

Orange & Rockland Utilities Proposed Distribution Substation

Electromagnetic Field (EMF) Assessment & Site Impact Report

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Written For:

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1.0 INTRODUCTION

VitaTech Engineering was originally invited in early January 1997 by Mr. George Potanovic, Jr., President of S.P.A.C.E., to examine the potential impact of electromagnetic fields (EMFs) emanating from a proposed Orange & Rockland distribution substation in Stony Point, New York. Several weeks later Mr. Potanovic presented our credentials to the Town Board and Mr. Steven Hurly, Town Supervisor. On 16 January 1997 VitaTech Engineering was retained as a *second opinion* by the Town of Stony Point to evaluate the impact of the proposed substation.

Unfortunately, our proposal letter was *accidentally* faxed to the *first retained opinion*, Mr. John Carden, P.E. of JMC Electrical/Forensic Engineering, P.C., who vehemently challenged the *wording* and *task descriptions* in the VitaTech proposal. Needless to say, the author was amused and somewhat disappointed by Mr. Carden's condescending tone; however, in the spirit of mutual cooperation the author agreed during a January 16, 1997 teleconference (Mr. Carden, Mr. Steven Hurley, Mr. Frank Phillips) to amend the VitaTech proposal and only perform the following tasks:

- 1) Electric and magnetic emissions during average, peak & worst-case conditions from the transmission lines, proposed distribution substation and local circuit feeders;
- 2) Extremely low frequency (ELF) EMF exposure and potential health issues;
- 3) Electrostatic & electromagnetic induction;
- 4) Ground & plumbing currents; and,
- 5) Residential property devaluation.

The author of this report is not a *licensed professional engineer* (P.E.), and some members of the local community challenged his right to "practice engineering without a license" in the State of New York. It should be understood the author is not an *electrical power engineer*, and is not evaluating how the substation is electrically, designed including the *potential risks* from catastrophic substation equipment and gas pipeline failures, explosions and lightning strikes. This is the expertise expected from a *licensed and insured* forensic power engineer such as Mr. John Carden, P.E. who delivered a report on 18 February 1997. Refer to his report regarding the aforementioned *potential risks*.

Nevertheless, it is the opinion of the author that the Stony Point distribution substation is absolutely necessary to improve the load management, reliability, electrical distribution and delivery to the Town of Stony Point and assure long-term stability as the demand for electrical power increases.

Is this the best site for a distribution substation in Stony Point? That is the fundamental question. VitaTech was retained to evaluate the EMF and property value impact of the proposed distribution substation on the neighborhood and any other site where the substation may be located in Stony Point. Few people want a prison, hog farm, junk yard or toxic waste dump next to their homes. Within the last decade, substations and transmission lines have been added to this list of undesirable neighbors. Unfortunately, there is an impact on the neighborhood whether *real* or *perceived* from both the proposed substation and the existing transmission lines.

Final comment about Orange & Rockland Utilities: Mr. Peter McGoldrick, Delivery System Design Manager, and Mr. John Coffey, Electrical Engineer, have been very responsive and totally cooperative regarding every request by VitaTech for technical information and assistance throughout this project. The author wishes to express his appreciation for their professionalism and honesty, especially considering the complex technical, political and emotional issues associated with the proposed substation.

1.1 Brief Site Description

Orange & Rockland Utilities has proposed a Stony Point distribution substation to be located near West Main Street between Crickettown Road and Orchard Street. Two active 138 kV transmission lines (circuit #'s 53 and 54) and two inactive (disconnected) transmission lines travel southward along a right-of-way (ROW) from the Lovett generating station and pass adjacent to the proposed 80-by 140-foot (11,200 ft² or 0.251 acres) substation site located on 5.124 acres owned by O & R Utilities. Each 90-foot transmission line tower supports two vertically arrayed circuits (three single conductors per circuit) and the towers are separated by 50-feet measured at the centerline of each base. The width of the ROW varies from 30 to 200 feet along the 3.31-mile run from the Lovett generating station to the West Haverstraw 138 kV substation. A buried 16-inch pressurized O & R gas pipeline runs parallel to the transmission line near the east edge of the ROW and emerges near W. Main Street to expose a shut-off valve and pressure regulator. *It should be noted that the gas regulator is too noisy and requires a muffler or sound wall to reduce the noise level by 20-30 dB.*

A single 138/13.2 kV distribution transformer (rated 21/28/35/39 MVA at 65° C) is specified for the proposed fenced-in substation site. Electrical power will enter the substation from a single-circuit 138 kV tap on transmission line #54 (tower 18E), pass through a circuit-switcher, and tie to the primary input of the 138/13.2 kV transformer. In the transformer, electrical energy is converted from 138 kV (low-current) on the primary side to 13.2 kV (high-current) on the secondary side. The 13.2 kV secondary output from the transformer will enter the control module/switchgear building via an overhead busbar where it is switched, fused and monitored before distribution to the community.

