Frequently Asked Questions about Magnetic Fields and Homes

This fact sheet contains information about electric and magnetic fields (EMF) from power lines, building wiring, appliances, and other electrical equipment in residential settings. This information may be of use to people who are buying, selling, or renting homes or apartments, or have questions about EMF in their current residence. Some of the information in this fact sheet is specific to the state of California. For more general information about EMF, please see our long and short fact sheets, available on the Internet at *http://www.dhs.ca.gov/ps/deodc/ehib/*.

What are Electric and Magnetic Fields?

Wherever there is electricity, there are also electric and magnetic fields (EMF), which are fields of force (or energy) created by electric charges. Electric fields result from the *strength* of the electrical charges, or the voltage, while magnetic fields result from the *motion* of the charge, or the current. Because the electric current creates magnetic fields, appliances must be turned on to produce magnetic fields, but any appliance that is plugged in will produce an electric field. Electric fields are easily shielded: they may be weakened, distorted, or blocked by conducting objects such as earth, trees, and buildings, but magnetic fields are not as easily blocked. The intensity or strength of an electric field in a location is measured in volts per meter (V/m) or in kilovolts per meter (kV/m). The intensity of a magnetic field is measured in gauss (G) or tesla (T). The strength of both electric and magnetic fields decreases as you get further away from their source.

Direct current of the sort from a battery-operated appliance such as a flashlight flows only in one direction, unlike alternating current (AC) sources in which the energy flow changes direction with a specific frequency, measured in cycles per second or Hertz (HZ). Power systems in the United States create a specific type of alternating current electric and magnetic fields, called 60 Hertz or "power frequency" fields. This fact sheet focuses on power frequency fields created by power lines and other electrical equipment, and not on DC fields or on the higher frequency and higher energy fields generated by sources such as cellular phone antennas or television transmitters.

What are Some Sources of Power Frequency EMF in Homes?

There are power frequency electric and magnetic fields almost everywhere we go because electric power is so widely used. Exposure to these fields comes from many sources, such as high voltage "transmission" lines (usually on metal towers) carrying electricity from generating plants to communities and "distribution" lines (usually on wooden poles) bringing electricity from local substations to our homes, schools, and work places. Other sources of exposure are internal wiring in buildings, low voltage currents flowing back to the power grid on plumbing pipes, and electric appliances such as televisions, computer monitors, radios, hair dryers, and electric blankets. Sources with *high voltage* produce strong electric fields, while sources with *strong currents* produce strong magnetic fields.

If you are concerned about EMF from any of these sources in or near your home it may be helpful to know that electric and magnetic fields weaken as you move further away from their source. Electric and magnetic field strength gets lower more rapidly with distance from "point" sources such as appliances than from "line" sources such as power lines. In general, the fields from a particular source are down to "background" level (the typical amount a person might encounter even if that source were not present) about 3-4 feet from an appliance, 60-200 feet from a distribution line, and 300-1,000 feet from a transmission line. Fields can interact to strengthen or weaken their total effect in a given area. Because of this, the field

strength at a particular location depends not only on the distance from the major source but also the distance and location of other nearby sources.

Transformers convert high voltage electricity from "primary" distribution lines (that carry power from substations through neighborhoods) to electricity of the lower voltage used in homes, which is carried from the transformer through the neighborhood on "secondary" distribution lines until it is fed off to the individual homes. For overhead distribution lines, the transformers are the canisters or cylinders on some utility poles between the upper primary lines and the lower secondary lines. For underground lines, the transformers are boxes, usually at ground level, that are connected to the power lines below.

Transformers, like appliances, are point sources, and so fields decrease fairly quickly as one moves further away from them. Because of the large amount of electrical current that often goes through transformers, though, the fields from them may be higher than from some appliances and may require a greater distance to reach background levels.

Power substations contain electrical equipment that creates fields, but equipment (mostly point sources) inside most stations does not raise fields outside of the station itself. There are generally many power lines that run into and out of substations, however, and these power lines, like any others, produce fields. So, elevated fields in homes near substations may be from power lines connected to the substation rather than the equipment inside the station itself.

This fact sheet focuses on power frequency magnetic fields, since they have been the object of more concern and study than electric fields. This is because magnetic fields are not easily shielded and therefore can penetrate soil, building materials, and the body surface more easily than electric fields. For this same reason, they are also easier to measure.

