APPENDIX I

ELECTROMAGNETIC FIELDS MANAGEMENT PLAN

MEMORANDUM

FROM: Caitlin Rochon, Project Coordinator, Toronto and Region Conservation Authority
SUBJECT: Assessment of the Magnetic Field Exposures of Persons Using the East Don Trail
DATE: September 22, 2016

In 2015, Toronto and Region Conservation Authority retained the Radiation Safety Institute of Canada to undertake an electromagnetic field (EMF) survey on the portions of the proposed East Don Trail impacted by the transmission lines in the Gatineau Hydro Corridor. The study included calculating the levels of potential exposure to power frequency magnetic fields for individuals, with a focus on children, who will be using the path for recreational purposes and determining options, if necessary, to reduce individual's exposure to magnetic fields.

Magnetic field strengths were reported at a nominal height of 1 meter above ground level where feasible. Calculations, extrapolations, and substitutions of data from similar situations (e.g. mirror image, shift along the ROW) were performed to characterize magnetic field strengths at the Metrolinx/Go Transit owned Bala Subdivision rail line where measurements were not feasible.

Results of the study determined that exposure of children to magnetic fields from the Hydro One transmission towers using the proposed East Don Trail will be small. For individuals using the trail on a daily basis for nine months of the year, the increase in their annual average magnetic field exposure will be only about 9% of the City of Toronto guideline of 2 mG.

At the time of the study, the preferred crossing of the Metrolinx rail line at Metrolinx Crossing 2 (within the Gatineau Hydro Corridor) was a level crossing. Further discussions between the project team and Metrolinx indicated that it is Metrolinx's policy direction to not permit any new level crossings of active rail corridors, and therefore the proposed level crossing could not be selected as the preferred crossing option. Therefore the Metrolinx Crossing 2 has been changed to a bridge in the Environmental Study Report.

If required, the EMF exposure data may be updated to accommodate the change in Metrolinx Crossing type prior to construction.

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Assessment of the Magnetic Field Exposures of Persons Using the East Don Trail

for

Toronto and Region Conservation Authority

by

The Radiation Safety Institute of Canada

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Submitted to:

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Date: **October 23, 2015**

Submitted by: Natalia Mozayani, RSIC Executive Director, + 1 416 650 9090 ext 28

Contents

1 Introduction

The City of Toronto and the Toronto and Region Conservation Authority are designing a multi-use trail that will connect the Lower Don Trail at the convergence of the East Don River and Taylor Massey Creek, upstream through the East Don corridor to the existing East Don Trail, and provide a connection to the Hydro Gatineau Corridor. The preferred trail alignment is illustrated in Figure 1, with key elements such as bridges, tunnels and trail connections noted. A portion of the trail will be in close proximity to electrical transmission lines and, as required by the City of Toronto, Public Health in accordance with the City Prudent Avoidance Policy regarding children's exposure to electric and magnetic fields (EMFS), an assessment of the exposure to power frequency magnetic fields by individuals using this portion of the trail must be performed.

The Radiation Safety Institute of Canada was contracted by the Toronto and Region Conservation Authority to assess the magnetic field exposure of children and other individuals using the sections of the trail on or close to the Hydro One right-of-way, and to prepare an EMF Management Plan for these areas. This was done in order to meet the requirements of the document "Guidance Manual for the Preparation of an EMF Management Plan for the City of Toronto", which had previously been prepared for Public Health by W&W Radiological and Environmental Consultant Services. The Institute hired sub-contractor W&W Radiological and Environmental Consultant Services to perform the field measurements and prepare a draft report. The findings of the magnetic field measurements on the portions of the trail in the vicinity of the transmission lines are documented in this report. The work in this study involved the following:

- Conducting a magnetic field level survey on the portions of the proposed path impacted by the transmission lines.
- Calculating the levels of potential exposure to power frequency magnetic fields to the children who will be using the path for recreational purposes e.g. biking, running or walking;
- Determining options, if necessary, to reduce children’s exposure to magnetic fields.

2 Measurements of Magnetic Fields at the East Don Trail

2.1 Survey Procedure

Power frequency magnetic field levels were measured using a calibrated Tenmars model TM-192D EMF/ELF meter, Serial Number 40400860. The TM-192D meter employs orthogonal sensing coils that measure and then combine the magnitude of the magnetic field components along the three orthogonal axes. The display provides the total magnetic flux density in units of milligauss (mG) for the frequency range 30 Hz to 2000 Hz. Measurement readings may be converted to microtesla (µT) by dividing by a factor of 10. Following standard EMF survey procedures, magnetic field strengths are reported at a nominal height of 1 meter above ground level unless otherwise indicated. The field measurements are valid for the time of the measurement. However, ambient field levels generally vary with time primarily as a function of the electrical load on the source wires. Accordingly, where fluctuations in readings were noted while conducting the survey, the highest reading was recorded.

A section of the proposed trail currently consists of an existing Hydro One gravel access route. Distances between measurement locations on this section were performed using a measurement wheel. For those portions of the proposed trail that were in heavily wooded or bushy areas, or on uneven ground, wooden stakes were positioned at intervals along the proposed trail by staff from the Toronto and Region Conservation Authority a period of days prior to conducting the measurements. The distances between magnetic field measurements were determined using an optical range finder.

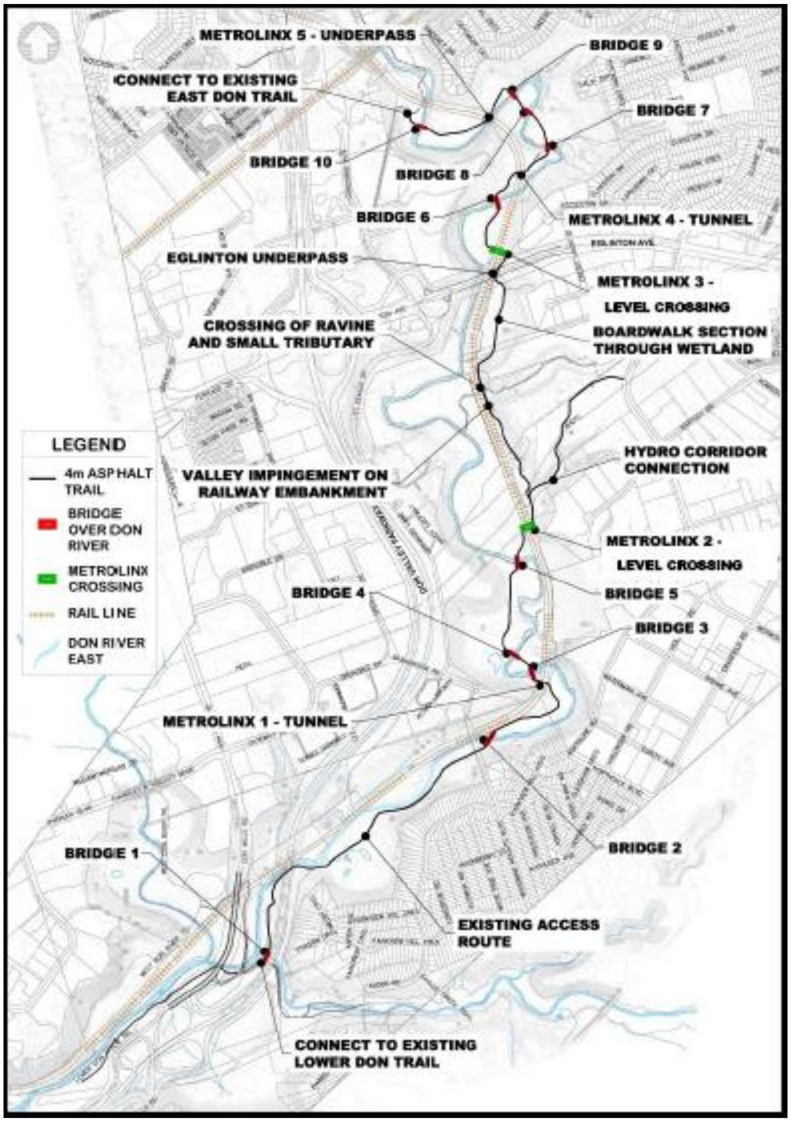

Figure 1: Preferred Alignment for the East Don Trail

2.2 Measurement Results on the Trail near the Transmission Right of Way

Figure 2 identifies the proposed trail and property ownership in the vicinity of the transmission lines. The Hydro One right-of way is shown in green and yellow. The brown strip on the right-hand side of the figure is the path of the Metrolinx rail corridor. The EMF survey crew did not access this area. Accordingly the magnetic field intensities within this area were estimated using measurements taken on either side of the track area. The route of the proposed trail alignment is indicated by the blue arrow. The rectangle in Figure 2 outlines the geographic area for this study.