Four underground triplexed circuits will exit the control module/switchgear building in a concrete encased duct, travel along the substation access road, and divide on West Main Street. Three of the underground circuits will travel north on W. Main St. where circuit #1 runs up a riser pole on Crickettown Road and the other two circuits (#3 & #4) run up two riser poles on W. Main Street

before heading west. Circuit #2 travels southeast underground on W. Main St. and up a riser pole near Orchard St. Currently, there is a single-circuit overhead distribution line on W. Main St. and Crickettown Rd. -- current (power) is supplied from the west end of W. Main St. and branches up Crickettown Rd., rather than past the intersection according to O & R engineers.

It is beyond the scope of our task to review the complex history of this project. Detailed information is available in the public record regarding the legal, political and environmental issues addressed previously before the Town and Planning Boards of Stony Point.

2.0 ELF MAGNETIC FIELD SITE SURVEY

On 28 February 1997 an extremely low frequency (ELF) magnetic flux density survey was performed using the *FieldStar 1000* gaussmeter (see section 2.5 for details) by the author, Mr. Louis Vitale, President & Chief Engineer, at the proposed distribution substation site. Magnetic field data was recorded around the site in both the morning and afternoon as shown in *ELF Magnetic Flux Density Site Surveys, February 28, 1997* in Appendix A. Survey work began at 8:00 A.M. with Mr. Peter McGoldrick - O & R Delivery System Design Manager, O & R Engineering Intern (sorry, name unknown), Steven Leonardo - S.P.A.C.E. and Don Decker - S.P.A.C.E. and resident living on Crickettown Road adjacent to the ROW.

2.1 Calibration Survey

Two calibration surveys were performed while transmission line load data was recorded by O & R engineers: 50 feet north of the tower base (see appendix A, Hatch & Profile Plots Rec 1 ID-L1T) at 8:13 A.M. and the north side of West Main Street (see appendix A, Hatch & Profile Plots Rec 2 ID-L2T) at 8:30 A.M. The purpose of the calibration survey is to validate the magnetic flux density simulations of the existing and proposed substation/distribution lines.

Unfortunately, there was a discrepancy between the recorded and simulated calibration surveys as shown in the Calibration Profiles (see appendix A). In the first simulated profile, *Calibration Profile (50' N. towers)*, the simulated peak is 10.75 mG, whereas the recorded data was 19.6 mG. In the second simulated profile, *Calibration Profile (W. Main St.)*, the simulated peak was 19.22 mG and the recorded data was 31.7 mG. Generally, a difference of 5-10% between the actual and simulated data is acceptable; however, there is a significant difference (65-82%) in the recorded data plots and simulated calibration plots. Needless to say, this caused great distress and VitaTech used a second simulation software package from Southern California Edison, *Fields 2.0*, to check the results. Both simulation programs produced nearly identical profiles, so why was there a difference? Only three parameters can adversely effect simulated data: incorrect load data (currents on transmission lines, phasing, and directional flow), elevation errors (height and spacing of conductors above grade), and other external magnetic field sources such as electromagnetic induction generating currents (and magnetic fields) on the de-energized lines and gas pipeline, ground currents in the earth, and plumbing currents on the underground water main on W. Main Street. When this problem occurred, VitaTech suspended our simulation work for several weeks until an acceptable explanation could

be reached.