How is Magnetic Field Exposure in Homes Measured?

There are several different ways of estimating a person's magnetic field exposure at home. The major ways this has been done are: 1) indirectly by assessing the types and proximity of power lines nearby (wire codes); 2) indirectly by taking area (spot) measurements; and 3) directly by taking repeated measurements with a meter worn by a person while at home (personal measurements).

1. Wire codes

Many early studies of magnetic fields and human health estimated exposure from powerlines by using "wire codes" rather than by directly measuring fields. Wire codes categorize homes based on the types of power lines near the house and their distances from it. The wire code system is based on the fact that magnetic field strength decreases with distance from the field source and the assumption that homes near power lines that have the potential to carry more current would have stronger magnetic fields than homes next to lines that are limited to carrying smaller amounts of current. Table 1 shows one type of wire code system and the ranges of "spot measurements" (brief magnetic field measurements taken at different locations) found in different wire code category homes in one study.[1] Using this system, all homes fit into one of four possible categories based on the type and distance of nearby power lines. These four categories are intended to reflect different levels of magnetic field exposure from power lines. Though the highest fields are found in homes in the highest categories, spot measurements in the homes show that there is a great deal of overlap between the fields found in the different categories. Note that while the average field in homes served by underground lines is lower than those served by above ground lines,[2] these homes still have fields from other sources such as wiring and appliances.

Table 1 Magnetic field spot measurements in residential areas by wire code (strengths in milliGauss)

	Under Line				Outdoor + Front Door				Indoor			
	UG	OL	OH	VH	UG	OL	OH	VH	UG	OL	OH	VH
Mean	X	1.2	2.2	3.3	0.8	0.7	1.1	1.5	0.8	0.9	1.1	1.5
10%	X	0.5	0.5	0.6	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5
50%	X	0.9	1.1	1.50	0.7	0.6	0.8	0.9	0.7	0.7	0.9	0.9
90%	X	2.0	5.0	6.1	1.3	1.2	1.9	3.2	1.2	1.5	1.7	2.8

Source: Lee, G., California Exposure Assessment Study (preliminary findings). California EMF Program. 1996

Wire Codes:
UG (Underground) All power lines within 150 feet of the house are below ground.
OL (Ordinary Low) The house is 130-150 feet from a transmission line or major primary distribution line, 65-150 feet from a minor primary distribution line, or 51-150 feet from most secondary distribution lines.
OH (Ordinary High) The house is 50-129 feet from a transmission line or major primary, 25-64 feet from a minor primary, or within 50 feet of certain types of secondary lines.
VH (Very High) The house is within 50 feet of a transmission line or major primary or within 25 feet of a minor primary.

Spot measurement categories:
Under Line – Directly underneath the power lines nearest the home being surveyed
Outdoor – Measured in the outdoor areas on the property of the home being surveyed
Indoor – Measured inside the home being surveyed

2. Spot measurements

A second measurement strategy that has been used to estimate an individual's magnetic field exposure is taking spot measurements (measurements over a short time period) in homes. Some people believe that spot measurements represent a person's residential exposure better than wire codes. This belief is based on the fact that spot measurements involve the measurement of actual levels and so could capture exposure from sources other than power lines, such as appliances and home wiring. Wire codes could not be expected to reflect these non-powerline field sources. Spot measurements have their own limitations, however. First, they only measure the field levels at one point in time, though magnetic fields change over time depending on energy use. In addition, they only measure magnetic fields at a few spots in a given home, typically the centers of the rooms that are used most often. These measurements may not capture the levels near walls or particular appliances, though people may spend time in these other locations.

Table 2A Distribution of average magnetic field strength in San Francisco Bay Area homes

Percent of homes with average spot measurements below field strength	Field strength
10%	0.4 mG
25%	0.5 mG
50% (median)	0.7 mG
75%	1.0 mG
90%	1.6 mG

Lee, G., California Exposure Assessment Study (preliminary findings). California EMF Program. 1996

Table 2B Percentage of San Francisco Bay Area homes in various milliGauss ranges

Field Strength Range	Percentage of homes with average spot measurements in range
0-0.7 mG	45.0%
0.7-1.0 mG	29.5%
1.0-2.0 mG	19.3%
2.0-3.0 mG	3.2%
3.0-4.0 mG	1.7%
4.0+ mG	1.3%

Lee, G., California Exposure Assessment Study (preliminary findings). California EMF Program. 1996