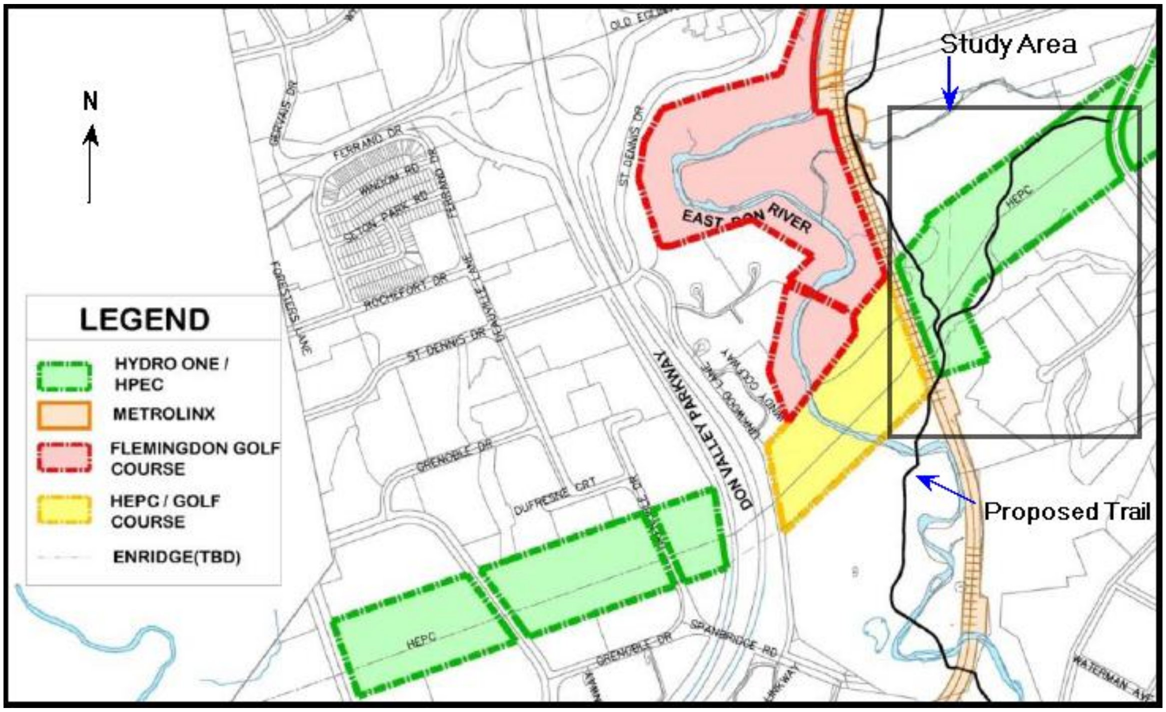

Figure 2: Overhead view of the East Done Trail Project Site, including Adjacent Land Ownership

The measurements of magnetic field strength were made on June 24 between the hours of 10:30 am and 3:00 pm, and on July 8, 2015 between the hours of 10:30 am and 3:00 pm. On both days the weather was sunny and dry. Outdoor temperature influences power consumption and thus the currents on the transmission lines. The changing line currents result in variations in the magnetic field strength. These effects were accounted for by normalizing the currents on the lines at the times of measurement to the yearly 85th percentile line currents (see below). Data on the currents on the transmission line circuits was obtained from Hydro One through a formal contact at Toronto Public Health (see Section 6.3, Appendix C). To estimate the exposure during the daytime in summer months when circuit currents are elevated (field levels are typically elevated at both low temperatures and high temperatures and during the day), all the measured magnetic field levels were adjusted to correspond to the 85th percentile of the electrical current values provided by Hydro One for 2014. Since the trail is likely to be utilized primarily during the day of warmer months of the year, the use of the 85th percentile provides a conservative estimate of people's average exposure over a one year period. The adjustments ranged from multiplying the measured values by values as low as 0.96 for a section near the south side of the right-of-way, to values as high as 2.2 for a section near the north side of the right-of-way. Different values were used, as adjustments at specific values on the path depend on the currents on the closest circuits.

Hydro One was requested to provide information on plans, if any, to modify the transmission corridor in the area of interest. The written response from Transmission System Development, Hydro One Networks was as follows, " There are no plans at this time for upgrading or replacement" of the lines.

2.3 Measurement Results

The part of the proposed trail impacted by the transmission lines was divided into eight sections as shown schematically in Figure 3, with letters showing the ends of each section. The brown line (RR) represents the Metrolinx railway tracks. Sections CB and DE represent two options available for crossing the Metrolinx tracks. The blue dashed lines show the paths of the 3 pairs of transmission line circuits. The pairs of line circuits are identified by circuit numbers shown in brackets. TS is a Hydro One Transformer Station. Values for the magnetic flux density in sections CB and DE were estimated assuming a linear change of the magnetic flux density between the end points.

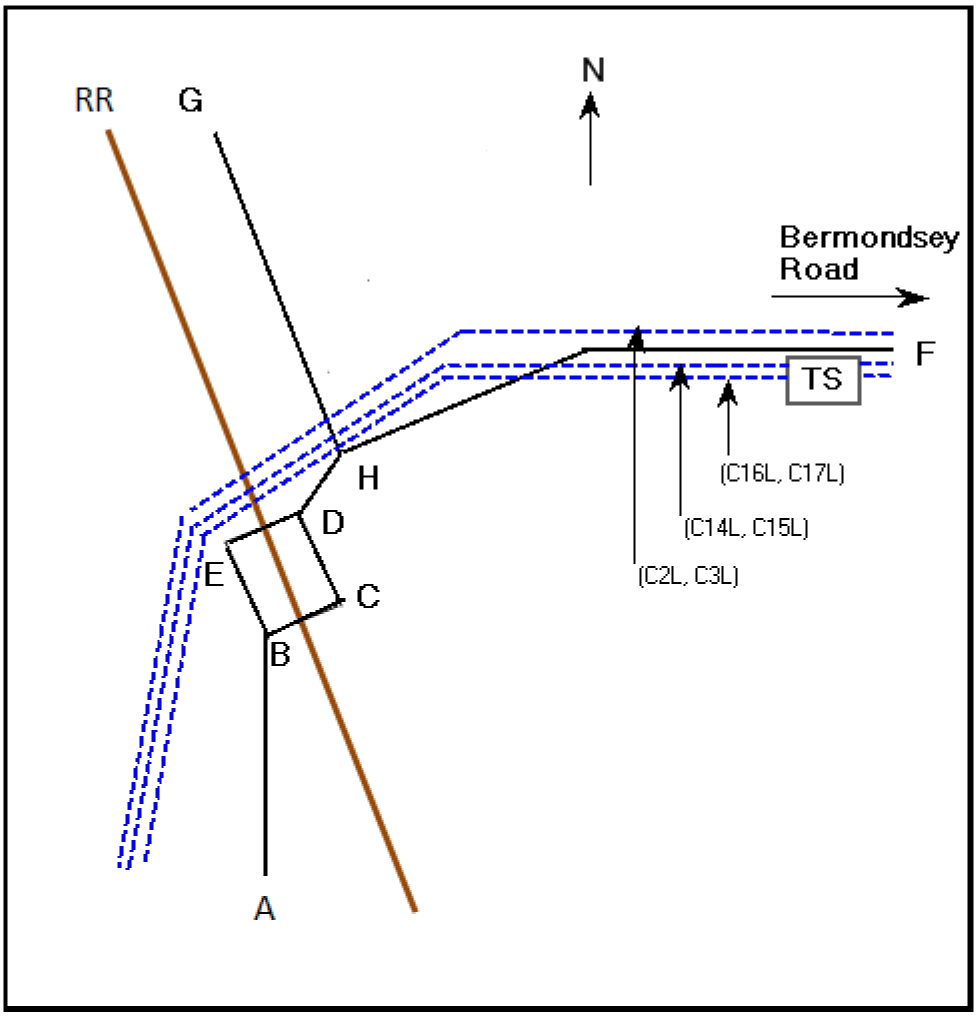

Figure 3: Schematic Showing Eight Sections of Proposed Trail

Field measurements along section FH were conducted at 6 meter intervals. The results are shown in Figure 4. The elevated readings from about 100 meters to 230 meters result from underground sources originating from the transformer station. The second wide peak in Figure 4 results from passing under the middle circuits (C14L, C15L) and the south most circuits (C16L and C17L) (see Figure 3 for the location of the various circuits). The increasing magnetic field strength approaching 600 meters is a result of the close proximity of the transmission lines at location H in Figure 4.