VitaTech contacted the O & R engineering department to help resolve the problem. Mr. Coffey sent a surveyor out to the site to measure and verify the conductor elevations. Another very complex problem was "how to model the elevations" at the site. The first attempt was a *sea level* referenced three-dimensional real-world model; however, it was very difficult to slice (term used to generate output data) the model without cutting through the proposed underground distribution feeders, which produced very high and erroneous peaks in the contour profiles. VitaTech changed to a "flat world" model that has a three dimensional (x, y and z) zero reference point at the center of transmission tower 18E. These changes increased the simulated peak values, but did not correct the overall discrepancy. Electromagnetic induction from the 138 kV lines will generate currents in the de-energized lines, however, these emissions would be minimal compared to the 250-270 amps on transmission lines 53 and 54. VitaTech also recorded a plumbing current on the W. Main Street water service main and induced currents on the gas pipeline, but these other magnetic field sources do not explain the discrepancy in the second calibration profile. Finally, after careful consideration and much trepidation, VitaTech assumes the following reasons for the variance between the simulated and recorded calibration profiles:

- 1) Errors have been introduced into the simulations because of the complex three-dimensional configuration (elevation) of the site, which cannot be easily corrected in the "flat world" model used by VitaTech. It should be noted that a 5-10 foot elevation error does not generate a 65-82% discrepancy between simulated and recorded data. Actually, if the elevations are increased by 17-20 feet, then the simulated and recorded data matches.
- 2) There is an error in the O & R load data recorded on 28 February 1997. **VitaTech does not infer nor imply that O & R Utilities provided erroneous data -- that must be perfectly clear.** Mr. McGoldrick and Mr. Coffey are just as concerned and perplexed as the author regarding this problem. We have worked as a collective group to find a reasonable cause for the discrepancy -- as of 6 May 1997 the exact cause is still unknown.
- 3) The transmission line phases are very unbalanced -- although this is not likely because transmission phases are relatively balanced, especially near generating plants unless some unrecorded *anomaly* occurred that day at the Lovett generating station or at the West Haverstraw substation (this is not a very likely scenario).

The author is very perplexed about the cause of this anomaly. It would irresponsible not to address our concern since the purpose of the calibration survey is to certify the validity of our average, winter peak, summer peak and worst-case substation simulations presented in Section 3, Simulated ELF Magnetic Emissions. *Refer to page 9, second paragraph in subsection 3, Average Load Simulation, for the solution to the simulation verification problem. Simply, the Average Load Simulation data plots are nearly identical with the two recorded calibration surveys, thereby validating the*

performance of all the simulation models.

2.2 West Main Street Surveys

Four magnetic flux density surveys were recorded on West Main Street. The first (see appendix A, Hatch & Profile Plots Rec 3 ID-MN1) starts at the property line of AMY and runs down W. Main St. and across Crickettown Rd. This is a magnetically complex survey because several magnetic sources (transmission line decay, plumbing currents on the W. Main Street water main and the overhead primary distribution/secondary lines running east on W. Main St.) produce a slightly elevated profile from 7 to 3.3 mG over 190 feet. Therefore, this profile is confusing unless each magnetic field source can be removed and analyzed, which is not possible when recording actual data.

The next survey (see appendix A, Hatch & Profile Plots Rec 6 ID-ORCH1) is near Orchard Street and runs from the ELY house, across W. Main Street and into the woods. About 35 feet from the house, a 2.5 mG plumbing current peak is recorded as the data cuts across the underground water main. The calculated current on the water pipe is 2.5 amps, however, the levels can vary from 2 - 20 amps depending on the residential daily and seasonal loads in the neighborhood. A second peak of 3.6 mG was recorded under the distribution line. This is a classic profile that is simple to understand.

The third survey (see appendix A, Hatch & Profile Plots Rec 8 ID-ORCH3) starts at the corner of Orchard St. (elevation ~120 ft.) and runs down W. Main Street and across Crickettown Rd. (elevation ~112 ft.), so there is an 8-foot dramatic change in elevation over the 650-foot survey. A peak of 32.1 mG was measured under the 138 kV transmission lines, which was nearly identical to the 31.7 mG peak measured at 8:36 in the morning. Plumbing currents on the water main were detected before and after the transmission line peak (between 230 - 470 feet). The distribution line that crosses the intersection of W. Main St. and Crickettown Rd. is barely detectable in this complex field profile.

The fourth survey (see appendix A, Hatch & Profile Plots Rec 9 ID-KUKL1) is a lateral across W. Main St. 250 feet west of the intersection of Crickettown Rd. The overhead primary distribution line produced a 5.3 mG peak directly under the conductors.

2.3 Orangeburg Substation #54

Mr. McGoldrick of O & R suggested that VitaTech survey the Orangeburg Substation #54 (see appendix A, Hatch & Profile Plots Rec 5 ID-SUB54 ORG) since this facility used the same transformer and basic layout as the proposed Stony Point substation. Data was recorded around the perimeter fence of the substation. Elevated levels between 20 - 27.4 mG were recorded under the 138 kV tie lines which quickly diminished to less than 6 mG around the perimeter until the entrance gate where a 10 mG peak was recorded due to the underground distribution feeders exiting the substation. Transformer emissions were only between 5-10 mG at the fence perimeter. It should be

noted that transformer levels quickly diminish according to the inverse cube rate of $1/r^3$ every meter, so 3-5 meters (10-16 feet) from the outside fence the transformer levels are below 3 mG.

