1990).

The social and economic assessment involved identifying potential beneficial or adverse impacts on social and economic activities in the area. High-use tourist areas were identified and right-of-way compensation procedures evaluated. Mitigation of impacts to agricultural lands, grazing, and mining operation are addressed in the Land Use section.

In general, the effects of transmission lines on existing social structures and economic activities are relatively small. Social and economic issues include potential effects from the influx of construction workers, disruption of land-based economic activities such as timber production or livestock grazing, and compensation for right-of-way.

Potential impacts from construction are typically minimal due to the small size and short-term work force characteristics of transmission line construction. Some conflicts may exist if the construction work force competes with tourists for space in motels, parks, trailers, and campgrounds. Increased traffic associated with transporting both workers and equipment to and from the worksite could also result in potential conflicts with tourist activities. Such conflicts may be minimized by scheduling construction to avoid tourist areas during holidays, establishing worker camps away from high-use campgrounds, or busing workers from large communities.

Fiscal impacts are assessed by estimating potential property tax revenues from the project by county. Estimates for assessed value for the project are derived by multiplying the distance of transmission line for each alternative route by the assessment ratio for each state and by the average cost per mile for the project. To calculate the project's average cost per mile, the value of substations and series compensation facilities are added to the transmission line costs and the total is divided by the length of the project. Property tax revenues by county are estimated by multiplying the assessed value by the average property tax rate in each county. The estimates represent annual property tax revenues for the first year of operation without depreciation.

Results

Alternative Route - Midpoint to Dry Lake

Route A

The demand for temporary accommodations along the routes would depend upon the workers' home base. Because the area is sparsely populated, workers would probably haul camper trailers to each jobsite and stay in nearby campgrounds, trailer parks, or other spaces with electrical hook-ups. Approximately 50 percent of the work force (estimated 52 workers) would require temporary accommodations near the jobsite. Along Route A, workers from outside the area may also relocate their families to the larger communities in the vicinity such as Twin Falls, Jerome, Elko, Wells, Ely, Delta, and Las Vegas.

Given the relatively small size of the construction work force, adequate facilities should exist to provide temporary accommodations. In more sparsely populated areas where few established campgrounds are available, jobsite camp areas may need to be developed or a program to bus workers from larger communities might be established. Potential conflicts could exist in the vicinity of Elko, Nevada, where there is a housing shortage resulting from increased mining activity. However, this alternative is approximately 30 miles from Elko, so it is unlikely that the majority of the workers would locate there.

Local communities would benefit from purchases by construction workers. However, since the construction work force is both small and mobile, the impact of these expenditures is expected to be minimal.

Displacement of agriculture, grazing, and other land uses is addressed in the Land Use section. Social and economic concerns would include potential disruptions to residences, agricultural properties, gravel pits or quarries, and a school. These impacts can be minimized or eliminated through tower placement, routing modifications, and other mitigation.

In general, new land rights would be required for the transmission line and transmission line access roads. Non-federal lands necessary for the transmission line right-or-way would be obtained as perpetual easements. Additional lands for substations, as necessary, would be purchased in fee simple. The land rights would be obtained in the name of IPCo. Every effort would be made to purchase all the land rights on private lands through reasonable negotiations with the present owners. A grant for a 200-foot right-of-way has been requested for the portions of the transmission line that would cross federal lands administered by the BLM, FS, and the Bureau of Reclamation.

Property taxes paid by IPCo would benefit tax jurisdictions within the counties crossed by the transmission lines and associated facilities. Although these taxes are centrally assessed by each state, county jurisdictions would receive payments according to the length of the project in each county. Table 4-4 presents estimates of property tax revenues by alternative route.

Jerome, Twin Falls, and Cassia counties in Idaho would receive tax benefits from this route. Jerome County's tax revenues would be an estimated $455,700. Based on this estimate, Route A would represent approximately 5.3 percent of the county's assessed valuation in 1990 values. Revenues to Twin Falls County would be approximately $570,700 and to Cassia County would be approximately $20,800. The project would represent approximately 2.1 percent of 1990 assess valuation in Twin Falls County and 0.25 percent of 1990 assessed valuation in Cassia County.

In Nevada, Elko and White Pine and Lincoln counties would each receive over $500,000 in revenues from this alternative. Because of the relatively low tax bases in Lincoln and White Pine counties, the assessed value of the project would represent approximately 19 percent of White Pine County's assessed valuation in 1990 and approximately 45 percent of Lincoln County's 1990 assessed valuation. Nye and Clark counties would also receive tax payments between $150,000 and $261,000 from this alternative.

Route B

Since Route B is the same as Route A in Idaho, the assessment for Route A would also apply to Route B.

In Nevada, Route B would cross through the same counties as Route A, and socioeconomic impacts would be comparable. If Route B were constructed, workers might choose to stay in Wendover, since this route is near the Utah border. With respect to social and economic impacts, Route B would bypass ranching operations in the Steptoe Valley. Fiscal impacts would be the same for Lincoln, Nye, and Clark counties, slightly higher for White Pine County and Elko counties.

Route C

Since Route C is the same as Route A in Idaho, the assessment for Route A would also apply to Route C. In Nevada, construction, social, and economic impacts from this route are expected to be comparable to Route A. In terms of fiscal impacts, potential revenues would be the same for White Pine, Lincoln, Nye, and Clark counties. Route C would produce approximately $127,100 in potential revenues for Elko County compared with $759,200 from Route A.

Route D

Since Route D is the same as Route A in Idaho, the assessment for Route A would also apply to Route D. In Nevada, Route D extends to the west nearest Wells and closest to the Humboldt National Forest in this area. Route D represents the highest potential estimated tax revenues for Elko County, $767,600.

Route E

Since Route E is the same as alternative A in Idaho, the assessment for Route A would also apply to Route E. In Nevada, Route E would be a combination of Route A in the northern portion of the route and Route B in the southern portion of the route. This alternative would produce the highest revenues for White Pine County, $596,100.

Route F

Route F would head west out of Midpoint Substation through the Hagerman area near the Hagerman Fossil Beds National Monument. This route would result in potential conflicts with tourist activities during construction, depending upon when construction is conducted in this area. Jerome, Twin Falls, and Gooding counties in Idaho would receive potential tax benefits from this alternative. Jerome County would receive approximately $144,100 in revenues from this route. Twin Falls County would receive approximately $916,000 in potential revenues, nearly $350,000 more than would result from the other alternative routes. This is the only alternative route that would cross Gooding County which would receive approximately $211,500 in potential revenues. In Nevada, Route F would be the same as Route C.

Route G

Since Route G is the same as Route A in Idaho, the assessment for Route A would also apply to Route G. In Nevada, construction, social, and economic impacts from this route are expected to be comparable to Route A. In terms of fiscal impacts, revenues would be the same for Lincoln, Nye, and Clark counties. Route G would produce slightly less potential revenues for White Pine and Elko counties than Route A. Route G represents the least amount of estimated revenues for White Pine County, $568,400.

Alternative Routes Ely to Delta

Direct Route

The Direct Route would cross through the northeast portion of White Pine County and would be the shortest crosstie route in Nevada. Potential revenues to White Pine County would be approximately $255,700. In Utah, the Direct Route would pass through Juab County, generating approximately $296,100 in potential revenues for that county. Although this route is the shortest in length, construction costs per mile are expected be somewhat more than the other crosstie routes because of the requirement for shorter and more numerous towers where this route would cross military airspace. The Direct Route would produce approximately $355,200 in potential revenues for Millard County, far less than other crosstie routes. The estimated assessed value of the Direct Route would represent 0.9 percent of the 1990 assessed valuation of Millard County, 9.8 percent of Juab County's 1990 assessed valuation, and 8.5 percent of the 1990 assessed valuation for White Pine County.

Cutoff Route

Since the Cutoff Route would be the same as the Direct Route for most of the portion in White Pine County, the description of impacts for the Direct Route above would also apply to this route. In Utah, the Cutoff Route would cross through open country in Spring Valley then would meet and parallel the 230kV Corridor Route. This alternative would produce approximately $289,200 in potential revenues for White Pine County and $846,000 for Millard County.

230kV Corridor Route

The 230kV Corridor Route would pass through White Pine County parallel to two 230kV transmission lines into Utah. No potential conflicts with tourist activities are expected where this route pass would just north of Great Basin National Park. Demands for temporary accommodations and traffic associated with construction are not expected to conflict with tourism. Because accommodations are limited in Baker, it is expected that crews would stay in Ely. Potential revenues to Millard County would be approximately $853,700 and to White Pine County approximately $320,500.

Southern Route

The Southern Route pass would through White Pine and Millard counties to the south of the other crosstie alternatives. This route would pass around to the south of Great Basin National Park and would not conflict with tourist activity. Near Delta, this route would parallel U.S. Highway 6/50, however construction is not expected to create traffic problems. Because of its longer length, the Southern Route would produce the most revenues for Millard and White Pine counties. Estimated revenues would be almost $1 million in Millard County and approximately $.5 million in White Pine County. The project's assessed value would be approximately 2.4 percent of the 1990 total assessed valuation of Millard County and 16.5 percent of White Pine County's 1990 assessed valuation.

Electric and Magnetic Field Effects

Introduction

Questions about potential health effects from electric and magnetic field (EMF) exposures have centered around three areas: (1) cancer, (2) reproductive outcome, and (3) general physiologic and psychologic health. In a draft document on EMF health effects prepared by the Environmental Protection Agency (EPA), and currently under scientific review, the agency has restricted its analysis to cancer. Accordingly, the section on health effects that follows places a major emphasis on the research relevant to the potential for electric and magnetic-field associated carcinogenic risk.

In 1991 the University of Southern California (USC) released EMF research on childhood leukemia and EMF exposure. Additionally, there were three scientific meetings with strong emphasis on EMF exposure and effects on animals and humans (the Society for Epidemiologic Research, Bioelectromagnetics Society, and the U.S. Department of Energy Contractor's Review). In 1991 a total of $25 million was spent on nearly 200 ongoing EMF studies in 25 countries. The recent published research tend to support that there is no conclusive evidence to date to link EMF exposure and cancer. It remains difficult to identify the exposure variables to adequately assess health risks.

Several trends emerged from the recent studies. The focus of studies continues to move from studies on human exposure to transmission and distribution lines and household appliances. *In vivo* and *in vitro* studies are taking a more prominent role where human epidemiology has traditionally responded to public concerns. Specific mechanistic research topics (e.g., melatonin production, multiphasic, non-linear, restricted-range-optimal response, and AC/DC resonance phenomena) are gaining acceptance.