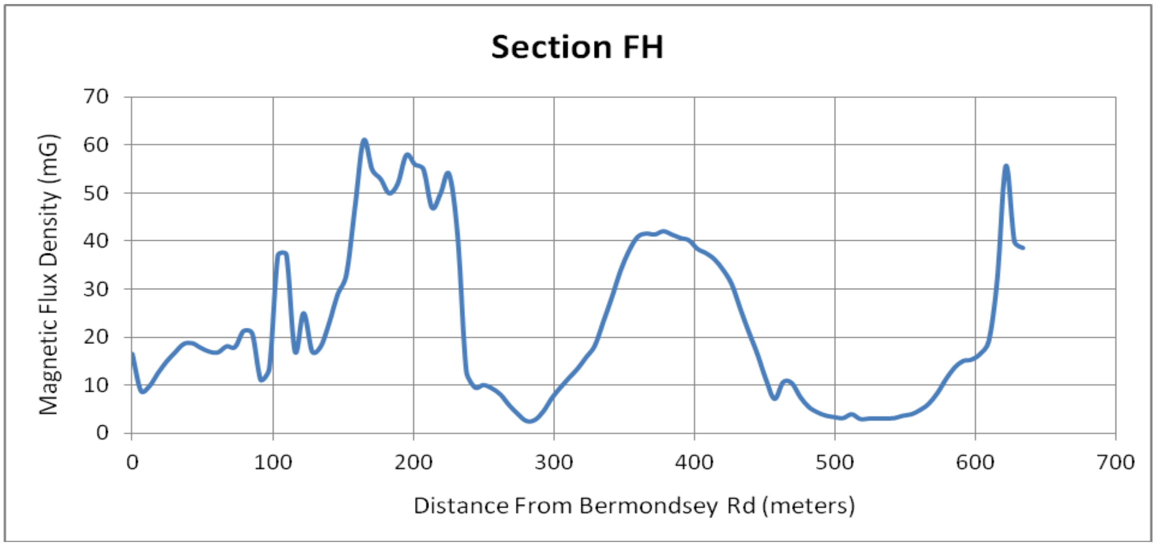

Figure 4: Magnetic Field Measured Along Section FH from Bermondsey Road

Measurements made along section HD are shown in Figure 5. The magnetic field decreases as the distance from the transmission lines at location H increases. The first large peak occurs beneath the southern and middle circuits, and the small peak at about 35 meters is from an overhead distribution line.

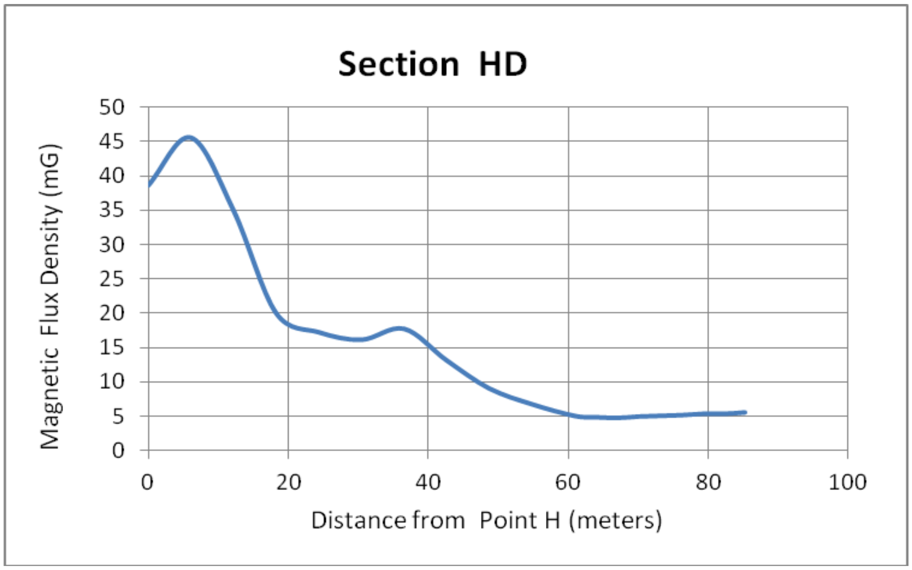

Figure 5: Magnetic Field Measured Along Section HD from Location H

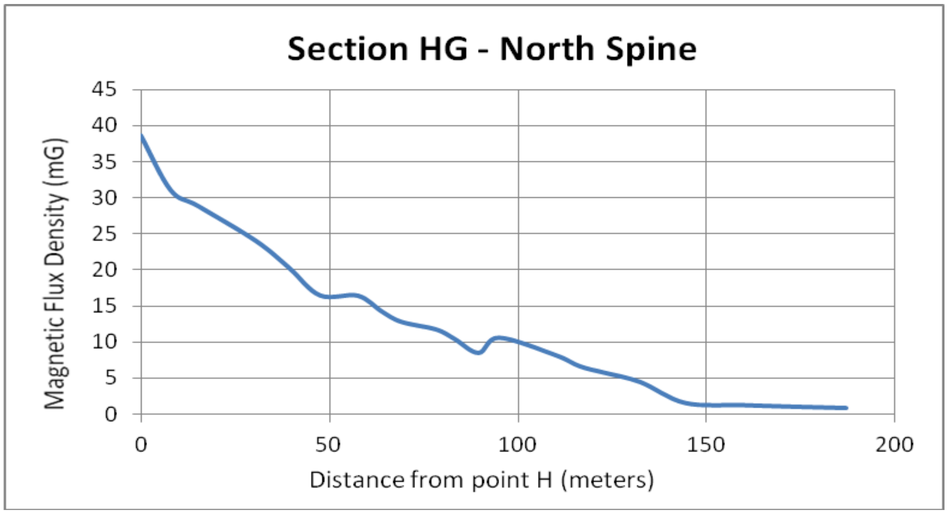

Figure 6: Magnetic Field Measured Along Section HG from Location H

The magnetic field strength on Section HG (referred to as the North Spine) shown in Figure 6 decreases to 1 milligauss at a distance of about 170 meters from location H. Beyond that point the magnetic field contribution from the transmission lines further decrease as the distance from the transmission lines increases.