This is the typical magnetic field profile for a distribution substation of this size and configuration in New York, Virginia and anywhere else in the United States. Generally, magnetic flux density levels are only elevated (above 10-15 mG) at the transmission line entry and distribution line (overhead or underground) exit points. Also, the spectrally rich harmonics and transient spikes that normally occur in substations quickly diminish as a function of distance.

2.4 Transmission Lines #53 & #54

Three transmission line surveys were recorded: two calibration surveys and one along W. Main St from Orchard St. to Crickettown Road. The first calibration survey (see appendix A, Hatch & Profile Plots Rec 1 ID-L1T) was recorded 50 feet north of the base of two transmission line towers. This has a very different profile (shape) when compared to the second calibration survey recorded on W. Main St. (see appendix A, Hatch & Profile Plots Rec 2 ID-L2T) and the W. Main St. survey (see appendix A, Hatch & Profile Plots Rec 8 ID-ORCH3). Although there is a 16-foot difference in conductor elevation height between the first and second calibration surveys, the profile (shape) of the curves should be very similar.

Electromagnetic induction of the de-energized transmission lines could increase the emission levels; however, there is an indication that ground currents are also producing magnetic fields around the first calibration survey area. Perhaps this complex phenomena is due to leakage current from the transmission lines down into the tower ground rods or some other unknown ground current source (i.e. ground currents on the water table, abandoned underground water pipe or cable).

The second calibration and the W. Main St. survey profiles are more normal. The elevation change along the east to west survey paths would shift the symmetry slightly to the left as shown in the profile plots. The plumbing currents on the water main are only detectable on the W. Main St. profile, which shows levels below 10 mG.

2.5 AC ELF Survey Instrument-FieldStar 1000 Gaussmeter

All AC ELF magnetic flux density measurements were recorded with a triple-axis *Dexsil Corporation FieldStar 1000* microprocessor-controlled gaussmeter (serial #31400009). This unit was factory calibrated according to ANSI/IEEE Standard 644-1987 on 17 April 1995. Inside the gaussmeter, three orthogonal coils simultaneously detect both horizontal (x-axis and y-axis) and vertical (z-axis) magnetic fields at 60 Hz. The microprocessor instantly converts the magnetic field at each axis (x, y, z) to magnetic flux density (milligauss) readings and simultaneously calculates the resultant R_{rms} (root-means-square) vector according to the following formula:

When collecting path data, a nonmetallic survey wheel is attached to the FieldStar 1000 gaussmeter and the unit is programmed to record mapped magnetic flux density data at selected (1-foot)

intervals. The FieldStar 1000 is exactly 39.37 inches (one-meter) above the ground with the survey wheel attached. Along each path the distance is automatically logged by the survey wheel and the relative direction entered on the keyboard. After completing the path surveys, magnetic flux density data with distance and directional information is uploaded to a 486 laptop computer and processed by the *FieldStar Graphics for Windows software* (version 1.02) into detailed plots. All plots display a record name, ID path number and the following statistical data defined below:

Peak - maximum magnetic field (flux) value measured in group.

Mean - arithmetic average of all magnetic field (flux) values collected.

Standard deviation - calculated using the formula below:

where B is the magnetic field (flux) and
 N is the number of samples

Median, L5 and L95 - calculated by first dividing the data set range into 1000 equal intervals or bins, then assigning each data point to a bin as the data is plotted. After the data has been assigned to bins, the number of points in each of the bins is summed beginning at zero. When the total number of points in the sum reaches 5% of the total, the mid-point of that bin is labeled **L95** or the magnetic flux value above, which the data is 95% of the time. Continuing the sum until 50% of the total is reached, the mid-point of that bin is then the **median**. When the sum reaches 95% of the total number of points in the data set, the mid-point of this bin is then **L5**, or the level above which the magnetic flux value is 5% of the time.

There are four types of survey plots presented in this document: hatch, profile and contour and 3-D surface. Each of the four plot types are defined below:

Hatch Plots - translates the sampled data (*Rrms* resultant magnetic flux density at one-foot intervals) into colored lines that represent magnetic flux density levels by defined *ranges* along the survey path. A key defines the *range* limits for each sampled data point by color and line size. Hatch plots show the two-dimensional survey path with four color ranges of resultant *Rrms* levels.