Ongoing Research

Some of the current research now in progress include:

- EPRI occupational study of utility workers (Fall 1993)
- National Cancer Institute childhood leukemia study
- National Toxicology Program chronic exposure rodent study
- Canadian chronic exposure rat brain cancer study
- California Department of Health Services - Office of Environmental Epidemiology in conjunction with the Kaiser Permanente Department of Research in Oakland, Calif. (October 1992)
- Dr. Susan Preston-Martin - University of Southern California (1994)
- Data analysis of the "back-to-Denver" study, by Enertech Consultants Campbell, Calif. (now completed)

Methods

Transmission Line Electric Fields

The electric field created by a high voltage transmission line extends from the energized conductors to other conducting objects such as the ground, towers, vegetation, buildings, vehicles, and people. The strength of the vertical component of the electric field at a height of 1 meter (3.28 ft) is frequently used to describe the electric field under transmission lines.

The most important parameters of a transmission line that determine the electric field at 1-meter height are conductor height above ground and line voltage.

For evaluation of electric and magnetic fields from transmission lines it is necessary to calculate the fields for a specific line condition. The National Electrical Safety Code states the condition for evaluating electric-field-induced short-circuit current for lines with voltage above 98kV line to ground as follows: conductors are at a final unloaded (e.g., no wind or ice) sag, at a temperature of 120°F (49°C), and at a maximum voltage [NESC (National Electrical Safety Code), 1990]. For the calculation of electric and magnetic fields from the proposed transmission lines the maximum operating voltage, the maximum continuous current, and the minimum conductor clearances at a conductor temperature of 120°F (49°C) were supplied by Idaho Power Company (refer to Table 2-1). Thus these calculations represent conditions that meet the NESC criteria.

The electric fields at the edge of the right-of-way are not as sensitive to conductor height as is the peak field. Computed values at the edge of the right-of-way for any line height are fairly representative of what can be expected all along the transmission line corridor.

Transmission Line Magnetic Fields

The magnetic field generated by currents on transmission line conductors extends from the conductors through the air and into the ground. The magnitude of the field at a height of 1 meter (3.28 ft) is frequently used to describe the magnetic field under transmission lines. Because the magnetic field is not affected by nonferrous materials, the field is not influenced by normal objects on the ground under the line. The direction of the maximum field varies with location. This is in contrast to the electric field which is essentially vertical near the ground. The most important parameters of a transmission line that determine the magnetic field at 1 m height are conductor height above ground and the currents in the conductors.

Calculations of magnetic fields from transmission lines are performed using well known physical principles (Deno and Zaffanella, 1982). The calculated values usually represent the ideal straight parallel conductor configuration. For simplicity a flat earth is usually assumed. Balanced currents, i.e. currents of the same magnitude for each phase, are also assumed. This is usually valid for transmission lines where balanced loads on all three phases are maintained during operation. Induced image currents in the earth are usually ignored for calculations of magnetic field under or near the right-of-way. The resulting error is negligible. Only at distances greater than 300 feet from a line do such contributions become significant (Deno and Zaffanella, 1982). Unless the direction of power flow is known, the currents for equivalent phases on different lines have been assumed to be in the same direction.

The clearance for magnetic field calculations is taken as the same as for electric fields that is specified in the NESC: namely, the clearance at a conductor temperature of 120° F (49° C), and the conductors are at final unloaded sag.

Standard techniques for measuring magnetic fields near transmission lines are described in ANSI IEEE Standard No. 644-1987 [1987]. Measured magnetic fields agree well with calculated values provided the currents and line heights that go into the calculation correspond to the actual values for the line. To realize such agreement, it is necessary to get accurate current readings during field measurements because currents on transmission lines can vary considerably over short periods of time.

As with electric fields, the maximum or peak magnetic fields occur in areas near the centerline and at midspan where the conductors are the lowest. If more than one line is present, the peak field would depend on the relative electrical phasing of the conductors. The magnetic field at the edge of the right-of-way is not very dependent on line height. The various cases where fields were calculated are illustrated in Figure 4-1.

In general, the scientific process used to evaluate the potential effects of environmental exposures, be they chemicals, or electric and magnetic fields relies upon the data from research studies. The research encompasses two complementary approaches, namely epidemiologic investigations and laboratory studies, each with its own strengths and limitations.

The objective of environmental epidemiology is to measure the associations between exposures to environmental factors (e.g., asbestos, benzene) and health outcomes (e.g., lung disease, leukemia). The measure of the association between exposure and outcome that is most common in the epidemiologic literature on magnetic fields, as in many other areas of epidemiology, is the relative risk. The relative risk describes the risk of disease in an exposed group relative to the risk in a reference group. Studies that report risk estimates greater than one indicate a positive association between the exposure and the disease. Studies with risk estimates less than one indicate an inverse association. Risk estimates near one indicate no association.

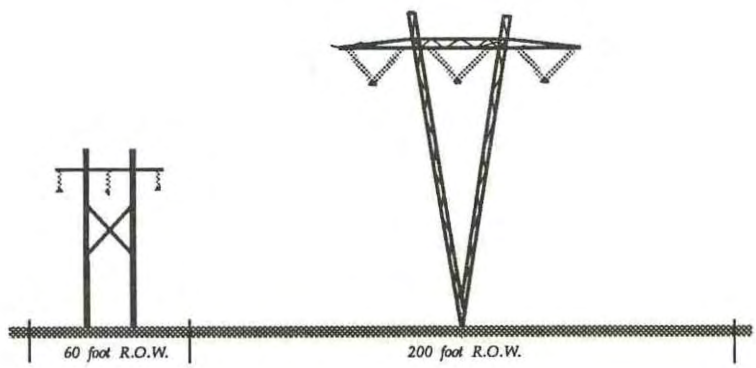
Because data collected on human populations are subject to random variations, a single value of relative risk is not a sufficient descriptor of association. Epidemiologist and statisticians have developed computational techniques that estimate the variability inherent to an epidemiologic study's data. These techniques help determine if a reported relative risk is reasonably precise and indicative of a true association, or whether the reported data are so highly variable so as to be compatible with a conclusion that no association exists.

The goal of laboratory research studies is to identify the nature of an observed effect and the dose of the agent at which it appears. A most critical distinction, therefore, must be made between natural harmless biological responses, or "effects," and those that are truly adverse or deleterious. Many chemical substances and physical agents (food, medicines, light or electric and magnetic fields) produce biological responses in organisms--like the response of the eye to light or the influence of food and water on growth and body metabolism--at quite low concentrations or intensities. Hence, the mere demonstration of a biological response or effect per se **does not** indicate that an exposure to an agent is hazardous. Rather, it is imperative to ascertain under what conditions (intensity or level of exposure, duration of exposure, etc) an agent may be toxic. In fact, toxicological studies are designed classically to identify the highest dose that does not cause an adverse effect.