Table 2 shows magnetic field home spot measures from a survey conducted by the California Department of Health Services of about 600 homes in the San Francisco Bay Area and individuals residing in these homes. For the home spot measurements, the strength of magnetic fields was obtained for the bedroom, family room, and kitchen, and averaged for the total home exposure. Any appliances or electrical devices that were on at the time of measurement were left on. As shown in Table 2A, about half of the houses had an *average* magnetic field level below 0.7 milliGauss (mG) and 90 percent had *average* levels below 1.6 mG. Measurements from a national survey were similar.[3] All of the measurements reflect the average field strength of the 60-Hertz frequency magnetic fields when the measurements were taken, and the levels could be higher or lower at other times. For example, readings taken at dinnertime, when more appliances are in use, are often higher than ones taken in the middle of the night. Table 2B shows the percent of the same houses that fell into certain milliGauss categories.

3. Personal measurements

In fact, neither wire codes nor spot measurements capture the true magnetic field levels experienced by people while they are at home. Some recent studies have attempted to capture a person's actual exposure by having study participants wear magnetic fields meters, generally for 24 hours, so their measurements can be recorded throughout a full day. Participants keep track of where they are throughout the day, so their location (at home, at school or work, etc.) can be matched to their measurements. Table 3 shows the personal average magnetic field measurements for about 600 San Francisco Bay Area residents while they were at home. These measurements are similar to the home spot measurements. Overnight exposures were slightly lower than those found for the "awake" times. Comparing Table 2A and Table 3 demonstrates that the spot measurements taken in the middle of rooms in these women's homes provide a good estimate of the magnetic fields these same women experienced as they moved around inside those houses. The personal measurements are a little higher than the spot measurements.

The strength of the personal magnetic field exposures may be measured in different ways. The average shown in the table above captures the average field strength over a given time period. Another thing to consider is that a person's exposure over time may be of a constant strength or the strength may vary. One way of assessing the changes in strength over time is by looking at how much and how quickly the intensity changes over time, or the "rate of change." This can be assessed using a "rate of change metric" (RCM). A slightly different way of measuring fields is to compare the minimum level to the maximum level experienced over time; this shows the overall range of

Table 3 Distribution of average home personal magnetic field measurements of residents (strengths in milliGauss, as measured with a meter worn by a resident of the home during the time spent in the home)

Percent of homes (persons) with average measurements below field strength	Personal Average Total Home	Personal Average Home "awake time"	Personal Average Home "bed overnight"
10%	0.5	0.7	0.4
50% (median)	0.7	0.8	0.6
90%	1.7	1.8	1.6

Lee, G., California Exposure Assessment Study (preliminary findings). California EMF Program, 1996

intensity, but not the rate at which the level changes. These metrics may capture different sources of magnetic field exposure. A person with a high average exposure may not necessarily have a high RCM.

Figures 1A and 1B show the overnight magnetic field tracing for two different people, John and Joan. The strength of the field is on the vertical y-axis while the time period is on the horizontal x-axis of each graph. Both John and Joan have the same average exposure (about 2.0 mG). However, the variation in their measurements (the rate of change metric) is different. Joan's nighttime exposure is constant in field strength while John's nighttime exposure fluctuates considerably. As a result, John has a greater range of nighttime exposure (1 mG minimum to 3 mG maximum) than Joan, whose minimum and maximum values are the same.

In the study of San Francisco Bay Area women mentioned above, the maximum magnetic field experienced by 75% of women was above 14 mG, 50% experienced brief maximum fields above 23 mG, and 25% experienced maximum fields above 35 mG. Most women only experienced a few such high exposures a day, probably from moving near appliances, underground power lines, or indoor fields from building wiring or plumbing.

Though these personal measurements capture a person's actual exposure at different places and times, rather than the estimated average fields in their homes, this strategy also has limitations. For example, it is possible that the measurements may be taken on an atypical day, one on which a person does not participate in usual daily activities or is exposed to different sources than on most days. For example, a person who cooks with an electric stove almost every day may seem to have lower exposure if he is measured on a day when he does not cook. So, a person's average daily exposure over the course of a year may be very different from that person's exposure on any given day.