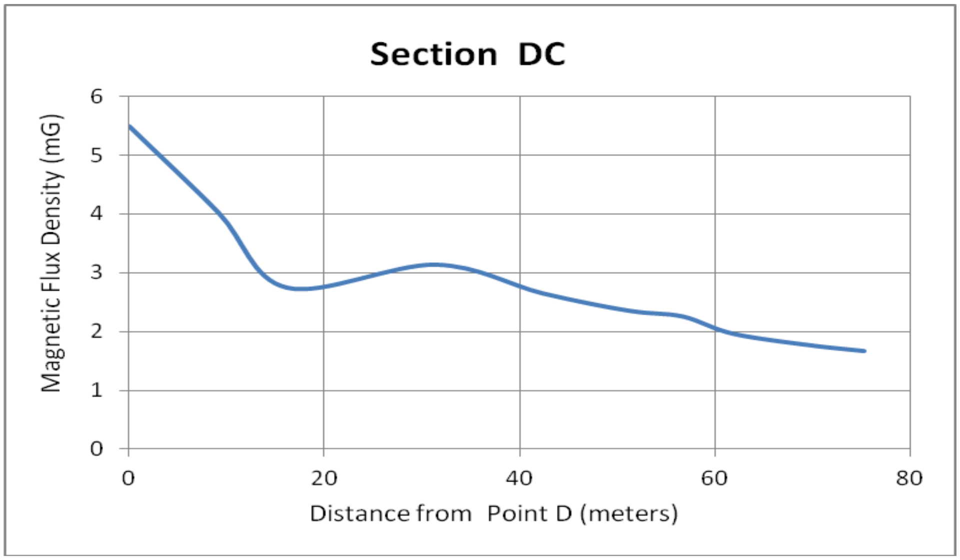

Figure 7: Magnetic Field Measured Along Section DC from Location D

Section DC runs along the east side of the Metrolinx tracks. As shown in Figure 7, the field decreases as a result of the increasing distance from the transmission lines. The changes in trend in the fields result from significant variations in elevation as one continues south along this section of the proposed trail.

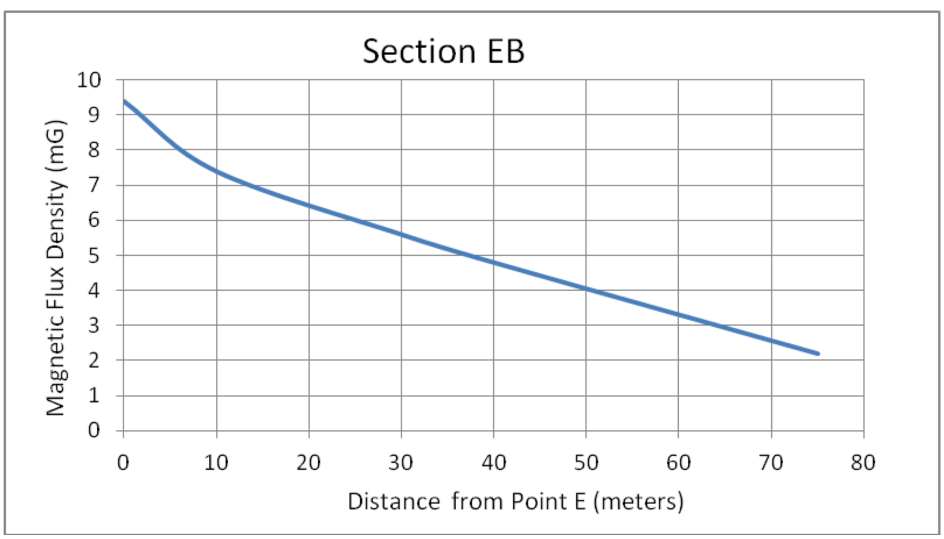

Figure 8: Magnetic Field Measured Along Section EB from Location E

Section EB runs approximately parallel to the Metrolinx tracks. The land elevation decreases and the distance to the transmission lines increases as one proceeds in a southerly direction. The result shown in Figure 8 is a monotonically decreasing magnetic field.

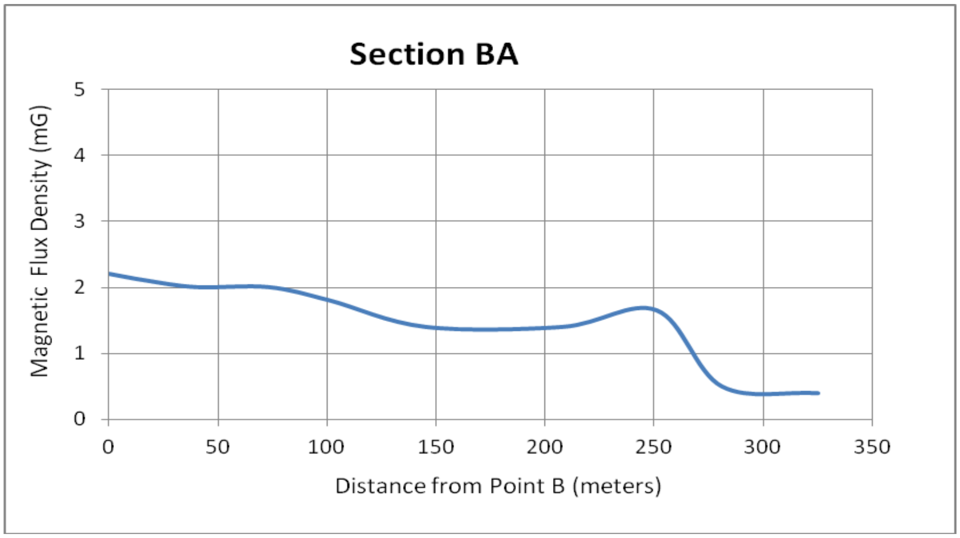

Figure 9: Magnetic Field Measured Along Section BA from Location B

As one proceeds in a southerly direction along section BA from point B in Figure 3, the magnetic field generally continues to decrease (see Figure 9), as the proposed trail and transmission lines diverge in direction and elevation. At a distance of approximately 280 meters south of point B the magnetic flux density is less than one milligauss. As one travels further south from this point, the contribution of the transmission lines to the magnetic field on the proposed trail decreases as the distance to the transmission lines increases.

2.4 Magnetic Field Exposure of Children on the Proposed Trail

The objective of an EMF Management Plan is to ensure that the development of land within or adjacent to a right-of-way is planned such that the collective magnetic field exposures of children 12 years or under are minimized. This is consistent with the principle of prudent avoidance (see section 3.2) as adopted by the City of Toronto. Exposure is defined as the time-averaged magnetic field strength. Accordingly, calculation of a child's exposure requires considering of the magnetic field levels and also the exposure duration in each significant location.

Calculation of Exposure On the Proposed Trail

The magnetic field exposure of children on the part of the proposed trail in proximity to the right-of-way will depend on the time they spend on that part of the trail and the average magnetic field for the portions of the trail they travel.

In order to estimate the exposure of a child walking on the trail, one must assume some value for their velocity. A value of one meter per second, the approximate average walking speed of a six year old child, has been chosen. For each interval between consecutive measurements, the magnetic flux densities at the beginning of the interval and at the end of the interval were averaged, and this result multiplied by the interval length. The resultant values for all intervals in a section were combined, and the results are presented, in units of mG meters, in the second column of Table 1. The values for the sections DE and CB were calculated by taking the average of the magnetic flux densities measured at D and E, and at C and B, and then multiplying the average magnetic flux densities by the corresponding distance from D to E and C to B. These results are provided in Table 1.

Assuming a walking speed of one meter per second, the exposure of a child traversing each section can be determined by dividing the values in the second column of Table 1 by [1 meter / second] x [3600 seconds / hour]. This gives the exposure for traveling one way for each section in units of mG hours (see Table 1, column 3)

Table 1: Exposure for Sections of the Proposed Trail

Section	mG.meters	mG.hours*
FH	14045	3.90
HD	1346	0.37
HG	2205	0.61
DC	213	0.06
EB	258	0.07
BA	50	0.01
DE	225	0.06
CB	60	0.02

*assuming a walking velocity of 1 m/sec

To calculate the exposure of a child travelling a given route past the transmission lines, the results for the sections defined above were combined to yield 5 route options a child may take. The 5 options are shown in Figure 10, with the routes shown in red. The exposure received in traversing each route one way at a velocity of one meter per second is provided in Table 2 below.