CASE 1

Existing
Upper Salmon - Wells
138kV Wood H-Frame

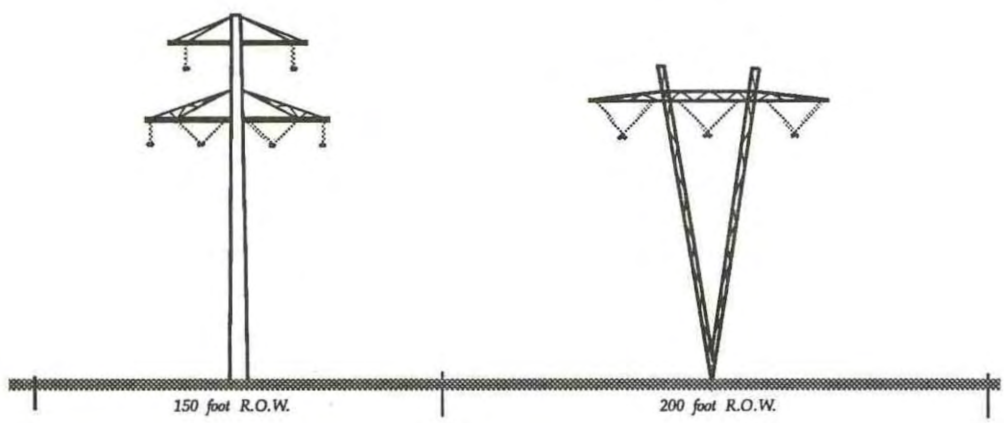
Proposed
500kV Guyed-V
steel lattice



CASE 2

Existing Midpoint - Hunt
230/345kV Double Circuit
Steel Monopole

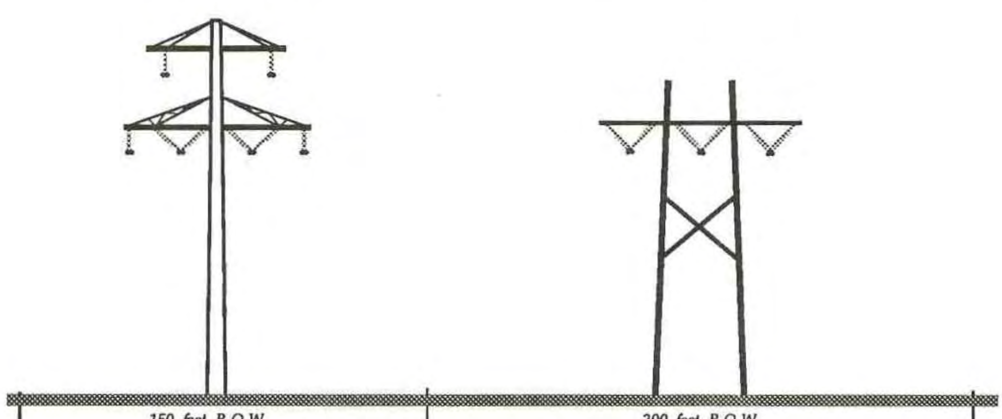
Proposed
500kV Guyed-V
lattice steel



CASE 3

Existing Midpoint - Hunt
230/345kV Double Circuit
Steel Monopole

Proposed
500kV Steel H-Frame



Source Dames & Moore
Note: Not to scale

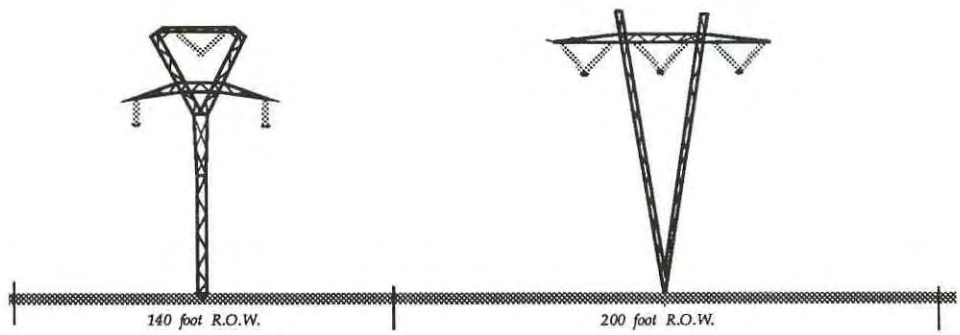
EMF Case Studies

Figure 4-1

CASE 4

Existing
Midpoint - Stateline
345kV Guyed Delta

Proposed
500kV Guyed-V
steel lattice

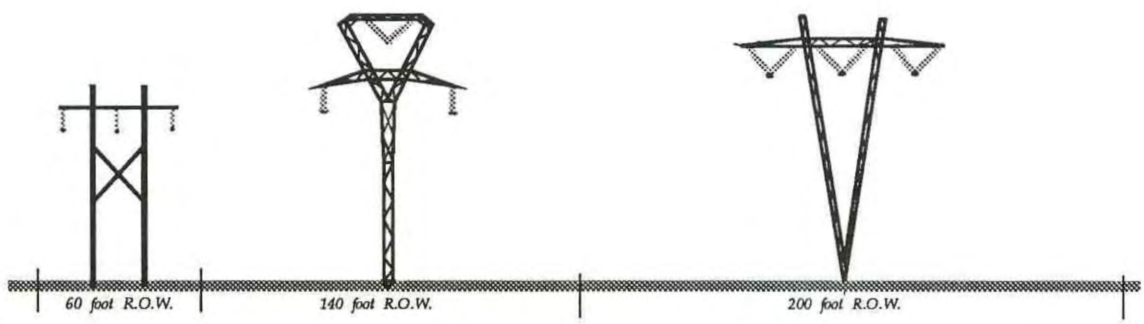


CASE 5

Existing
Upper Salmon - Wells
138kV Wood H-Frame

Existing
Midpoint - Stateline
345kV Guyed Delta

Proposed
500kV Guyed-V
steel lattice

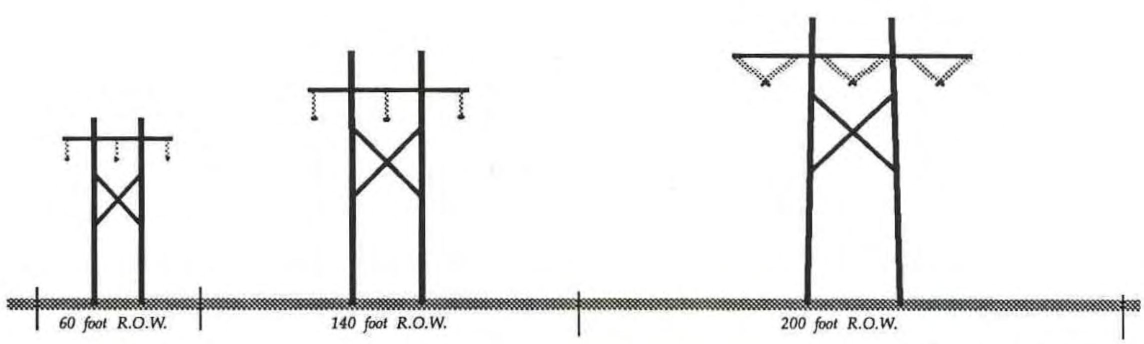


CASE 6

Existing
Upper Salmon - Wells
138kV Wood H-Frame

Existing
Midpoint - Stateline
345kV Steel H-Frame

Proposed
500kV Steel H-Frame

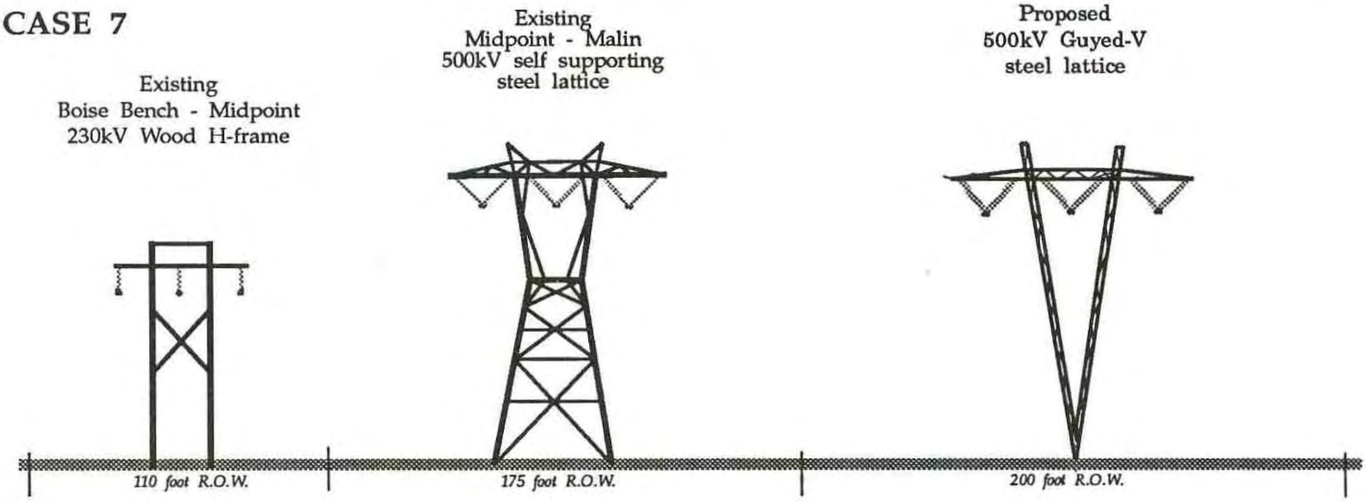


Source: Dames & Moore
Note: Not to scale

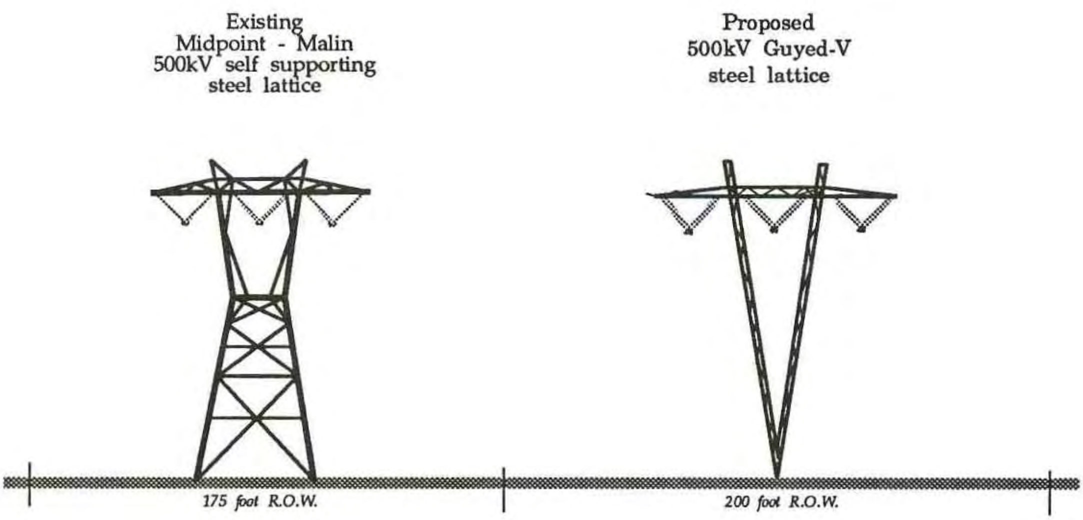
EMF Case Studies

Figure 4-1
(Continued)