Profile Plots - displays horizontal (x-axis and y-axis) and vertical (z-axis) magnetic flux density data components by color and the calculated *Rrms* resultant in black as a function of distance (at one-foot intervals). Profile plots provide detailed component (i.e., dominate axis, minimum and maximum levels, etc.) and resultant *Rrms* magnetic flux density information.

Contour Plots - displays a spatial representation of the mapped area over a superimposed reference grid. The software calculates and translates the sampled data into color contour levels. A key defines the *range* limits for each band (contour) by color.

3-D Surface Plots - displays a three-dimensional spatial representation of the mapped data over a reference grid. The software calculates and translates the sampled data into z-axis Bmax RMS levels. The z-axis is scaled to show magnitude at that point in space.

It is important to understand the difference between the terms *magnetic field* and *magnetic flux density*. When an emanating *magnetic field* **H** permeates through a cross-sectional area of a medium (vacuum, free space or material), it converts to *magnetic flux density* **B** according to the following formula:

$$\mathbf{B}_{\text{magnetic flux density}} = \mu \mathbf{H}_{\text{magnetic field}} \quad \text{where } \mu \text{ is the permeability of the medium}$$

The permeability of a vacuum designated as μ_0 and free space (air) are nearly identical: $4\pi \times 10^{-7}$ **henry per meter** (H/m) in MKS units and **1-gauss/oersted** in CGS units. *Magnetic flux density* **B** is defined in MKS units as **tesla** (T) and in CGS units as **gauss** (G). It should be noted that in the United States CGS units **oersted** (Oe), **gauss** (G), and **milligauss** (mG) are the normal convention in power engineering and electromagnetics rather than the MKS units, except in scientific journals. Also, when working in free space both **gauss** (G) and **oersted** (Oe) are equal in magnitude as shown: $\mathbf{B}_{\text{gauss}} = \mu_0 \mathbf{H}_{\text{oersted}}$ where $\mu_0 = 1\text{-gauss/oersted}$.

For example, a 0.020 **oersted** *magnetic field* **H** in free space is equal to a *magnetic flux density* **B** of .020 **gauss** (20 mG). Although not technically accurate, the terms *magnetic field* **H** and *magnetic flux density* **B** usually appear synonymously in the engineering literature. *Magnetic flux density* **B** is measured with a gaussmeter in **milligauss** (mG) and easily converted to *magnetic field* **H** in either CGS and MKS units with the conversion factors listed below:

Magnetic Field/Flux MKS and CGS Conversion Factors

1 gauss (G) = 1×10^3 milligauss (mG)	1 milligauss (mG) = 1×10^{-7} tesla (T)
1 gauss (G) = 1×10^{-4} tesla (T)	1 milligauss (mG) = $1/(4\pi)$ A/m
1 A/m = $4\pi \times 10^{-3}$ oersteds (Oe)	1 tesla (T) = 1 weber (Wb)/m ²

3.0 SIMULATED ELF MAGNETIC EMISSIONS

VitaTech simulated ELF magnetic field levels around the proposed distribution substation site using the *MF3D (Magnetic Field, 3 Dimensional) version 2.1* modeling program developed by Electric Research & Management, Inc. This software provides the capability to model magnetic flux densities in three dimensions for transmission lines and substations. According to Electric Research & Management, "there is an average error of 10.5% between the measured and the predicted magnetic flux densities. Discrepancies were caused by the induced and ground currents, in and around (transmission lines) and substations, which were not modeled." In Appendix E, VitaTech presents the configured program models and the parameters (load currents, elevations, conductor spacing, etc.) used in each simulation. It required more than three weeks to correctly configure the

models using several graphics and CAD programs. The author constructed a three-dimensional (x, y & z) Cartesian model of the substation site accurate to 1/1000 of a foot. This was not a trivial task.

3.1 Existing Site ELF Simulated Magnetic Field Emissions

The first graphic in Appendix B shows the conductor diagram in three-dimensions. These are the transmission and distribution lines that will be simulated at the current site. The de-activated transmission lines were simulated with only 1 amp of current because it is very difficult to accurately estimate the induced currents on the lines. Four simulations were generated for the following load conditions: average load, winter peak, summer peak and worst-case.