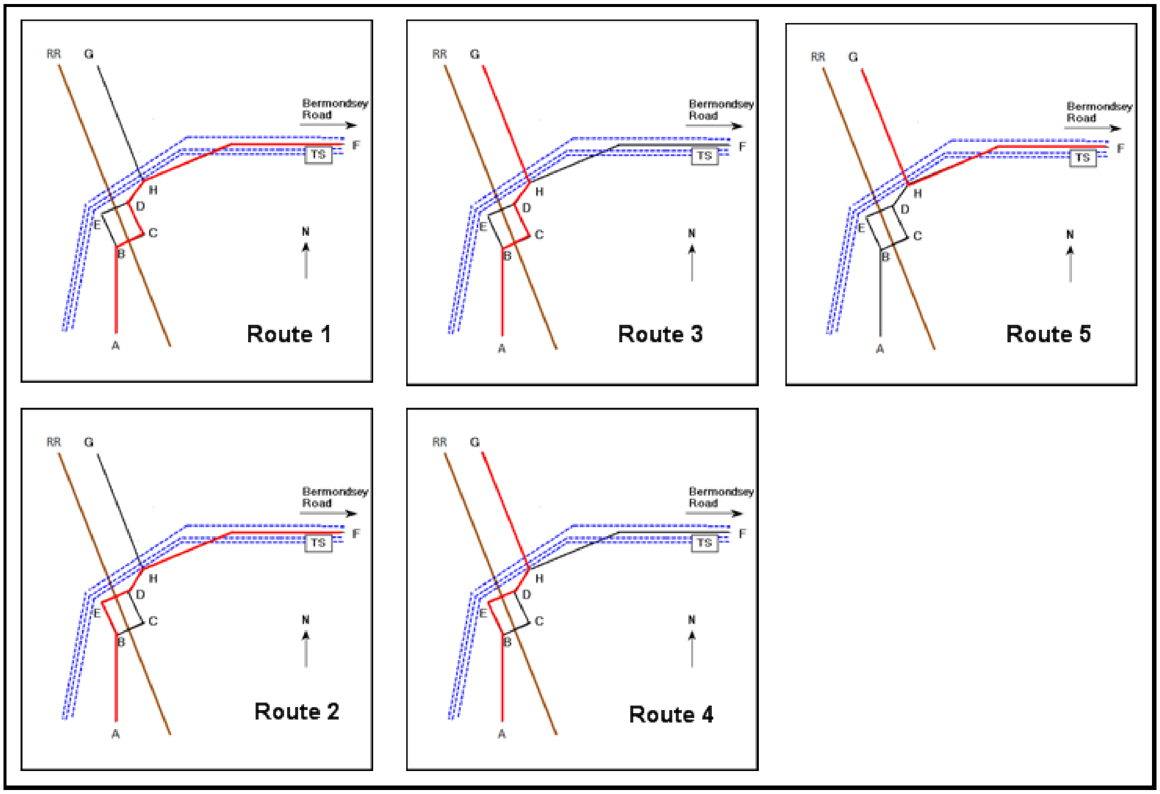

Figure 10: Route Options on the Proposed East Don Trail

Table 2: Exposure from Single Traversal of the Proposed Trail

Route	Path	Exposure mG.hours*
1	ABCDHF	4.38
2	ABEDHF	4.42
3	ABCDHG	1.08
4	ABEDHG	1.13
5	GHF	4.51

*assuming a walking velocity of 1 m/sec

The Toronto and Region Conservation Authority has proposed two scenarios for the use of the trail by children.

1. Average Usage Scenario: Assume young children will walk back and forth (i.e., 2 one-way trips) on the trail once per week during snow-free months, beginning on March 1st and ending on November 30th. Accordingly, the children will make (4x9) x2 =72 one way trips on the trail each year.
2. High Usage Scenario: Assume young children will use the trail 5 times per week from March to November to travel back and forth to school, to the local community centre or to attend an extracurricular activity. Accordingly, the children will make (5x4x9) x2 =360 one way trips on the trail each year.

The resulting magnetic field exposures in a one year period, according the route taken and the usage scenario, are shown in Table 3.

Table 3: Yearly Exposure of Children Using the Trail

Scenario	Number 1-way trips	Exposure (mG hours)				
		Route1	Route 2	Route 3	Route 4	Route 5
1	72	314	318	77	82	325
2	360	1571	1592	387	408	1625

Toronto Public Health has established a guideline of 2.0 mG for the maximum increase in a child's annual average exposure resulting from a development on or adjacent to a transmission corridor. The increase in a child's average magnetic field exposure over a 12 month period resulting from exposure to the magnetic fields near the Hydro One right-of-way while traveling on one of the possible routes of the proposed trail will be:

$$= \frac{\text{(magnetic field exposure received using trail in one year in units of mG hours)}}{\text{8760 hours per year}}$$

The increases in the average magnetic field exposure over a 12 month period after traveling one of the routes for each scenario are provided below in Table 4.

Table 4: Increase in Child's Average Annual Magnetic Field Exposure

Scenario	Number of 1-Way Trips	Increase in Average Annual Exposure (mG)				
		Route1	Route 2	Route 3	Route 4	Route 5
1	72	0.0359	0.0364	0.0088	0.0093	0.0371
2	360	0.1794	0.1818	0.0442	0.0466	0.1855

The highest increase in average annual magnetic field exposure of 0.18 mG occurs with scenario 2 using routes 1, 2 and 5. This represents an increase in the annual average magnetic field exposure that is well below (9%) the 2 mG guideline recommended by Toronto Public Health.

3 Discussion, Mitigation Strategies, and Mitigation Actions Taken

There are no recommended standards in Canada at the federal or provincial level for 60 Hz electric and magnetic fields. The federal limits for electromagnetic radiation contained in Health Canada Safety Code 6 do not address power frequency fields. However, in January 2005, the Federal-Provincial-Territorial Radiation Protection Committee (FPTRPC), coordinated by Health Canada's Radiation Protection Bureau, issued a Position Statement stating that adverse health effects from exposure to power frequency EMFs at levels normally encountered in homes, schools and offices have not been established. "…FPTRPC is of the opinion that moderate measures and the participation in the process of acquiring new knowledge are sufficient. These types of activity are consistent with the Canadian government framework on precaution."

A few international organizations have recommended power frequency magnetic field exposure standards (Table 5). The most stringent are those of the International Commission on Non-Ionizing Radiation (ICNIRP), which limit the exposure of members of the public to 2000 mG. It should be noted that these bodies have concluded that the available scientific data on the long-term effects, such as cancer, are insufficient to provide a basis for setting exposure restrictions. Therefore, these guidelines are not based on preventing long term effects such as cancer, but rather on preventing short-term immediate effects such as stimulation of peripheral nerves and muscles, shocks and burns caused by touching conduction objects, and elevated tissue temperature resulting from absorption of energy during exposure to EMF.

Table 5: Recommended Exposure Limits for 60 Hz Magnetic Fields

Organization	Protected Group	Magnetic Flux Density at 60 Hz (milligauss)
ICNIRP	Workers	4,167
	General Public	2,000
IEEE/ICES	General Public	9,040 (632,000 for arms and legs)
ACGIH	Workers	10,000

ICNIRP: International Commission on Non-Ionizing Radiation (World Health Organization)
IEEE/ICES: Institute of Electrical and Electronic Engineers/International Committee on Electromagnetic Safety
ACGIH: America Conference of Industrial Hygienists

The maximum measured field measured (Section FH) was 61 mG. This level is about 3% of the most restrictive level (2000 mG) recommended for members of the general public.

4 Magnetic Field Mitigation Strategies and Actions Taken

The Magnetic Field Mitigation Strategies consistent with the Prudent Avoidance Concept are listed below**.** After reviewing the applicable mitigation strategies, the site development team initiated the actions associated with each mitigation strategy.

4.1 Discussion

There are two potential sections as options for crossing the Metrolinx railway tracks, DE and CB. While prudent avoidance would recommend the use of the section with the lowest exposure, the difference in exposure is small even for 360 single trips (26 mG hours), and the difference in the impact the two sections have on the increase in average annual exposure following 360 single trips will be 0.003 mG. Unless there are no other meaningful reasons for selecting one of the two options for crossing the railway tracks, magnetic field exposure need not be considered.

Rest areas will be provided for users of the proposed trail. If it is necessary to provide one or more rest areas on the trail in the vicinity of the transmission lines, it would be prudent to position them in places exhibiting low magnetic field strength. The places where the fields are elevated are small and few in number. Accordingly there are many suitable locations for rest areas..

4.2 Recommendations

Rest areas, if required near the transmission lines, should be selected from those areas that are considered suitable in terms of factors such as safety, utility, cost, and accessibility standards, and that have the lowest magnetic field strength. If rest areas are necessary within section FH, where the magnetic fields are generally higher than in other sections, it is recommended to perform measurements at potential rest areas prior to installation, to allow selection of an area with as low a field as possible, since magnetic field strengths in this area change quickly with distance.