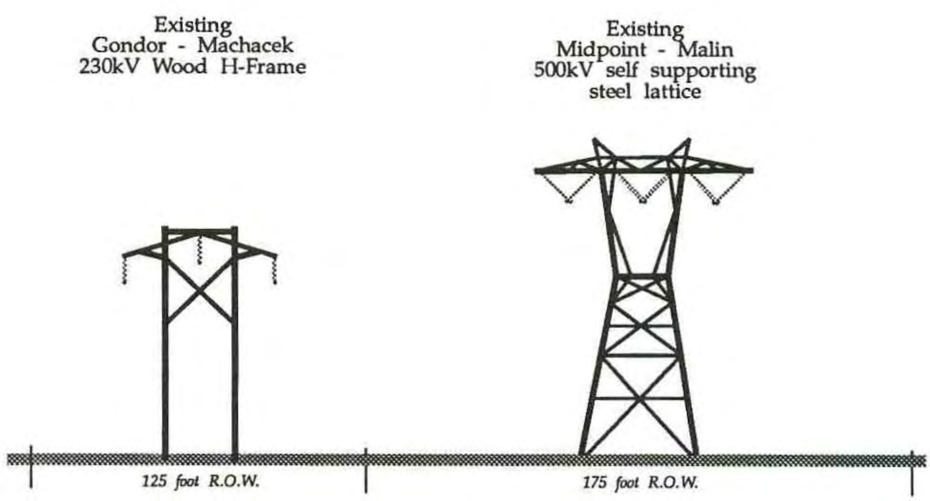
CASE 7



CASE 8



CASE 9

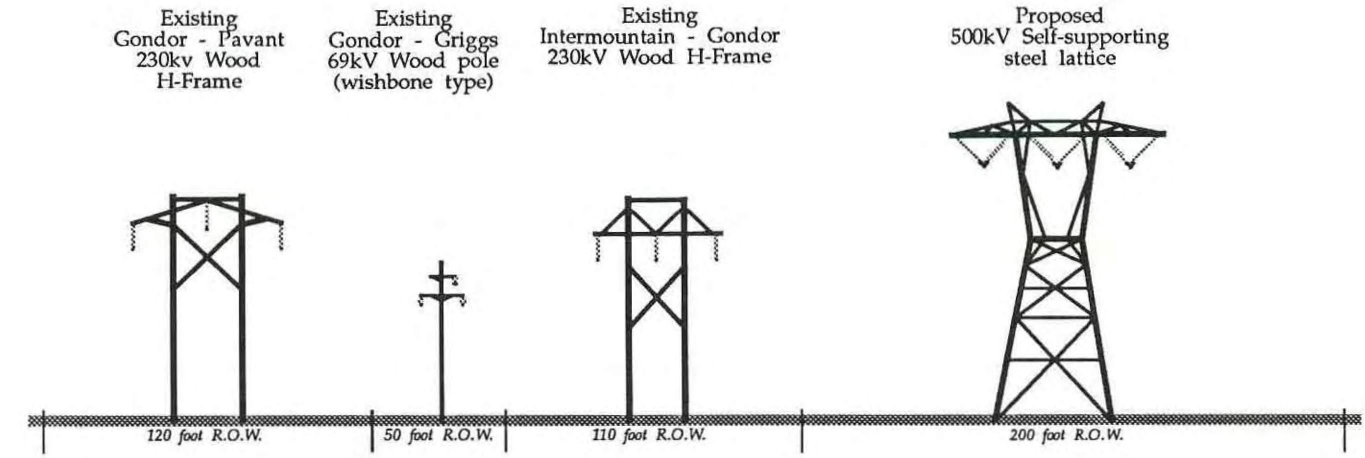


EMF Case Studies

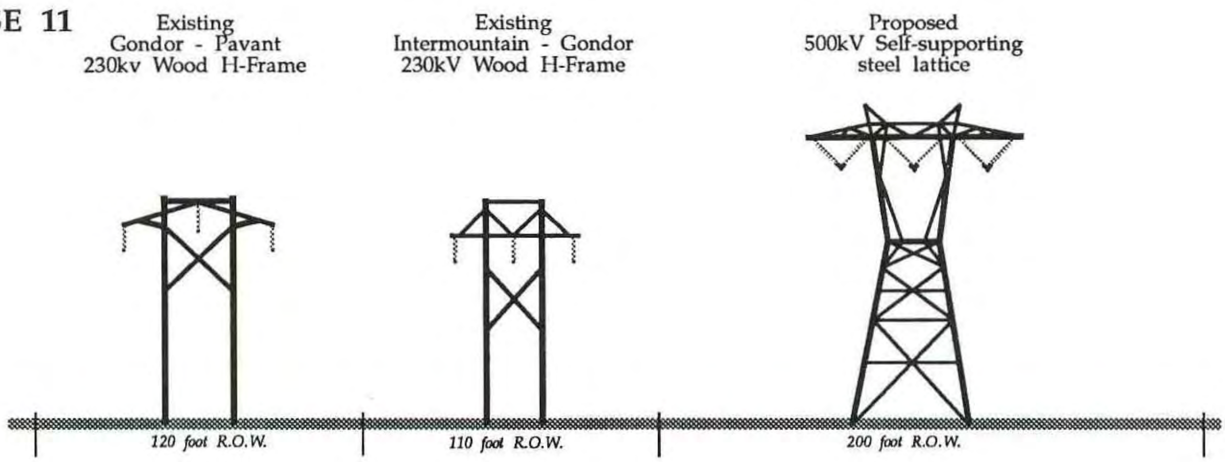
Source: Dames & Moore
Note: Not to scale

Figure 4-1
(Continued)

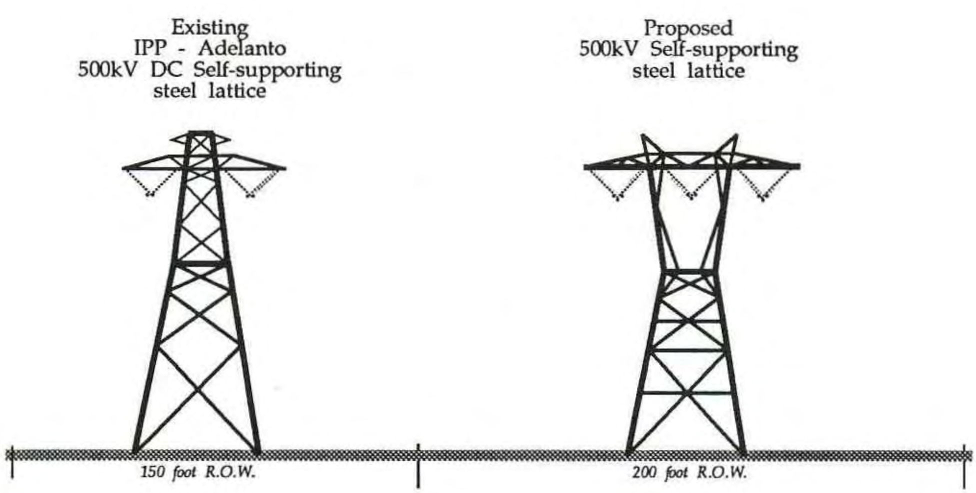
CASE 10



CASE 11



CASE 12

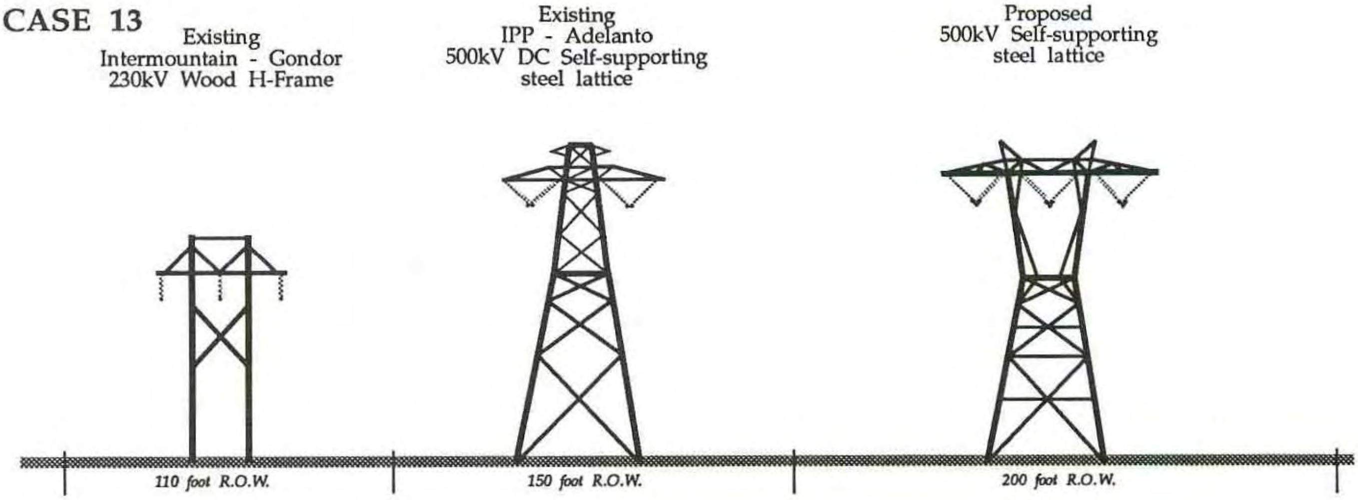


EMF Case Studies

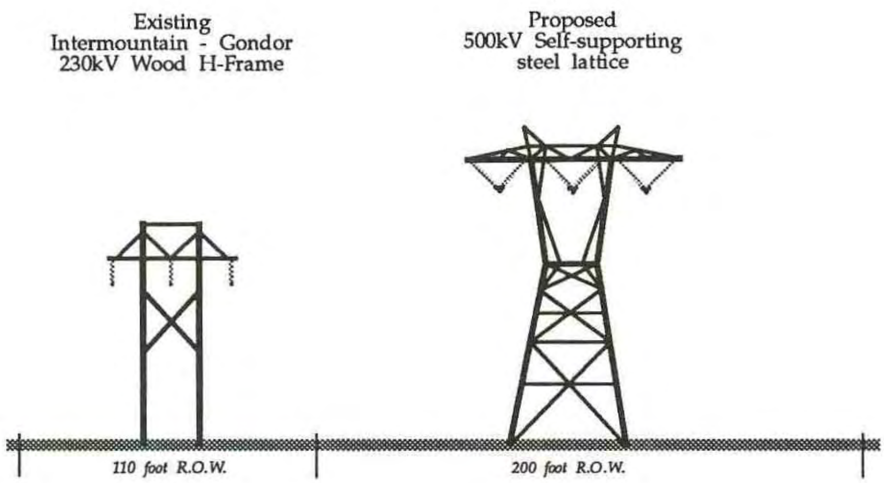
Source: Dames & Moore
Note: Not to scale

Figure 4-1
(Continued)