Figure 1A

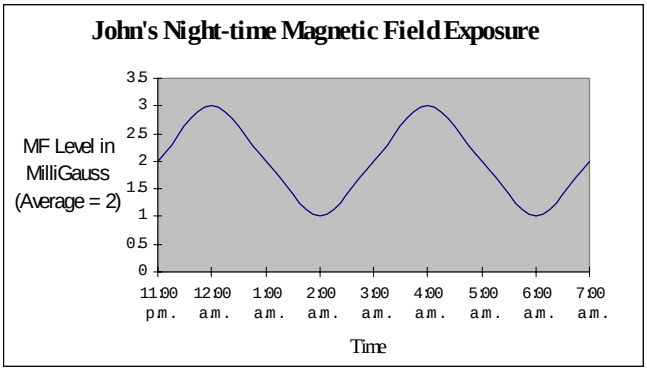
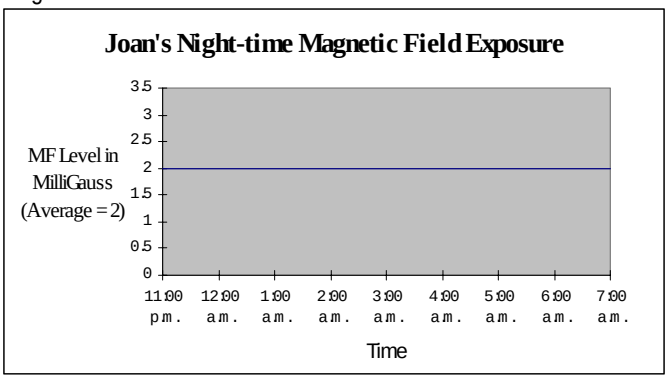


Figure 1B



Advantages and Limitations of the Different Measurement Strategies

Each of these ways of measuring a person's home magnetic field exposure has advantages and limitations. Wire codes estimate exposure on the basis of something

relatively constant over time: proximity to different types of power lines. Because of this they might provide good estimates of exposure from power lines, even for times in the past. The different wire code categories overlap, however, and only consider power lines, not other sources, so wire codes may not capture differences in exposure between homes as well as some of the other measurement strategies. Also, wire codes may only capture certain types of exposures such as the average level rather than the level's rate of change.

Spot measurements capture more of these differences because they measure actual fields at different locations in the home; however, they are generally only taken at specific locations around the home and at one point in time, and so may not capture people's actual exposure in the areas where they spend time or over the course of a year. Personal measurements capture a person's actual exposure, but generally only measure a short period of time that may not be representative of a person's exposure on a typical day or a person's average annual or lifetime exposure. Unlike spot measures, measurements taken over a longer period of time (i.e., for a 24-hour period) allow researchers to see some changes in the exposure over time.

How High are the Magnetic Fields Likely to Be in A Home Near an Overhead Power Transmission Line (Usually on a Large Metal Tower)?

Every situation is different because the fields near any power line depend on several factors, including the exact distance of a home from the line and many engineering aspects of how the lines are set up. As stated earlier, fields from power transmission lines often reach background levels between 300 and 1,000 feet from the line. The only way to be sure of the fields in a given area at a particular time is to get measurements taken.

What is a "Safe" Level of Magnetic Field Exposure?

Scientists are not sure whether there are health risks from exposure to power frequency magnetic fields or, if so, what is a "safe" or "unsafe" level of exposure. There have been many studies on this but none conclusively show whether magnetic fields are a health risk, and some studies have had contradictory results. In 1998, a work group formed by a federal program that studied this issue classified EMF as a "possible human carcinogen" for childhood leukemia, meaning that they believe that it might increase the risk of getting childhood leukemia, but they are not sure. That program's final report states that "... [power frequency] ELF-EMF exposure cannot be recognized as entirely safe because of weak scientific evidence that exposure may pose a leukemia hazard."[4]

But because it is not clear whether exposure to EMF increases health risks, the report does not recommend taking difficult or expensive actions to reduce exposure. It does suggest that people consider reducing their exposure if it is easy or inexpensive to do so.

Because we do not know whether electric and magnetic fields are a health risk, it is impossible to say whether a given amount of magnetic field exposure or particular distance from a power line or other source is "safe" or "unsafe." It is possible to compare the levels measured in a home to average (or typical) levels found in a survey of homes such as the survey conducted by the California Department of Health Services (CDHS).

CDHS is currently conducting a Risk Evaluation to determine how likely it may be that EMF, especially magnetic fields, might increase health risks. Researchers are reviewing the evidence and writing a report to explain their conclusions and recommendations. This report is expected to be available by the end of 2001.