5 Conclusion

The exposure of children to magnetic fields from the Hydro One transmission towers using the proposed East Don Trail will be small. For children using the trail on a daily basis for nine months of the year, the increase in their annual average magnetic field exposure will be only about 9% of the City of Toronto guideline of 2 mG. The options for reducing children's average magnetic field exposure on the proposed trail near the Hydro One right-of-way are limited. The magnetic fields themselves cannot be altered and the velocity of children travelling on the path cannot be controlled. The only practical option is to minimize the incentives for children to spend extra time in areas of higher magnetic field strength. By placing rest areas in locations exhibiting low magnetic field strengths, the exposure of children can be reduced and the principle of prudent avoidance applied at little or no cost.

6 Appendices

6.1 Appendix A – EMF Management Plan Checklist

ITEM INCLUDED	Y	N	COMMENTS OR JUSTIFICATION
1.The planned development was assessed to determine if children will congregate at the site.	X		Multi-use path
2. The plan contains a map of the ROW and, if appropriate, the adjoining property showing transmission lines and other electrical facilities?	X		Maps showing location of electrical facilities
3. The plan contains the results of a magnetic field survey across the ROW and if appropriate, across the abutting property, encompassing the area where the development is planned? (The area surveyed should include nearby electrical facilities, e.g. distribution lines.)		X	See Fig 6 (contour of ½ ROW). ROW contours not useful because of highly variable land elevation, and difficult to obtain because of forest & heavy vegetation in most areas.
4. Data from Hydro One and Toronto Hydro were obtained relating line loadings during measurements to yearly average loadings.		X	Info from Toronto Hydro not available for distribution line
5. The survey was performed during a typical load period.	X		Survey conducted during typical conditions
6. Information has been obtained from Hydro One and Toronto Hydro on planned upgrades, energizing of unused lines, and new lines or equipment	X		No modification of the lines planned at this time
7. Calculations, extrapolations, substitutions of data from similar situations (e.g. mirror image, shift along the ROW) were performed to characterize locations where measurements were not feasible, and the results noted on the site map.	X		Estimated magnetic field across Metrolinx property
8. The survey data are presented on a map (preferable to a spreadsheet).		X	One dimensional surveys
9. Alternative designs or types of use been	X		Considered

considered to minimize magnetic field exposures.			alternative RR crossings and rest areas
10. The plan includes expected changes (addition or removal of lines and other electrical equipment) and their expected impacts on magnetic fields levels at the development site.		X	No changes identified by Hydro One
11. A site map/spreadsheet has been prepared showing expected magnetic fields and electrical equipment, following the changes noted in Item 10.		X	NA
12. Exposure reduction strategies have been considered for each alternative development plan. (Examples are locating areas occupied by children in low-field areas and away from internal sources.)	X		Considered alternative RR crossings
13 The plan includes estimates of exposures for children aged 12 and under, for individual children and in the aggregate (number of children exposed)?	X		No calculation for aggregate.
14. The plan includes estimates of the aggregate and individual exposures avoided through various exposure reduction strategies and the choice of alternative development plans.	X		Estimates for reducing individual exposure by altering trail route
15. The plan includes the choice of the development plans and the exposure reduction measures to be implemented.	X		Options and exposure reduction impact presented

6.2 Appendix B – Toronto Public Health EMF Management Plan

Summary of Magnetic Field Exposure Reduction Actions

Development Designation: **East Don Trail Project**

Date: **August, 2015** Prepared by: Radiation Safety Institute of Canada

Authorized by:

Title: **Project Manager, City of Toronto**

Signature : ___________________________

Reduction of Exposure:

Exposure reduction Option	Accept/Reject	Rationale for Rejecting Option
Rest areas, if required near the transmission lines, will be selected from those areas that are considered suitable in terms of factors such as safety, utility, cost, and accessibility standards, and that have the lowest magnetic field strength		
If there are no other meaningful reasons for selecting one of the two options for crossing the railway tracks, the option with the lower magnetic field exposure will be used, pending Metrolinx approval		

6.3 Appendix C – Hourly Transmission Line Loading Data from Hydro One

Time	C2L	C3L	C14L	C15L	C16L	C17L
06/24/2015 00:00:00s	163	266	260	463	423	419
06/24/2015 01:00:00s	148	239	233	448	412	410
06/24/2015 02:00:00s	143	230	224	430	400	397
06/24/2015 03:00:00s	142	223	218	414	388	386
06/24/2015 04:00:00s	151	221	216	415	393	391
06/24/2015 05:00:00s	162	240	229	437	409	406
06/24/2015 06:00:00s	211	309	311	504	449	455
06/24/2015 07:00:00s	238	345	353	544	485	485
06/24/2015 08:00:00s	256	373	383	588	512	512
06/24/2015 09:00:00s	256	385	399	604	522	526
06/24/2015 10:00:00s	191	332	344	551	476	475
06/24/2015 11:00:00s	171	307	321	546	473	475
06/24/2015 12:00:00s	166	305	320	537	464	466
06/24/2015 13:00:00s	151	295	311	539	464	463
06/24/2015 14:00:00s	126	280	296	481	408	408
06/24/2015 15:00:00s	101	262	278	435	368	367
06/24/2015 16:00:00s	138	293	303	494	424	421
06/24/2015 17:00:00s	99	250	261	452	389	387
06/24/2015 18:00:00s	96	240	252	424	368	365
06/24/2015 19:00:00s	89	229	240	406	353	350
06/24/2015 20:00:00s	73	215	221	395	345	342

Time	C2L	C3L	C14L	C15L	C16L	C17L
06/24/2015 21:00:00s	94	223	228	415	365	362
06/24/2015 22:00:00s	220	350	352	531	467	463
06/24/2015 23:00:00s	190	299	305	498	456	451
07/08/2015 00:00:00s	145	210	198	430	437	428
07/08/2015 01:00:00s	135	196	183	418	424	415
07/08/2015 02:00:00s	129	184	173	394	406	398
07/08/2015 03:00:00s	119	184	178	397	405	401
07/08/2015 04:00:00s	118	183	178	405	403	398
07/08/2015 05:00:00s	132	199	192	424	429	415
07/08/2015 06:00:00s	171	242	244	468	468	464
07/08/2015 07:00:00s	173	251	253	535	527	522
07/08/2015 08:00:00s	188	277	284	555	541	537
07/08/2015 09:00:00s	181	286	284	588	569	566
07/08/2015 10:00:00s	122	225	226	510	494	491
07/08/2015 11:00:00s	131	237	239	531	504	509
07/08/2015 12:00:00s	91	196	199	479	466	465
07/08/2015 13:00:00s	58	160	172	434	422	426
07/08/2015 14:00:00s	55	164	174	415	402	407
07/08/2015 15:00:00s	63	162	177	415	402	407
07/08/2015 16:00:00s	58	147	165	425	412	420
07/08/2015 17:00:00s	59	147	162	395	396	401
07/08/2015 18:00:00s	57	145	155	387	382	378
07/08/2015 19:00:00s	115	207	211	445	436	438

Time	C2L	C3L	C14L	C15L	C16L	C17L
07/08/2015 20:00:00s	118	206	212	445	436	442
07/08/2015 21:00:00s	107	197	199	418	415	419
07/08/2015 22:00:00s	145	224	226	475	476	475
07/08/2015 23:00:00s	135	205	199	426	426	426

Yearly Average Transmission Line Loading Data from Hydro One

Circuit	50 percentile (A)	85 percentile (A)	99 percentile (A)	Peak	Emergency*
C2L	306	406	555	684	825
C3L	316	409	556	763	825
C14L	375	470	649	806	825
C15L	372	462	583	645	825
C16L	391	472	570	624	825
C17L	405	497	633	717	825

6.4 Appendix D – A Word about Radiation

6.4.1 Introduction

Scientific knowledge about radiation is extensive. What follows is merely a brief description which is intended to serve as a background to this survey.