3.11 Average Load Simulation

A color simulated Contour Map is superimposed over the O & R site drawings to clearly show the magnetic flux density levels at various locations during normal average load conditions. The dark blue edge represents the 5 mG lowest contour boundary level while the red edge represents the 60 mG highest contour level. The scale is divided into 12 color ranges (5 mG per range) and all simulated levels represent the B maximum (RMS) magnetic flux density level at that point in space.

According to the Contour Map, levels are below 5 mG in most of the homes and backyards along Crickettown Rd. and W. Main Street. Under the energized transmission lines (#53 and #54), the levels range from 20 to 30 mG. What is amazing is that these levels are very similar to the two calibration surveys recorded on February 28, 1997. The simulated 30 mG spot on W. Main Street is exactly where the 31 mG peak was recorded on the second calibration survey. Furthermore, the simulated level 50 feet north of the transmission line is 20 mG while the recorded first calibration survey was 19.6 mG. This is not a mere coincidence because these are average load levels -- exactly the same conditions that would occur on a mild winter morning in February. **Therefore, VitaTech is very confident that all our simulated models are very accurate and represent the conditions during average, summer peak, winter peak and worst-case conditions.**

The next set of five black-and-white graphics are surface plots of the simulated data. Without a doubt, surface plots provide a very dramatic three-dimensional view of the magnetic field emissions, especially emanating from the transmission lines. The first surface plot shows the perspective view and the four other plots a rotational view around the Bmax z-axis. The existing distribution line emissions on W. Main St. and Crickettown Rd. are rather diminished when compared to the transmission line emissions. *It should be noted that only the first set of surface plots will be marked in each of the three simulated groups: existing site, substation/distribution lines and reverse phase with substation/distribution lines.*

3.12 Winter & Summer Peak Load Simulations

Winter and summer peak load simulations are very similar because there is only a 60-100 amp difference between the summer and winter peak loads. The color Contour Maps show the 5-mG boundary to be outside the homes on Crickettown Rd. and W. Main Street. However, the winter and

summer peak contours have a slightly wider footprint and the 10-mG line has penetrated the LYNCH property line.

3.13 Worst-Case Load Simulation

Worst-case conditions (600 amps on the transmission lines) should only occur during emergency conditions when power must be shunted through lines 53 and 54 to other O & R facilities (transmission lines, substations, generating plants, etc.) in the service area. Fortunately, the 5-mG boundary line just intersects with two homes on W. Main Street. When the current load is 120 amps on the distribution line, there is a 5-9 mG emission at the corner of W. Main St. and Crickettown Rd.

3.2 Substation & Distribution ELF Simulated Magnetic Field Emissions

The conductor diagram in Appendix C shows the exact locations for the transmission lines, proposed substation tie lines and the four distribution feeder circuits. The de-activated transmission lines were simulated with only 1 amp of current because it is very difficult to accurately estimate the induced currents on the lines. Four simulations were generated for the following load conditions: average load, winter peak, summer peak and worst-case.

3.21 Average Load Simulation

The proposed substation with four underground distribution lines, riser poles and overhead circuits are shown in the color simulated Contour Map and five black-and-white surface plots. Look at the substation, it does not produce a very significant emission signature because it is within the magnetic envelope of the transmission lines. This is a remarkable pictorial that clearly shows the limited magnetic field impact of a proposed Stony Point substation. Furthermore, the recorded Orangeburg Substation #54 levels are very similar to the simulated contour and surface map levels, which verifies the performance and accuracy of the model. The four underground distribution feeders emanate a 5-9 mG elevated level under W. Main Street and west on W. Main Street (circuits #3 & #4). However, levels are below 3 mG on Crickettown Rd. (circuit #1) and east on W. Main (circuit #2).

3.22 Winter & Summer Peak Load Simulations

There is only a 60-100 amp difference between the peak seasonal transmission line loads, so the simulations are very similar even with the substation included. The color Contour Maps show the 5-mG boundary to be outside the homes on Crickettown Rd. and W. Main Street. However, the winter and summer peak contours have a slightly wider footprint and the 10-mG line has penetrated the LYNCH property line. In the summer peak maps, the overhead distribution lines (circuits 3 & 4) are in the 5-mG range heading west.