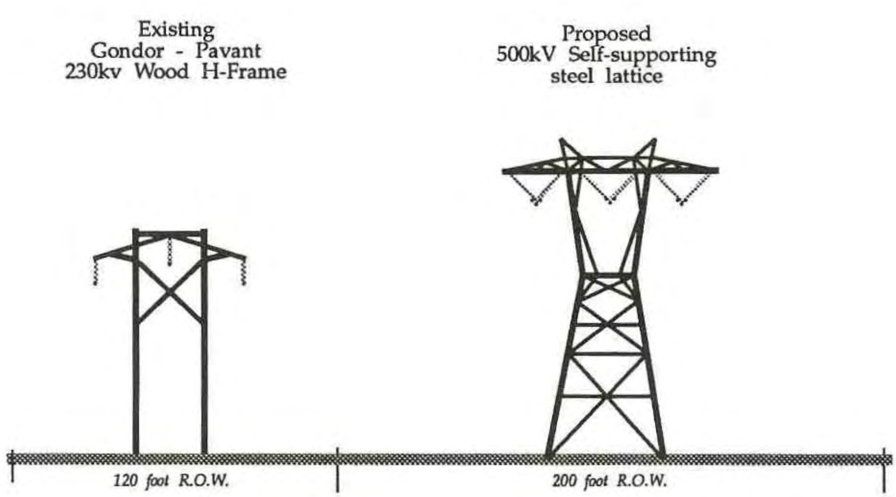
CASE 13



CASE 14



CASE 15

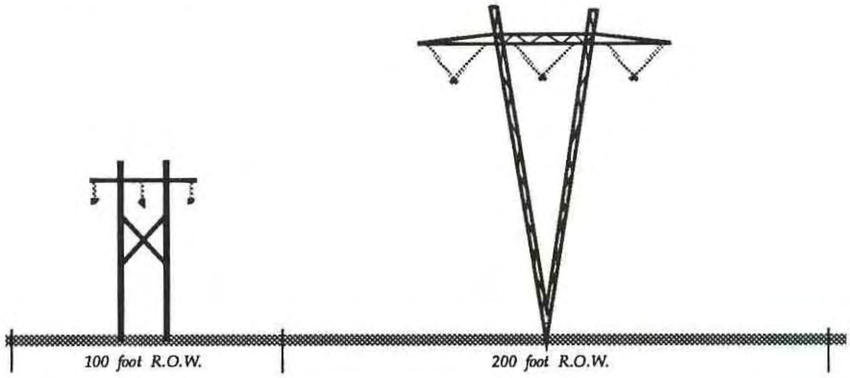


EMF Case Studies

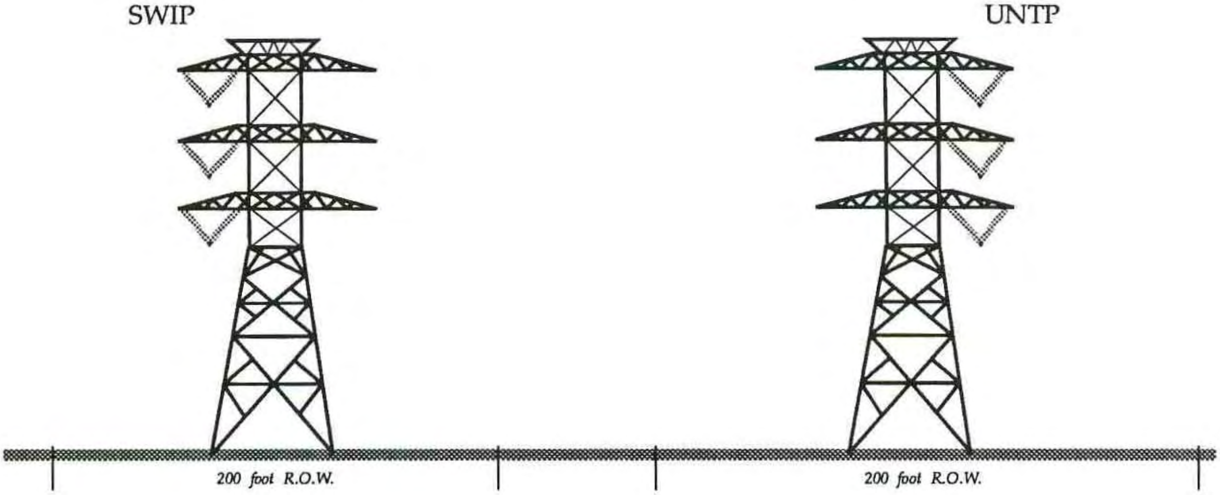
Source: Dames & Moore
Note: Not to scale

Figure 4-1
(Continued)

CASE 16



CASE 17



EMF Case Studies

Source: Dames & Moore
Note: Not to scale

Figure 4-1
(Continued)

Exposure levels in laboratory studies are usually very high relative to those that people experience. Thus an effect observed in a laboratory experiment does not necessarily translate into an effect under exposure conditions found in the real world.

Results

In most cases, the impact from the proposed line would be to extend the existing radio interference (RI) levels over an additional 200 feet corresponding to the width of the proposed new right-of-way. During foul weather there would be RI, in the form of static on AM radios, under or on the right-of-way of the proposed (and existing) lines.

Based on the predicted levels, the potential for television interference (TVI) from the proposed line is expected to be the same as that experienced from the existing lines with the area of possible interference increased by the 200-foot width of the proposed new right-of-way.

IPCo has an active program to identify, investigate, and mitigate legitimate RI and television interference (TVI) complaints. It is anticipated that TVI caused by the proposed SWIP line can be effectively mitigated.

Transmission Line Electric Fields

The calculated values of electric field at 1 meter height for the proposed SWIP 500kV single circuit transmission line are given in Table 4-5. The peak value on the right-of-way and the value at the edge of the right-of-way are given for the proposed line and for the existing corridors, and is illustrated in profile in Figure 4-2.

Electric Fields: Short-term Effects

Short term effects due to transmission line electric fields are associated with perception of induced currents and voltages or perception of the field. Induced current or spark discharge shocks can be experienced under certain conditions when contacting objects in an electric field.

Induced currents are always present in electric fields under transmission lines and would be present near the proposed line. However, during line construction, IPCo routinely grounds fences and metal buildings that are located on or cross the right-of-way. This eliminates these objects as sources of induced current and voltage shocks.

Unlike fences or buildings, mobile objects such as vehicles and farm machinery cannot be grounded permanently. Limiting induced currents to persons from such objects is accomplished in several ways. First, required clearances from ground tend to limit field strengths to levels which do not represent a hazard or nuisance. The NESC (1990) requires that sufficient conductor clearance be maintained to limit the induced short-circuit current in the largest anticipated vehicle under the line to 5 milliamperes (mA) or less. This can be accomplished by limiting access or by increasing conductor clearances in areas where large vehicles could be present.

Impacts of electric field coupling can be mitigated through grounding policies and through adherence to the NESC. Worst-case levels are used for safety analyses but, in practice, currents and voltages are reduced considerably by inadvertent grounding. Shielding by conducting objects, such as vehicles and vegetation, also reduces the potential for electric field effects.

Transmission Line Magnetic Fields

The calculated values of magnetic field at 1-meter height for the proposed and existing lines are given in Table 4-6. Field values on the right-of-way and at the edge of the right-of-way are given for average and maximum continuous current conditions. Lateral profiles of maximum magnetic field under average and maximum conditions are given in Figure 4-3 for the proposed 500kV lines alone and with an existing 345kV line (Case 4 in Figure 4-1). The actual magnetic field levels would vary considerably as current on the lines varies.

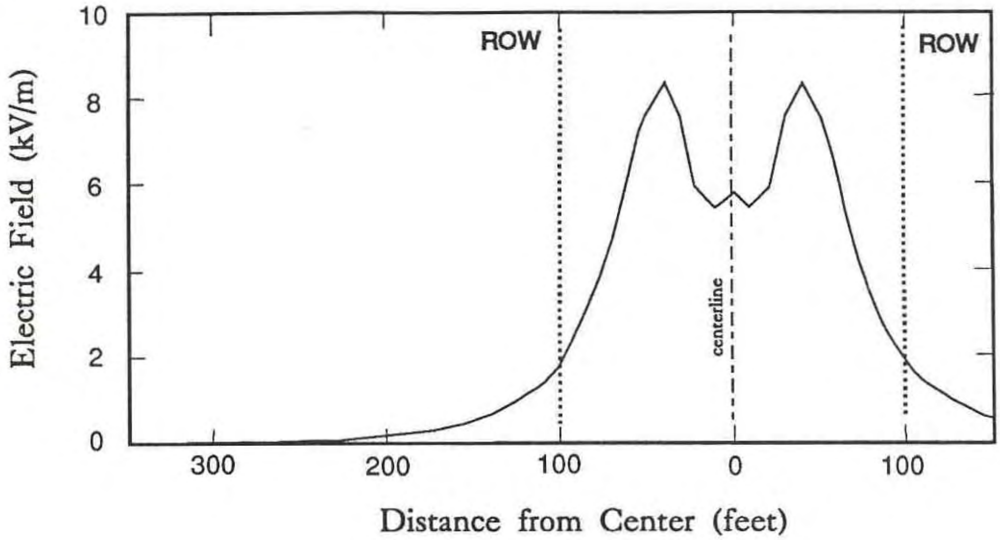
The peak magnetic field expected on the right-of-way of the proposed line under average current conditions is 118 mG. The peak calculated magnetic field under the existing lines with average current is 133 mG for the existing Midpoint-Summer Lake 500kV line (Cases 7 and 8 in Figure 4-1). Under maximum continuous current conditions which might be experienced over short periods during the year, the peak fields on the proposed right-of-way would be 230-237 mG depending on the corridor. The peak fields under the existing Midpoint-Summer Lake 500kV lines is 277 mG.

The parallel DC line in Case 12 generates DC magnetic fields similar to the earth's field. This DC magnetic field would be superimposed on the 60 Hz field from the proposed line. However, just as the earth's field does not affect the 60 Hz field, the magnetic field from the DC line would not impact the 60 Hz field or the currents induced by the 60 Hz field.

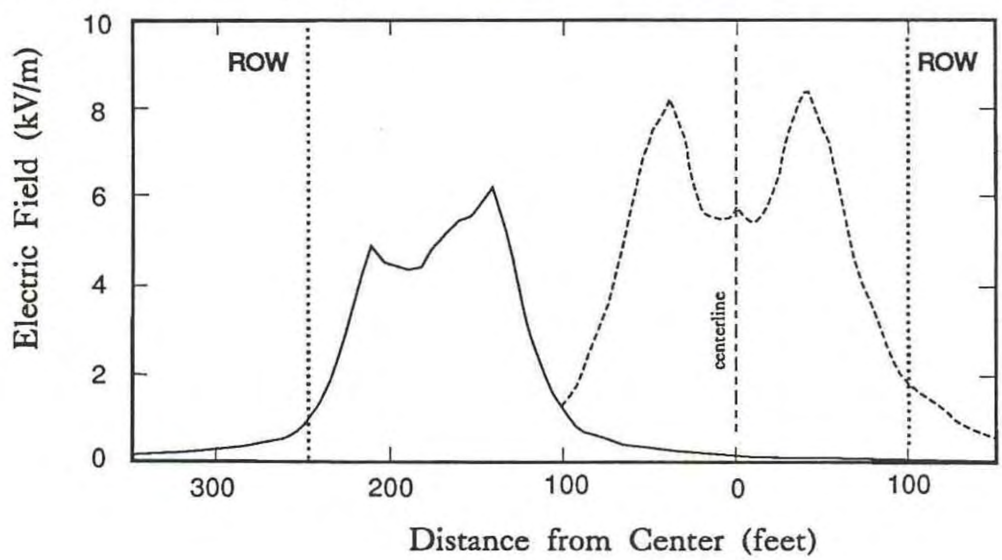
At the edge of the right-of-way near the proposed line, the calculated fields for average current load conditions are 27 to 31 mG depending on the corridor. The fields at the other edge of the corridor range from 4 to 40 mG. Under maximum continuous current conditions, the field at the edge of the right-of-way nearest the proposed line ranges from 55 to 62 mG. At the other edge of the right-of-way the fields range from 9 to 74 mG.

The magnetic field levels associated with the proposed line configurations are generally comparable with fields from the existing 500kV line along a portion of the route and from other 500kV transmission lines as characterized in Table 4-6. The levels at the edge of the right-of-way are comparable to the fields measured one foot away from some small appliances such as hair dryers, electric shavers, mixers, and portable heaters. [Gauger, 1985] At a distance of 200 feet from the edge of the right-of-way the fields from the proposed line are 3 and 6 mG for average and maximum current conditions, respectively.