Are There Any Government Standards for Magnetic Fields Levels in Homes?

There are no federal or California state laws limiting the level of EMF in residences or the amount to which a person can be exposed. This is because no one is certain whether magnetic fields might increase health risks. Still, in some cases the effect of EMF on residences may be considered in new development. The California Public Utilities Commission, which regulates most of the electric utility companies in California, encourages utilities to take low-cost actions to reduce the fields created by new power lines and facilities. Local governments have the authority to approve new residential and commercial development, and sometimes consider the location of nearby power lines and other electrical equipment in their approval process.

Table 4 Setbacks for siting new schools near power transmission lines

Transmission line voltage	Required setback
50-133 kV	100 feet
220-230 kV	150 feet
500-550 kV	350 feet

School Facilities Planning Division, California Department of Education, "School Site Selection and Approval Guide," 1993

City and county governments can require new building projects to meet certain conditions, and in some cases may require projects to take action to minimize fields where people will live or make possible tenants and buyers aware that they are near electrical facilities. These requirements vary by location and sometimes by project.

Currently, the only relevant state regulation in California requires that when new schools are built, they must be at least a minimum distance from transmission lines. The required setback varies depending on the voltage of the line (see Table 4). This regulation does not apply to existing schools that are near power lines, and is not based on any evidence that the setback might decrease health risks. For more information on this regulation, contact the School Facilities Planning Division of the California Department of Education.

If I Am Concerned About the Possible Health Effects of Magnetic Fields, What Factors Should I Consider When Looking at A Home or Apartment?

If you are concerned about EMF, there are questions that you can ask when buying or renting a home or apartment to help you address your concerns. Some questions include:

- Are there any overhead or underground power lines nearby? If so, what types (transmission, sub-transmission, overhead distribution, or underground distribution) and how far are they from the home?
- Are there any electrical facilities (such as power stations) located in the immediate area?
- Does the electrical wiring in the home meet current electrical safety standards? Improper wiring can cause high magnetic fields in the home's electrical system or on metal plumbing pipes, and may also create a potential fire or shock hazard.
- How old is the wiring, and has it been updated using current standards? Older "knob and tube" wiring creates higher fields than more modern wiring.
- Where are the other major sources of high EMF in and near the home located? These sources may include electric appliances, transformers, track lighting, lights with dimmer switches (if not wired correctly), and the place where the electrical wire from the power line enters the building (called the "service drop").
- How close are these sources to the areas in which your family members will spend most of their time (bedrooms, living room, etc.)?

Where you live is a very individual decision, but the answers to these questions may help you decide whether you are concerned about EMF exposure in the home.

How Do I Find Out the Magnetic Field Levels in A Residence?

You can learn whether the field levels are above average in a home or yard by getting magnetic field measurements taken by your utility company or a consultant.

In California, you can ask your utility company to take measurements of field levels on your property. California requires most utilities to do this free of charge for their customers. To get measurements taken by your utility company, call their customer service telephone number and tell the operator that you would like to get the electric and magnetic field levels measured in your home. If you are the owner or current utility customer of the property you would like measured, you should be able to make an appointment to have measurements taken. If you are considering renting or buying the property but do not yet live there, your utility company should be able to explain to you the requirements for getting the current customer or homeowner's permission to have measurements taken on their property; your real estate agent or rental agent may be able to help with this.

If you live outside of California and your utility does not take measurements, or if you prefer not to have your utility company take measurements, you can take measurements yourself with the proper equipment or pay a consultant to do this. Magnetic fields are measured with an instrument called a gaussmeter. There are many different types of these meters available; a publication focusing on EMF called Microwave News has a list on the Internet at ***http://www.microwavenews.com/EMF.html*** of some meters and the companies that sell them. There may also be other meters available through other sources.

To find a private consultant to take measurements for a fee, you should look for someone experienced in taking these measurements. The California EMF Program has a list of non-utility measurement providers that volunteered information about their businesses in order to make their services known. Another resource that may be helpful in finding a consultant to take measurements is the National Electromagnetic Field Testing Association (NEFTA), which may be able to refer you to consultant in your area. The NEFTA Web site can be accessed at ***http://kato.theramp.net/nefta/***. The Public Health Institute, the California Department of Health Services, and the California EMF Program do not certify, accredit, license, or endorse any EMF measurement consultants, EMF meters, or their providers.