3.23 Worst-Case Load Simulation

Worst-case conditions (600 amps on the transmission and distribution lines) should only occur during emergency conditions when power must be shunted to other O & R facilities (transmission lines, substations, generating plants, neighborhoods, etc.) in the service area. The underground distribution lines (circuits 1, 3 & 4) would emanate 10-30 mG under W. Main Street and 10-15 mG

along the overhead lines (circuits 3 & 4) on W. Main Street. Elevated levels from 10-15 mG would also emanate from the Crickettown Rd. distribution line (circuit #1) and on the line (circuit #2) that heads east on W. Main Street. It must be reiterated, worst-case load conditions can only exist for a very short time (i.e., minutes and a few hours), otherwise the conductors (lines) will self-destruct (sag and short-out, melt or break) under the intense current loads and thermal (heat) demands. Utilities do not operate their power systems under worst-case conditions - something will eventually fail if the demand exceeds supply and good load management.

3.3 Reverse Phase Substation & Distribution ELF Simulated Magnetic Field Emissions

The conductor diagram in Appendix D shows the exact locations for the transmission lines, proposed substation tie lines and the four distribution feeder circuits. In this model the A and C phases of circuit #53 are in reverse order compared to the phases in circuit #54. A cancellation effect occurs, significantly reducing transmission line emissions. All double-circuit vertically arrayed transmission lines should be reverse phased - it significantly lowers magnetic emissions and reduces energy losses. The de-activated transmission lines were simulated with only 1 amp of current because it is very difficult to accurately estimate the induced currents on the lines. Four simulations were generated for the following load conditions: average load, winter peak, summer peak and worst-case.

3.31 Average, Summer, Winter and Worst-Case Load Simulations

The four reverse phase simulations have been grouped in this subsection because the mitigation effects on the transmission lines are remarkable as shown in the color simulated Contour Maps and black-and-white surface plots. In average, winter, summer and worst-case simulations the transmission line emission footprint is within the ROW boundaries for the first time. Also the substation emissions are noticeable, but not dominant because of the underground and overhead distribution lines carry 600 amps, which generates elevated emissions along W. Main St. and Crickettown Road. **Based upon these simulations, VitaTech highly recommends reverse phasing transmission lines #53 and #54.**

4.0 ELF EMF EXPOSURE & POTENTIAL HEALTH ISSUES

Based upon simulated magnetic flux density emissions during average, winter peak, summer peak and worst-case loads, the proposed Stony Point distribution substation only produces a slight increase in the magnetic field profile at the site. The dominant magnetic field sources at the site are the two active transmission lines #53 and #54. **Therefore, the proposed substation does not increase the potential EMF health risk at the site nor to the local neighborhood because the transmission lines are the primary source of ELF magnetic fields. The transmission lines are the potential threat, not the substation.** Nevertheless, the following precautions should be implemented to reduce overall exposure to elevated magnetic field levels (defined as levels exceeding 10 mG) at that site and along the entire ROW:

- 1) Reverse phase the active transmission lines #53 and #54 to significantly reduce the ELF

magnetic emissions to within the limits of the ROW boundaries as shown in the Reverse Phase Contour Maps in Appendix D.

- 2) Seek a written guarantee from O & R that states the other two transmission lines will be reverse phased, if energized, to limit magnetic emissions within the ROW limits.
- 3) No homes will be built within 100 feet of the substation fence line.

Finally, there will be an increase in magnetic emissions (ranging from 5- to 9-mG) under the four overhead distribution circuits (#'s 1-4) along W. Main Street and Crickettown Road after the substation is built. Levels will quickly diminish to less than 3 mG about 10-15 feet away from the lines under normal loads (average, winter and summer peaks) because O & R uses armless tangent construction (delta arrayed) 45-foot poles (the additional height also helps). Magnetic field emissions diminish linearly as the conductors are moved closer together because of the self-cancellation effects between phases. So, the magnetic emissions from the underground (triplexed) distribution lines will be less than 10 mG under the street, except during worst-case conditions when the levels may exceed 20 mG. Remember, worst-case conditions rarely occur and should not be considered a long-term exposure issue.

4.1 ELF EMF Health Issues

Currently, there are no Federal standards for AC ELF electric and magnetic field levels. New York State has set a 200 mG limit along the ROW of transmission lines; however, according to Dr. Daniel Driscoll of the New York State Public Service Commission, Office of Energy Efficiency and Environment (518-486-2872), the 200 mG limit only applies to new transmission line projects, not existing lines and sites.