Proposed 500kV transmission line



Existing 138kV with proposed 500kV transmission lines



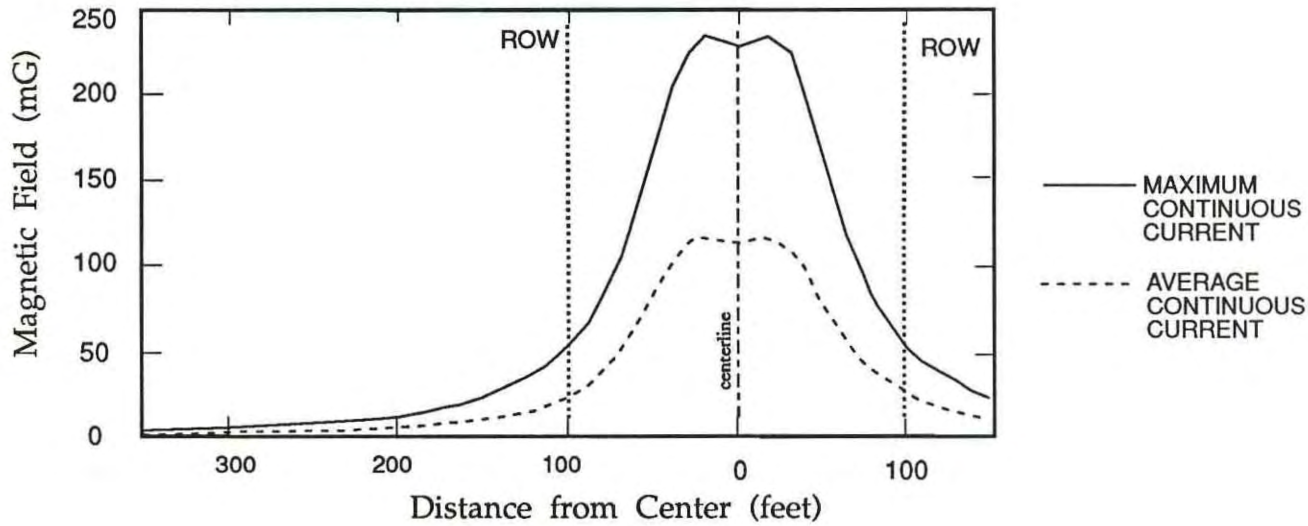
Note: Maximum voltage and minimum clearences have been used.

Source: T. Dan Bracken, Inc.

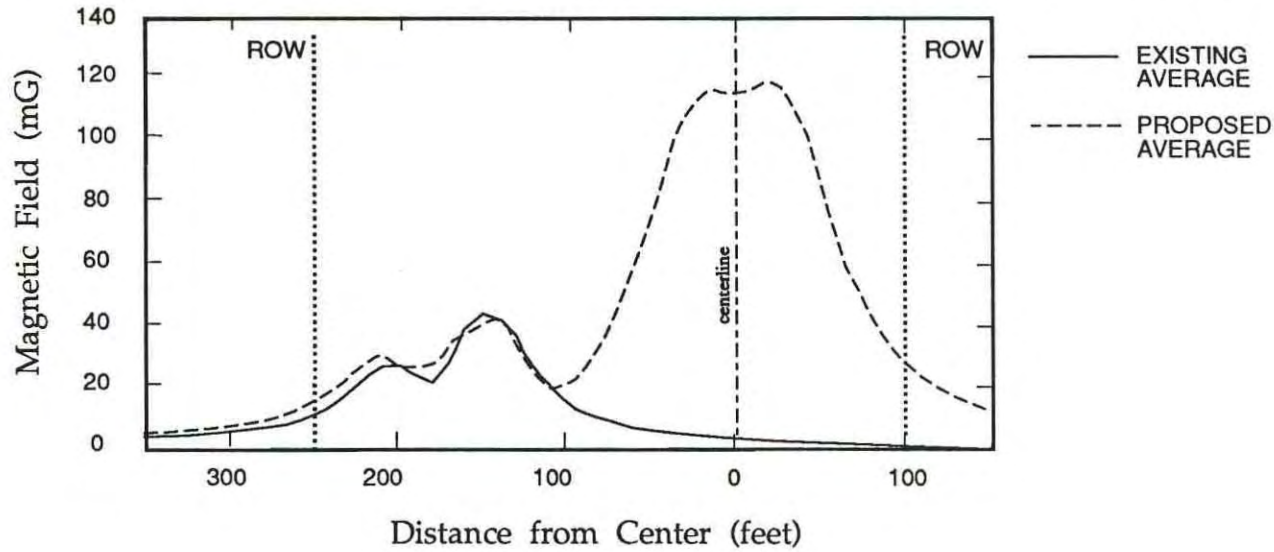
Electric Field Profiles

Figure 4-2

Proposed 500kV transmission line



Existing transmission lines and the proposed 500kV transmission line



Source: T. Dan Bracken, Inc.

Magnetic Field Profiles

Figure 4-3

Magnetic Field: Short-Term Effects

Magnetic fields associated with transmission and distribution systems can induce voltage and current in long conducting objects that are parallel to the transmission line.

A fence, irrigation pipe, pipeline, electrical distribution line or telephone line forms a portion of a conducting loop when it is grounded. The earth forms the other portion of the loop. If only one end of the fence is grounded then an induced voltage appears across the open end of the loop. The possibility for a shock exists if a person closes the loop at the open end by contacting both the ground and the conductor.

Knowledge of the phenomenon, grounding practices, and the availability of mitigation measures mean that magnetic induction effects from the proposed 500kV line would be minimal. To a great extent, grounding of fences, pipelines, etc. would already be in place where the proposed route would parallel existing transmission lines. It is not anticipated that magnetically induced voltages and currents would have any major impacts along the proposed line.

Epidemiologic Studies

The epidemiology literature concerned with magnetic fields and cancer contains studies that focus on either (1) the general population (community studies) or (2) working populations (occupational studies).

Nine community studies have been reported that deal with the possible relationship between magnetic fields from electric utility lines and cancer. These studies are numerically listed according to age group studied and the country in which they were conducted in the technical report. Of the nine, five have focused exclusively on childhood cancer, two on adult populations, and two on all age groups. Five of these have been conducted in the United States, three in the United Kingdom, and one in Sweden. Other community epidemiology studies are now in progress and results from some of these studies are now available.

Exposure Assessment For Community Cancer Studies

Exposure assessment is the branch of environmental sciences concerned with characterizing the extent to which people are exposed to environmental agents. The most relevant way to express a person's exposure to magnetic fields, and indeed to any environmental factor, is in terms of total individual exposure. Total exposure for each person includes the contribution from transmission lines, distribution lines, domestic appliances, and sources in the workplace or at school. Unfortunately, none of the magnetic field epidemiology community studies reported to date (i.e, those listed in Attachment A) were conducted at the level of the individual person to either directly quantify or estimate total exposure to magnetic fields.

The methods that have been used thus far to assign magnetic field exposure values are summarized in the following brief descriptions. The first two discussed (wiring codes and spot measurements) are particularly relevant to the key studies in this area:

Wiring Codes: The most widely cited studies have included wiring codes as an index of exposure. The use of wiring codes as a residential magnetic field exposure surrogate is based on the postulate that the nature of the electric utility wiring outside a house predicts the relative magnitude of the magnetic field within a home, and, therefore, predicts the magnetic field exposure of the home's residents. For virtually every home this wiring includes the neighborhood distribution line. In rare cases, up to perhaps one or two percent of an entire study population, does outdoor wiring adjacent to a home include overhead transmission lines (Wertheimer and Leeper, 1979; McDowall, 1986; Tomenius, 1986). When considering the issue of the cumulative exposure of large populations to magnetic fields from outdoor utility wiring, transmission lines play a negligible role. Because of the lack of a sizable abutting population none of the community epidemiology studies conducted to date have been able to evaluate large populations near transmission lines.

In 1979, Wertheimer and Leeper introduced a wire coding scheme that classified distribution lines in the Denver area, according to both their current carrying capacity and distance from the residence. The objective of this coding system was to identify distribution lines that generate high and low levels of magnetic fields in the adjacent homes, without having to actually enter the homes and conduct measurements. Homes were labeled as belonging to either the high current configuration (HCC) category or the low current configuration (LCC) category. One of the immediate uncertainties about this coding scheme was whether or not it truly represented actual field levels in the home. Studies conducted subsequently by Savitz (1987) and Kaune et al (1987 a,b) have both shown that, although wiring code rank correlates with measured magnetic field, the correlation is relatively weak. Of course, any wire coding scheme still fails to account for exposure an individual receives when away from the residence or exposures within the residence unrelated to the distribution lines.

Spot Measurements: The term "spot measurement" refers to a measurement of the magnetic field strength at a single point in time. The main advantage of spot measurements is that they provide a direct measure of indoor exposure levels. Their disadvantages are that (a) they do not reflect temporal variations in the field, which do undergo daily cycles, and (b) they do not account for exposure from local sources, such as appliances.

Calculated Fields: Based on information on the electric loads carried on power lines, the lines' physical characteristics (e.g., height of wires from ground), and their distance to residences, the magnetic fields due to power lines can be calculated. These calculations are accurate when a power line is the sole outdoor magnetic field source.

Distance from Source: Magnetic field strength increases as the distance to a line carrying current decreases.

The studies conducted to date, when analyzed collectively, fail to substantiate a link between magnetic field exposure and an increased risk of cancer. As explained below, a major problem in interpreting this literature is the lack of consistent results across, and also within studies.

Perhaps the most widely known of all the community studies is the childhood cancer study conducted by Savitz and colleagues. This study was conceived as a replication of a 1979 study by Wertheimer and Leeper, who had reported that wiring codes were associated with childhood cancer in the Denver area. Savitz reported that cancer was weakly associated with wiring codes, and that the association was statistically significant. In contrast, when the low-power measured magnetic field (i.e., field measured with in-home power consumption minimized), rather than wire code, was used as the index of exposure, the association of exposure with disease appreciably weakened, and was no longer statistically significant. For high power fields (residential power turned on), no association was observed. Savitz questions the lack of an association of cancer with high-power fields, the weak relationship with low-power magnetic fields, and the positive relationship of cancer with wiring code:

> "High power fields more closely reflect the actual in-home exposure conditions when the home is in use. The supposed noise in measurement from superimposing internal and external sources of magnetic fields would actually be a more complete picture of the exposures associated with living in that residence. Low power magnetic fields would reflect that less accurately, and wire codes would be a more distant proxy measure of such exposures." (Savitz, 1987)

Thus, the study by Savitz and co-workers, though better executed than the study of Wertheimer and Leeper, did not produce internally consistent data indicating that residential magnetic field exposure levels are associated with excess risk of cancer.

Two studies, both conducted in the U.S. have examined the association of magnetic fields with cancer in adults. In 1982, Wertheimer and Leeper published a study conducted in the Denver area in which they report that adult cancer was positively associated with wiring code. Like their childhood study published in 1979, measures of magnetic field strength inside the study homes were not taken. The second study of adult cancer was conducted in the Seattle, Washington area, and focused only on acute nonlymphocytic leukemia, rather than on all cancers (Severson et al, 1988). A rationale for this selection was that a number of occupational epidemiology studies had reported an excess of acute leukemias among workers in electrical occupations (e.g., electrician, utility linemen).