The person taking measurements should measure field

levels in several places on the property, especially inside the rooms in which people will spend a great deal of time (such as bedrooms). If there are power lines or other electrical equipment nearby, measurements should be taken at different distances from them, to discover whether the fields from those sources are raising field levels inside the home. A good technician will also be able to identify areas with unusually high fields and the sources (such as improper wiring or power lines) of those fields.

How Do I Interpret Measurements Once I Have Them?

Because we do not know whether EMF exposure is a health risk, magnetic field measurements may allow you to compare the levels in your home to levels in other homes, but even if the levels are above average, this does not necessarily mean that they increase your health risks. Similarly, if the levels are below average, this does not necessarily mean that the field exposure in the house is "safe." There is no general agreement about whether exposure to magnetic fields might increase health risks or, if it does, what level could be considered safe; these measurements will just give you an idea of whether the magnetic field levels in your home are similar to measurements typical in other homes or residential settings.

If you get measurements taken, your utility or other measurement provider may also be able to give you some information about how the measurements compare to those in other homes. You may compare your measurements to those found for various published home surveys such as the 600 homes surveyed by the CDHS (as summarized in Tables 1, 2A, and 2B).

How can I reduce my EMF exposure from sources in and near my home?

Until we have more information, some communities and individuals are adopting a "no and low cost avoidance" strategy. Whether or not you get magnetic field measurements taken in your home, there are things that you can do to reduce your exposure. For example, you can move electrical appliances further away from places where you spend your time. In most cases, fields almost disappear at distances of 3 to 5 feet from a regular household appliance. It is usually easy to move an electric clock a few feet away from your bed, or to sit further away from your computer monitor. Sometimes, you may have sources in or near your home that cannot be moved, like major appliances or power transformers connected to overhead or underground power lines. If you find that this type of source is producing higher fields in your home, you may be able to rearrange your furniture so you spend less time near the source. For example, if there is a power transformer on the outside of your bedroom wall, you might be able to move your bed to the other side of the room or to another room so you spend less time in the field from this source.

If you are building a new home or remodeling or adding to your home, there are things that you can do to minimize fields in the areas where people spend time. Proper wiring and the thoughtful placement of electric appliances can help reduce exposure. The *EMF Checklist for School Buildings and Ground Construction* provides some specific ideas for reducing EMF in schools that may be helpful when planning and carrying out residential construction.[5] The California EMF Program also co-sponsored a video in which an EMF consultant demonstrates techniques that electricians can use to identify and correct some common wiring errors that create high fields and may pose a potential fire hazard. This video was created for schools, but may also be useful for residential settings. The school checklist and a description of this video (with ordering information) are available on the Internet; go to *http://www.dhs.ca.gov/ps/deodc/ehib/* and click on California Electric and Magnetic Fields Program.

How Important Should EMF Be When I Am Deciding Where To Live or What Home To Buy?

In the absence of conclusive evidence that EMF is or is not a health risk, it is up to each individual to decide how important the presence of EMF sources is in choosing a place to live. EMF may be one of many factors considered in this choice. Other important factors may include a home's cost, the quality of local schools, and proven risks of the location, such as the possibility of earthquake, flooding, or fire, or the presence of traffic, radon, or air pollution. To some people even limited evidence for a possible EMF risk weighs heavily in their decisions. For others, different considerations take precedence. There really is no one right answer to this question because each situation is unique.

[1] Lee, G., California Exposure Assessment Study (preliminary findings), California EMF Program, 1996.

[2] The reason that underground lines usually produce lower fields in nearby houses than overhead lines is not because the dirt blocks the magnetic field; it is because several heavily insulated cables can be placed closer to each other than relatively uninsulated overhead cables could be, allowing the magnetic fields from the different cables to cancel each other out. Nonetheless, fields directly above an underground line can be quite high because they are only a few feet below the surface.

[3] Zaffanella, L., Survey of residential magnetic Sources, EPRI Final Report, 1993. No. TR 102759-v1 and No. TR 102759-v2.

[4] National Institute of Environmental Health Sciences, *Assessment of health effects from exposure to power-line frequency electric and magnetic fields,* NIEHS Final Report to Congress, 1999.

[5] Cavin, B., *EMF Checklist for School Buildings and Grounds Construction,* California EMF Program, 1996.