In the simplest terms, radiation is a packet of energy. Radiation consists of waves or particles emitted from naturally occurring radioactive materials or from certain man-made materials or devices. The radiation type most familiar to the general public is electromagnetic radiation which includes visible light.

6.4.2 Ionizing and Non-Ionizing Radiation

Often, radiation is categorized as "ionizing" or "non-ionizing." Ionizing radiation is a type of radiation that is energetic enough to produce ions (electrically charged atoms) when it passes through a material such as the human body. Types of ionizing radiation include alpha, beta, and gamma radiation which are emitted from the decay of radioactive materials (either naturally occurring or man-made). Another type of ionizing radiation is X-rays which are most commonly used in the field of radiology.

Non-ionizing radiation, as its name indicates, is radiation which does not possess enough energy to ionize the atoms of a material as it passes through. Types of non-ionizing radiation include radio-frequency waves, microwaves, infrared light and visible light. Ultra-violet light is also categorized as non-ionizing radiation even though it has some ionizing ability.

The electromagnetic radiation emitted from high voltage transmission lines is non-ionizing.

6.4.3 Electromagnetic Radiation

Electromagnetic radiation is composed of electromagnetic waves. A graphical representation of a typical wave is shown in Figure 11 on the following page.

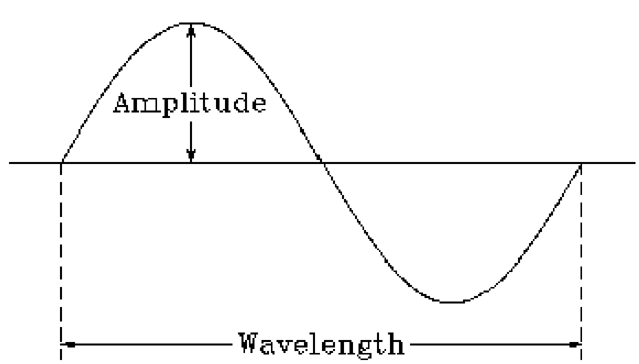

Figure 11: Example of a Waveform.

A wave is characterized by its frequency, wavelength and amplitude. The frequency of a wave is simply the number of complete cycles of a waveform that occur in one second. One complete cycle per second is 1 Hz (Hertz). The wavelength, λ is literally the physical length of the wave and is related to the frequency, f and the speed of light, c by the expression:

$$\lambda = \frac{c}{f}$$

The wave amplitude, as shown in Figure 11, is simply the height of the wave.

In electrical power generation, electrical charges are forced to oscillate at the familiar frequency of 60 Hz in North America (or 60 cycles per second).

Electromagnetic radiation is actually a general term which describes a broad range of wave type radiation which includes both ionizing and non-ionizing radiation. The electromagnetic spectrum, as shown in Table 6, is a continuous spectrum which includes all types of electromagnetic radiation from low energy radio waves to high energy gamma rays. As the frequency of the radiation is proportional to the energy of the radiation, it is easy to see that gamma rays and X-rays are much more energetic than radio waves or microwaves.

It is important to note that the only difference between the types of electromagnetic radiation is their frequency or energy.

Table 6: Electromagnetic Radiation Spectrum.

Type of Radiation	**Frequency Range (Hz)**	**Wavelength Range**
Gamma Rays	1×10^{20} - 1×10^{24}	(1×10^{-12} - 1×10^{-16}) m
X-Rays	1×10^{17} - 1×10^{20}	1 nm - 1 pm
Ultraviolet Light	1×10^{15} - 1×10^{17}	(400 - 1) nm
Visible Light	4.3×10^{14} - 7.5×10^{14}	(700 - 400) nm
Infrared Light	1×10^{12} - 1×10^{14}	2.6 µm - 700 nm
Microwaves	1×10^{8} - 1×10^{12}	1 mm - 2.5 µm
Radio Waves	1 - 1×10^{8}	(1×10^{8} - 1) m

6.4.4 Radiofrequency and Microwave Band Designations

Radiofrequency and microwave electromagnetic radiation can further be subdivided into what are called band designations. A list of the newer official band designations are given in Table 7.

The electromagnetic radiation emitted from transmission lines belongs to the extremely low frequency (ELF) region of the electromagnetic spectrum (30 – 300 Hz or 0.00003 - 0.0003 MHz). The extremely low frequency (ELF) range is also commonly known as the *power frequency* range. As stated, the energy emitted from ELF radiation does not possess sufficient energy to cause ionization and as such is classified as non-ionizing radiation.

Table 7: Radiofrequency and Microwave Band Designations.

Frequency (MHz)	Wavelength (m)	Band	Description
0 - 0.00003	0 - 10^7	SELF	Sub-extremely-low frequency
0.00003 - 0.0003	10^7 - 10^6	ELF	Extremely low frequency
0.0003 - 0.003	10^6 - 10^5	VF	Voice frequency
0.003 - 0.03	10^5 - 10^4	VLF	Very low frequency
0.03 - 0.3	10^4 - 10^3	LF	Low frequency
0.3 - 3	10^3 - 10^2	MF	Medium frequency
3 - 30	10^2 - 10^1	HF	High frequency
30 - 300	10^1 - 10^0	VHF	Very high frequency
300 - 3000	10^0 - 10^{-1}	UHF	Ultrahigh frequency
3000 - 30000	10^{-1} - 10^{-2}	SHF	Superhigh frequency
30000 - 300000	10^{-2} - 10^{-3}	EHF	Extremely high frequency
300000 - 3000000	10^{-3} - 10^{-4}	SEHF	Supra-extremely-high frequency

6.4.5 Electromagnetic Waves

Electromagnetic waves (electromagnetic radiation) consist of oscillating electric and magnetic fields that are perpendicular to each other and mutually perpendicular to the direction of propagation of the wave (see Figure 12). The energy carried by the wave, referred to as the power density, depends upon the strength of the associated electric and magnetic fields.

It is important to note that at ELF wavelengths, the electric and magnetic fields are not coupled and act as discrete fields. Consequently, almost all exposure to ELF electric and magnetic fields (EMF) is to discrete electric and magnetic fields and not to electromagnetic radiation.

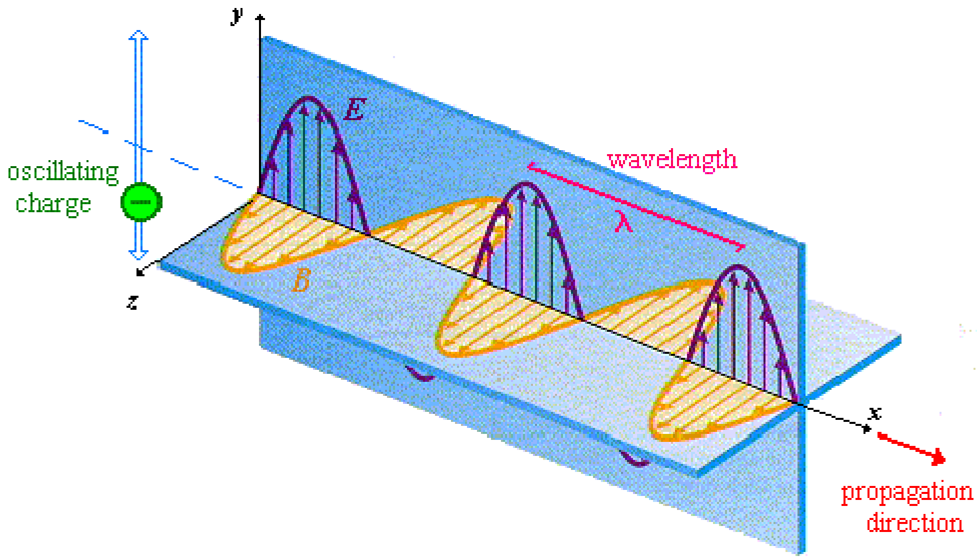

Figure 12: Graphical Representation of an Electromagnetic Wave. The electric field, E, and magnetic field, B, are at right angles to each other and both are at right angles to the direction of propagation.