The Severson/Stevens/Kaune study assessed indoor exposure levels in three ways:

- the Wertheimer-Leeper wiring code
- the wiring code that Kaune developed for this project, which provides improved correlation with magnetic fields
- both low-power and high-power indoor magnetic field measurements

None of these three estimates of magnetic field exposure was associated with the incidence of leukemia. The authors concluded:

> "There was no consistent evidence of an increased risk of acute nonlymphocytic leukemia associated with residential exposure to power-frequency magnetic fields. None of the risk estimates were significantly greater than 1.0, and no convincing dose-response relation was observed for the various measures of exposure that were considered in this study." (Severson et al, 1988)

The other epidemiologic studies that have been conducted in community settings have produced mixed results. A number have failed to detect an association between proximity to magnetic field sources and cancer (Fulton et al, 1980; Myers et al, 1985; Coleman et al, 1989; McDowall, 1986), while one other has reported a positive association (Tomenius, 1986).

Other Exposure Sources for Community-Based Studies

Electric blankets are a source of particular interest, because (a) the magnetic field they produce is high (roughly 20 mG) relative to average ambient background in rural areas (about 1 mG); (b) exposure takes place over the course of hours, in contrast to many appliances (e.g., blenders) for which exposure takes place over the course of minutes or less and; (c) exposure is close to the body.

Savitz et al (1990) re-examined the data sets from the Denver childhood-cancer/ powerline study, but instead of wiring codes and spot measurements, they focused on reported use of appliances. These included electric blankets, heated water beds, bedside electric clocks, and heating pads, all of which have the potential to involve extended exposure. For most of the positive findings in this study, some of which achieve statistical significance, the estimates of risk are imprecise, and further research would be required to unravel the meaning of the results presented.

Several population-based studies have been conducted on the potential association between childhood tumors of the nervous system and parental occupations. Spitz and Johnson (1985), as well as Wilkins and Hundley (1990) are careful to point out that chemical exposures in the occupations under study need to be factored in to epidemiologic analyses that address EMF. Two other population based-studies, Johnson and Spitz (1989) and Nasca et al (1988), also examined tumors of the central nervous system among children and again found no consistent pattern.

Occupational Studies

Within the past decade many studies have evaluated the association between employment in an occupation that includes presumed magnetic field exposure and cancers of various types. These studies have taken a variety of approaches and have produced mixed results, some reporting slight, but statistically significant, elevated rates of leukemia or brain cancer among workers in electrical occupations, and other studies reporting no apparent association.

A key issue within the occupational literature is that most of the investigators have been unable to adequately control their data for the potential effects of simultaneous exposure to chemicals. For example, in a study of leukemia deaths at the Portsmouth Naval Shipyard, Stern et al (1986) identify potential confounding exposures for electricians, who had an elevated risk: "Electricians may frequently encounter exposures from metal fumes (i.e., nickel, chromium, iron, or lead, etc.), solvents (including benzene), fluxes, chlorinated biphenyls, epoxy resins, chlorinated naphthalenes, and electrical current." The inability to evaluate exposure to electric and magnetic fields separately from other chemicals complicates studies of brain cancer as well. Thomas et al (1987) reported a statistically significant increase in brain tumors in a group of men in electrical and electronics work. These investigators concluded, "Our data suggest that certain jobs involving ... electronics or electrical equipment involve exposures that are related to excess risk of astrocytic brain tumors. Because these jobs may involve a wide variety of exposures, a specific etiologic [causative] agent cannot be identified from the present data."

The second weakness in occupational studies is that exposures to magnetic fields have not been not directly measured, a problem quite similar to that found in residential studies. Those who investigate occupational exposures have had to rely on occupation, often as reported on the death certificate, or on job title as a surrogate to indicate presence of exposure.

The literature on occupational exposures is too extensive for each study to be reviewed in detail in this document. Nevertheless, the general limitations noted above indicate that conclusions about the possible contribution of electric or magnetic field exposure to cancer cannot be deduced from the occupational literature because of the lack of exposure assessments, and, in most cases, the absence of control for other potential carcinogenic factors. Further occupational research into this issue is continuing.

The epidemiologic studies conducted to date fail to conclusively demonstrate that magnetic field exposure leads to an increased risk of cancer. A universal deficiency in this literature concerns exposure assessment. In no case was total exposure of study subjects to magnetic fields estimated. Rather, exposure was based largely on surrogate measures, such as wiring codes. The best attempts to estimate personal exposure occurred in two community studies in which direct spot measurements of the magnetic fields in subject homes were taken (Savitz et al, 1988; Severson et al, 1988). In neither of these cases was cancer incidence correlated with actual magnetic field strength.

Because virtually all studies include some level of uncertainty about data quality, decisions about causality are predicated, not on the findings of a single study, but on the entire body of literature available. Select key factors to be taken into account in determining causation include (see HEW, 1964; Hill, 1965):

- Consistency - The results from epidemiologic studies of different designs on different populations should be in reasonable agreement with one another.

- Strength of association - Causative arguments are strengthened when the relative risks are high and when the associations between exposure and effect are statistically significant. For high-level associations of exposure with disease, risk estimates can tolerate imprecision. The risk of lung cancer from asbestos exposure (relative risks between roughly 5 and 20), especially among cigarette smokers (relative risks between roughly 25 and 50), is an example of a strong association (Hammond et al, 1979; Selikoff et al, 1980; Berry et al, 1985).

- Coherence - causation is more plausible if it can be based on known scientific principles or established findings. Coherence, thus, may rely on data from scientific disciplines other than epidemiology (e.g., laboratory research).

- Dose-response relationship - The magnitude of the association should increase with increasing exposure. For example, higher exposures to radon gas lead to higher risks of lung cancer.

Thus, the epidemiology studies conducted on magnetic fields and cancer, considered as a body of information, fail to satisfy criteria traditionally considered in assessing causation. The studies are inconsistent, do not have particularly strong associations, lack coherence and fail to demonstrate a positive relation between exposure and response. On the weight of this evidence, one cannot conclude that magnetic fields cause cancer.

Reproductive Outcome

Only two studies concerned with the potential effect of electric and/or magnetic fields on pregnancy outcome within community populations have been published as full papers. The sources of exposure to the fields in these studies were electric blankets and electrically-heated waterbeds (Wertheimer and Leeper, 1986) and ceiling cable heat (Wertheimer and Leeper, 1989). A third study on malformations and use of electric blankets and electrically-heated waterbeds was recently presented by Dlugosz et al (1990). None of these studies examined the association between pregnancy outcome and exposure to fields from transmission or distribution lines, nor did they include actual measures of field exposure.

Wertheimer and Leeper (1986) attempted to determine whether or not the use of an electric blanket or heated waterbed influenced several reproductive parameters, including gestation time, birth weight, and fetal loss due to miscarriage. (Although electric blanket and heated waterbeds both produce user exposure to electric and magnetic fields, they also produce heating, which has been associated with adverse reproductive outcome (e.g. congenital malformations) in both humans and animals. The potential confounding influence of heating is acknowledged by the investigators.) Of these, gestation, birth and limited demographic data (from published records), and information about electric blanket and waterbed use (from telephone survey) were available for only 29 percent of the base population. In addition, no data were collected on potentially confounding exposures, such as smoking, alcohol and drug use, all of which may exert adverse effects on reproduction (e.g. retarded growth, congenital malformations) (Kalter and Warkany, 1983).

Several other problems in design and analysis beset this study. First, gestation time and birthweight are not expressed in terms that are appropriate for the assessment of environmental effects. Both gestation time and birth weight fluctuate from birth to birth and the norms for these two parameters span a range. (For example, a normal gestation period is between 38 and 42 weeks.) Wertheimer and Leeper do not express their data in a format that one can tell if unexposed and exposed groups were within the norm or if one group was different from the another in a meaningful way. Second, fetal loss was not expressed on the basis of the number of pregnancies at risk, but rather in a totally unorthodox fashion on the basis of subsequent livebirth. The bias this approach introduces may be appreciable but cannot be estimated with the available data. Therefore, the study design and sample selection scheme used by Wertheimer and Leeper are inadequate for assessing potential effects of electric blanket and waterbed use on pregnancy outcome.

Laboratory Studies

Cancer

The weak association between wiring configurations of distribution lines outside of homes and the occurrence of childhood cancers observed in some epidemiological studies has raised the possibility that exposure to magnetic fields may in some way influence the development of cancer. A number of laboratory studies have investigated responses that bear upon this question. Biological responses to electric and magnetic fields that may be relevant to the appearance of cancerous tumors, and to stages in the development of those tumors in animals, have received considerable study.

Cancer development is generally divided into three sequential stages: initiation, promotion and progression. Initiation is an irreversible step, likely to involve damage to the cellular genetic material (DNA). Promotion, the second event, involves the growth of initiated cells. This step, unlike initiation, does not usually involve damage to the DNA, and hence is reversible. Progression, the final stage, is believed to involve further changes to the DNA, and like initiation is irreversible.

Tumor Initiation - The ability of electric and magnetic fields to produce mutations to the genetic material of cells and so lead to initiation has been studied in whole animals and in a variety of cells in vitro.

Some investigators have examined chromosomal abnormalities in blood cells taken from workers in high voltage facilities. Bauchinger et al (1981) reported that white blood cells from these workers showed no increase in chromosome abnormalities. However, other researchers (Nordenson et al, 1984, 1988) showed a larger number of chromosomal abnormalities in substation workers. These authors convincingly argued (Nordenson et al, 1984) that the observed chromosomal alterations were not attributable to electric field exposure, but may have resulted from spark discharges received by substation workers in the course of their work.

In summary, there is a consensus among studies of cells from a variety of species (including human), that exposures to either or both electric and magnetic fields, at a range of intensities, in vivo or in vitro, are unable to produce damage in the DNA or chromosomes of a variety of cells.

Tumor Promotion and Tumor Progression - The biology of tumor promotion and progression are not as well understood as that of initiation. For a tumor promoter to act, it is generally required that cells must have first been initiated. In fact, a tumor promoter administered to an animal in the absence of prior initiation does not generally cause tumor promotion. Unlike the situation for initiators, there is no general agreement on the validity of specific assays for the identification of tumor promoters or progressors (Yamasaki, 1988; Langenbach et al, 1988).

During in vivo studies for tumor promotion to determine if electric fields promoted the growth of mammary tumors, Le Bars et al (1983) exposed rats to a 50 kV/m electric field for one and one-half months before, and for 7 months after receiving a chemical initiator. There was no difference between control and exposed rats in the time of tumor appearance, the number of tumors per rat, or the histological appearance of the tumors that developed. The study by Leung et al (1988) used a similar experimental design to Le Bars et al (1983), although the electric field exposures were of shorter duration and lower field intensity.

Most recently, Buntenkotter et al (1990) examined the development of mammary tumors in female rats first fed a chemical initiator followed by no exposure, sham-exposure or exposure to 30 mT (300,000 mG) magnetic fields for 91 days. (No positive control was included in the experiment). This study reported that exposure to magnetic fields had no effect on promotion. Therefore, no consistent effect of exposure of rats to electric or magnetic fields has been observed on the development of mammary tumors.

During in vivo studies in a series of experiments examining tumor progression, Thomson et al (1988) first injected mice with leukemia cells and then exposed the animals to 60 Hz magnetic fields of up to 5 G for five days each week (six hours per day) until death. Control mice were injected with tumor cells but not exposed to magnetic fields. Several indicators of the progression of leukemia were examined and no effect of magnetic field exposure was observed on the progression of the disease. A limitation of this assay is that the follow-up time is short so that control and experimental mice survive for only two weeks after injection of cells.

Still other studies have found no consistent capability of either electric or magnetic fields to enhance the development of established tumors. These include:

- the effect of long-term exposure to a 50 kV/m electric field on spontaneous development of leukemia in the AKR mouse (Le Bars et al, 1983; Le Bars et al, 1988)

- the time of appearance and weight of neuroblastoma tumors transplanted to mice and followed by 16 days of exposure to a 12 G magnetic field (Batkin and Tabrah, 1977)

- the survival of mice repeatedly exposed to 1.6 G magnetic fields following transplantation of mammary carcinomas (Chandra and Stefani, 1979)

In Vitro Studies - Since a characteristic often associated with tumor promotion is alteration of growth properties, many investigators have examined the results of exposure to electric or magnetic fields on the rate of cell growth and DNA synthesis in different types of cells in vitro (Liboff et al, 1984; Whitson et al, 1986; Adolphe et al, 1987; Basu, 1987; Cohen, 1987; Noda et al, 1987; Rodan, 1987). However, many of these studies fail to show any effects of electric and magnetic fields on cell growth or DNA synthesis.

Possible effects of electric or magnetic fields on biochemical measurements of enzymes believed to be 'markers' of growth or proliferation have also been examined. They reported that the intermittent exposure of various cell types in vitro to electric fields of 10 mV/cm for one hour increased the activity of ornithine decarboxylase (ODC) by 175-500 percent. From these data the authors have suggested that because electric fields induce ODC activity they could also induce tumor growth. This, however, is by no means the only -- nor the most likely -- explanation for their findings.

In summary, investigation of the responses of animals and many kinds of cells in vitro has not revealed that the growth, proliferation or any other parameter that would be indicative on cancer-initiating, cancer-promoting or cancer-progressing responses is affected to any significant extent by exposure to 60 Hz electric and magnetic fields. The appearance of tumors, stimulation of cells to uncontrolled growth or damage to DNA have not been observed consistently in well-controlled and reproducible experiments that exposed animals or cells to 60 Hz electric and or magnetic fields. A few isolated reports which have suggested that exposure to these fields may lead to DNA damage or to alterations in the growth potential of cells have failed to be replicated in subsequent, more comprehensive studies. Thus, the experimental data available to date fail to support the suggestion that exposure to 60 Hz electric or magnetic fields may be associated with an increased risk of cancer development.

Studies of Cellular Function

Production of RNA and Proteins - Protein synthesis is an essential and continuous activity of cells. The process of protein synthesis involves the production of messenger ribonucleic acid (mRNA) molecules from the DNA template and translation of the mRNA into proteins. Goodman and colleagues have investigated the effects of electric and magnetic fields on RNA transcription and the production of proteins (Goodman and Henderson, 1986; Goodman et al, 1987; Goodman and Henderson, 1988; Goodman et al, 1988, 1989a, 1989b).

More recently Goodman et al (1988, 1989a, 1989b) have run similar experiments using a human cell line, Hl-60. They have reported that exposure of these cells to electric and magnetic fields also results in changes in RNA transcription and protein synthesis. Preliminary results from a study of similar design reported different results (Skowronski et al

1990). The investigators found that exposure of Hl-60 cells to 10 G magnetic fields resulted in an increase in RNA transcription.

Since changes in transcription are part of the normal repertoire of cellular responses to various stimuli, these data in themselves are not indicative of a harmful effect.

Studies of Immunological Function

The immune system is the body's first line of defense against disease. The function of the immune system is to recognize and destroy substances identified as "foreign" to the organism. These can be chemicals, bacteria, viruses, or cells that have acquired altered characteristics, such as cancer cells.

Many studies have been performed to evaluate the effect of exposing humans, mice or rats to 60 Hz electric and/or magnetic fields on the function of the immune system (Morris and Ragan, 1979; Morris and Phillips, 1982; Ragan et al, 1983; Seto et al, 1986; Fotopoulos et al, 1987; Morris 1989, Graham et al, 1990). None of the in vivo assays show that electric and/or magnetic fields affect the competence of the immune system.

Further analyses of the effect of electric and magnetic fields on immune function have been performed using isolated immune cells in vitro. Winters (1987) exposed canine and human lymphocytes to electric, magnetic or combined fields and they did not observe any effects in levels of cell surface antibodies or specific receptors.

Adverse effects on the immune system from exposure to 60Hz electric and/or magnetic fields have not been demonstrated by in vivo data. Since the in vitro data are inconsistent, they require replication with further in vitro assays and verification in an in vivo system.

Studies of Endocrine Function

A number of studies have examined the effect of electric fields on endocrine function (Free et al; Seto et al, 1984; Quinlan et al, 1985; Wilson et al, 1981; 1983; 1986; 1988; Maresh et al, 1988). Most of these studies show no effect on endocrine parameters.

The only consistent endocrine response that has been reported is the reduction in the peak secretion of the hormone melatonin from the pineal gland during the night. This has been observed in albino rats continuously exposed to electric fields (Wilson et al, 1981; 1983; 1986; 1988) for at least three weeks. The levels of melatonin release nevertheless return to normal values within as few as three days after exposure with no apparent effects.

Reproduction

Numerous experiments have been performed to examine any possible effects of 60 Hz electric and/or magnetic fields on reproduction and fetal development. Several animal species have been used, and as a whole, the published reports in this area provide no conclusive evidence that such exposure constitutes a reproductive health hazard.

Some of the studies have exposed successive generations of mice continuously to 60 Hz electric fields. The purpose of such studies is to determine whether electromagnetic exposure could cause genetic mutations that might not show up in the offspring of exposed parents, but would affect later generations. Seto et al (1984) conducted a multigenerational study in which rats were exposed for four generations to a 60 Hz electric field strength of 80 kV/m. Conception, birth, and growth of each generation of offspring all occurred in the field. Based on examinations of more than 2600 offspring showed that electric field exposure produced no effects on fertility, nurturing, survival, or sex ratio. Benz et al (1987) conducted an investigation of potential multigenerational influences. In each generation data were taken for several parameters of reproductive importance, such as: impregnation rate, litter losses, litter size, gestation time, postnatal growth and survival, and sex ratios. None of these endpoints were affected.

Reproductive studies have also been conducted focusing specifically on 60 Hz electric field effects on in utero development. Sikov et al (1984), female rats were exposed to an electric field strength of 65 kV/m in one of three ways:

- From before mating through gestation
- From the beginning of gestation to 8 days post-natally
- from the 17th day of gestation to 25 days post-natally (Sikov et al, 1984). Each exposure lasted thirty days

None of these exposures produced effects on malformation rates and/or resorption, survival, or growth.

In a subsequent experiment on rats using the same electric field exposure strength as Sikov et al (1984), two replicates (i.e., repetitions) were carried out. The results of the two replicates differed. One replicate showed no deleterious effects on reproduction. In the other, however, female offspring that had been raised in the field were less fertile and their litters had more malformations than the exposed animals. The authors speculated that the differing results reflected biological variation among groups of animals.

Though most studies tested for potential effects of electric fields on reproductive outcomes, several studies have also been conducted with magnetic fields using mice (Fam, 1981) or rats (Brinkmann et al, 1988, Rommereim et al, 1990). None of these studies have shown any effects of magnetic field exposure on pregnancy outcomes or malformations. Although some of the studies cited have reported changes in reproductive outcome, the weight of evidence from animal experimentation supports the conclusion that 60 Hz electric exposures are not harmful to reproduction and development. When these infrequent positive results are considered among the studies that have reported no effects whatever, it is reasonable to conclude that there is very little likelihood that 60 Hz electric fields adversely affect reproductive processes. This conclusion was shared by the Scientific Advisory Panel of the New York State Power Lines Project in their evaluation of the possibility that the 60 Hz power transmission electrical environment could affect reproduction:

> "There is currently no convincing evidence for field effects on fertility or growth. Further animal studies would not seem warranted for these variables." (PLP, 1987, p. 133).

Physiological Systems

Numerous laboratory studies have been conducted to address the question of whether 60 Hz electric and magnetic field exposure could affect the performance, physiology or associated cognitive states of the nervous system. The specific questions asked have been the following:

- can electric or magnetic fields be perceived?
- can these fields modify the performance or responses of individuals, regardless of whether or not there is conscious perception of the fields?
- is exposure to electric and magnetic fields detrimental to individuals?

Although several studies have examined the general health of human or animal subjects exposed to electric and/or magnetic fields, few have been as thorough and well-controlled as the recent report by Graham and Cohen (1987). These investigators performed a comprehensive evaluation of possible effects of electric and magnetic fields on human performance, physiology, and subjective state. They created a unique, 60 Hz human exposure facility designed to generate electric (0-16 kV/m) and magnetic fields (0-400 mG) in a controlled laboratory environment. They used this facility to evaluate human physiological, sensory, neural, motor, perceptual and cognitive function (e.g. respiration, heart rate, visual acuity, focused attention, short-term memory, time perception, information processing and decision-making).

There were no responses to field exposures for the overwhelming majority of the physical, biological and psychological measures that were examined. No significant effects were observed on sleep, appetite, sexual activity, cognitive and physical functions, or on several measures of mood (e.g. vigor, anger, fatigue, confusion, depression). Furthermore, no significant effects were observed on the majority of the vital signs (e.g. blood pressure, oral temperature, skin conductance).

Other researchers have conducted experiments with electric and/or magnetic fields at the whole animal level on a large variety of endpoints that involve behavior, neurological development, and neurochemical metabolites in body fluids. In many cases, these experiments were conducted with field strengths much higher than those found commonly in human environments, or were conducted under extremely specific conditions that are not realistic in terms of human experiences and activities. While some investigators have reported observing biological changes, none of these changes is interpretable in terms of the health of people resident near transmission lines.