6.4.6 Electric Fields and Magnetic Fields

An electric field is produced by electrically charged objects whether stationary or in motion. Because electricity generation involves the movement of electrical charges, electric fields are produced by all types of electrical devices including transmission lines. A depiction of an electric field around a charged particle is shown in Figure 13. Electric fields near a transmission line will depend largely on the line voltage and the distance from the transmission line. The common unit used for the measure of electric fields is the volt/meter (V/m)[1]. Electric fields are denoted by the letter E.

[1] The units for electric fields are derived from the potential difference generated between two conducting plates separated by a known distance.

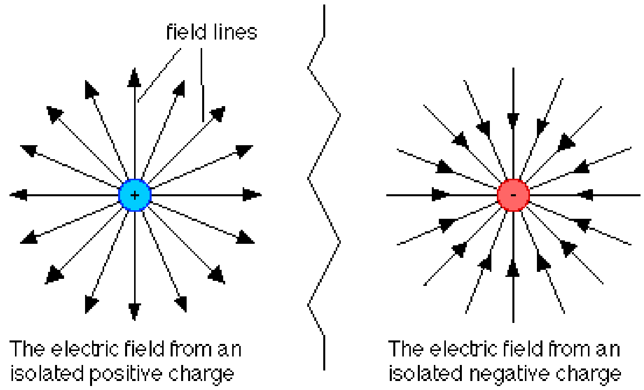

Figure 13: Electric Fields from Charged Particles.

Electric fields are easily attenuated (shielded) by building materials, landscaping and even our skin. Consequently, it is difficult to accurately measure electric fields simply because the person collecting the measurement actually perturbs (alters) the electric field that he/she is attempting to measure.

Magnetic fields are produced by moving electric charges, also termed current. Magnetic field lines form closed loops around the current and exist perpendicular to the direction of the current. A depiction of a magnetic field around a current carrying conductor is shown in Figure 14. The magnetic field near a transmission line will depend largely on the current load and the distance from the transmission line. The common unit used in the measure of magnetic fields is the tesla (T)[2]. Another conventional unit for magnetic fields is the gauss (G)[3]. Magnetic fields are denoted by the letter B.

Unlike electric fields, magnetic fields are not easily attenuated. Most materials are nearly transparent to magnetic fields.

Both electric and magnetic fields drop off quickly as one moves away from the source.

[2] Magnetic fields are quantified by the magnetic flux density, B which is the sum of the magnetic field components passing through a given area.

[3] Conversion between units: 1 T = 10^4 G.

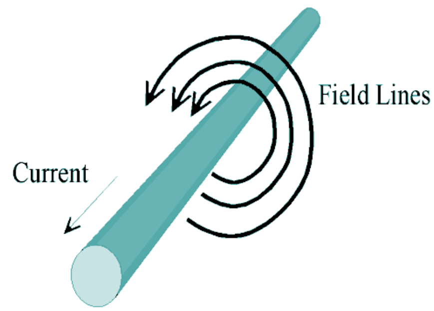

Figure 14: Magnetic Field around a Current Carrying Conductor.

6.4.7 Sources of Electromagnetic Radiation

ELF electric and magnetic fields (EMF) may be produced by natural or made-made sources. Naturally occurring fields are largely associated with global and local weather processes, and geological, solar, and stellar processes. The average naturally occurring electric field strength is 130 V/m. The average static magnetic field generated by the Earth (geomagnetic field) is 50 µT (1 µT = 0.000001 T) (500 mG). Solar processes can produce magnetic fields of the order of 1-3 µT (10-30 mG). The natural 50 Hz/60 Hz background magnetic field is approximately 0.001 nT.

EMF is produced primarily through electricity generation and the use of electrical devices. The major utility sources include power plants, power lines and substations. A summary of typical EMF produced by man-made sources is presented in Table 8.

It is important to note that EMF is present wherever electricity is used. Consequently, there is an inherent background level in any home, school or commercial building. Any measurement of EMF will include background or ambient levels. Background ELF magnetic field levels can vary significantly but typically range from 0.2 mG to 4 Mg.

Table 8: Sources of EMF.

SOURCE	E FIELD (V/m)	B FIELD (mG)	COMMENTS
POWER PLANT	15000	20000	LOCAL MAXIMUM VALUES
TRANSMISSION LINES			
115 KV	1000	20	MAXIMUM VALUES ON THE RIGHT OF WAY
230 KV	2000	35	
500 KV	7000	70	
SUBSTATIONS			
380 KV	<10,000	50-100	TYPICAL LEVELS 1 M ABOVE GROUND
DISTRIBUTION LINES	120-180	1.5-50	PRIMARY SIDE OF 14.4 KV AERIAL LINE
OFFICE ENVIRONMENT			
OFFICE FLUORESCENT LIGHTS	10-35	0.8	
30 CM FROM A VDT SCREEN	-	1.3-2.8	
HOME			
DOORSTEP LEVELS WITH POWER LINE AT FRONT OF HOUSE	-	0.1-4.7	
MEAN VALUE AND PEAK VALUE IN A TYPICAL ROOM	-	1.0; 12	
APPLIANCES	-	38249	AVERAGE VALUES DURING ROUTINE USE
HAIR DRYER	40	60-20,000	3 CM FROM DRYER
VACUUM CLEANER	16	10-100.5	30 CM FROM DEVICE
MICROWAVE OVEN	-	110-140	30 CM FROM DEVICE
MIXER	50	162	30 CM FROM DEVICE
REFRIGERATOR	60	2	30 CM FROM DEVICE
RANGE	-	8	30 CM FROM DEVICE
TELEVISIONS	-	7	30 CM FROM DEVICE

“-” denotes no data available or reported.

6.4.8 Transmission Lines

Simply put, a transmission line is a set of wires, called conductors, that carries electric power from generating plants to the substations that deliver power to consumers. At a generating plant electric power is “stepped up” to several thousand volts by transformers and delivered to the transmission line. At numerous substations on the transmission system, transformers step down the power to a lower voltage and deliver it to distribution lines which carry the power to consumers.

A sample of what the electric and magnetic field lines might look like at a transmission line is shown in Figure 15. Magnetic field lines are depicted in blue and electric field lines in red.

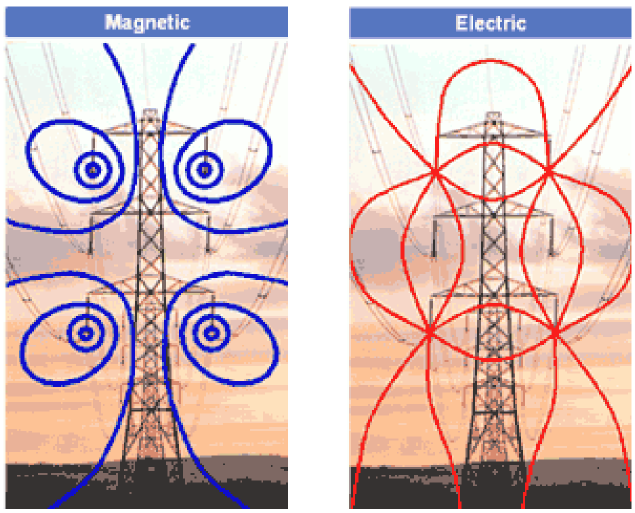

Figure 15: ELF Electric and Magnetic Field Lines Near a Transmission Line (illustration courtesy of NGT Group).

The electric field intensity near a transmission line depends on the line voltage, conductor geometry, height above ground and the environment. Electric fields are easily attenuated by objects including hills, vegetation, fences, vehicles, and building materials.

Magnetic fields are related to the line current, conductor geometry and conductor height above the ground. Unlike electric fields, magnetic fields are not significantly affected by the environment and thus are much more penetrating. Most materials (except magnetic materials) are virtually transparent to magnetic fields.

Electric and magnetic fields are highest near the transmission lines and decrease with distance from the line. Where there is more than one conductor in the circuit(s), there is also partial cancellation between the magnetic fields produced by the individual current carrying conductors. This cancellation generally becomes better at greater distances. Similar cancellation affects occur between electric fields produced by the voltages on individual conductors. These cancellation effects result in reduced electric and magnetic fields.

Electric fields from power lines are relatively stable because the line voltage remains relatively constant. Magnetic fields, however, can fluctuate dramatically as the current changes in response to changing loads (consumer usage).