Since there are no Federal, state or local occupational exposure standards for ELF magnetic field levels (except a 200 mG ROW limit in New York and Florida, and a 4 mG limit in the City of Irvine, California and Brentwood, Tennessee), it becomes the local community's option to establish an acceptable level of human exposure. **Based upon our professional engineering experience and review of the current ELF EMF research literature, VitaTech Engineering recommends 10 mG (1 μ T) as a reasonably achievable human exposure limit.**

Our 10 mG (1 μ T) human exposure limit is supported by section 8.4.1.3 option 3 in the National Council of Radiation Protection and Measurements (NCRP) draft report published in the July/August 1995 issue of *Microwave News* that states the following:

8.4.1.3 Option 3: *An exposure guideline of 1 μ T and 100 V/m: A considerable body of observations has documented bioeffects of fields at these strengths across the gamut from isolated cells to animals, and in man. Although the majority of these reported effects do not fall directly in the category of hazards, many may be regarded as potentially hazardous. Since epidemiological studies point to increased cancer risks at even lower levels, a case can be made for recommending 1 μ T and 100 V/m as levels not to be exceeded in prolonged human*

exposures. Most homes and occupational environments are within these values, but it would be prudent to assume that higher levels may constitute a health risk. In the short term, a safety guideline set at this level would have significant consequences, particularly in occupational settings and close to high voltage transmission and distribution systems, but it is unlikely to disrupt the present pattern of electricity usage. These levels may be exceeded in homes close to transmission lines, distribution lines and transformer substations, in some occupational environments, and for users of devices that operate close to the body, such as hair dryers and electric blankets. From a different perspective, adoption of such a guideline would serve a dual purpose: first, as a vehicle for public instruction on potential health hazards of existing systems that generate fields above these levels, as a basis for "prudent avoidance;" and second, as a point of departure in planning for acceptable field levels in future developments in housing, schooling, and the workplace, and in transportation systems, both public and private, that will be increasingly dependent on electric propulsion.

The above recommendation conflicts with a recent report released by the National Research Council on the *Possible Health Effects of Exposure to Residential Electric and Magnetic Fields*. The author does not want to debate EMF Health Issues in this document, however, many EMF professionals (researchers, engineers, physicists, and physicians) challenge the misleading statements in the Executive Summary, including Dr. Robert McGaughy of the Environmental Protection Agency (EPA) who co-authored an historic EPA report in 1990, the *Evaluation of the Potential Carcinogenicity of Electromagnetic Fields*, which the Bush Administration delayed release for two years. Incidentally, five years later in 1996 Dr. McGaughy co-authored a second EMF report as required by law. Now the Clinton Administration has ordered EPA not to release this new report. Recently, VitaTech contacted The Washington Post to obtain a copy using the Freedom of Information Act. The EPA claimed the report was not completed, and therefore not available for publication or release.

Questions regarding health issues and exposure levels can be only addressed by a qualified scientist. The following U.S. government scientists are responsible for EMF health issues and policies: Dr. Robert McGaughy at (202) 260-5889, Environmental Protection Agency (EPA) and Dr. Joseph Bowman at (513) 533-8510, National Institute for Occupational Safety and Health.

5.0 ELECTROSTATIC & ELECTROMAGNETIC INDUCTION

Electromagnetic induction occurs when magnetic fields from the transmission lines couple with the metal gas pipeline inducing currents -- this is a normal phenomena whenever a pipeline, fence or wire runs parallel with a transmission line. O & R has taken the required safety precautions (known as cathodic protection) to protect the gas pipeline from the long-term deleterious effects (ion depletion that weakens the integrity of the pipe and welds) of induced currents. During VitaTech's survey on 28 February 1997, the author calculated the induced currents on the gas pipeline to be 0.5 to 1.0 amps based upon the magnetic emission from the pipe. This was not an accurate measurement because the transmission lines emissions dominated the site. *Nevertheless, VitaTech suggests an induced current monitoring system should be installed around the gas pipe to reduce any potential*

problems since the substation will be in close proximity. Another alternative would be to log the induced current inspections at the town hall to insure proper preventative maintenance by O & R.

5.1 Effects Of Electrostatic & Electromagnetic Induction

Electrostatic induction occurs when alternating 60-Hz electric fields couple with conduction animate (humans) and inanimate objects, thereby inducing current and voltages within the objects. The actual current consists of minute movements of charged particles: electrons in metallic conductors and ionic conduction in body tissues and fluids. The voltages and currents induced directly into humans are of concern if they are high enough to cause direct biological, physiological, and psychological effects.

If the conductive object is grounded, the induced current that travels through the object to the ground is called the *short-circuit* current (units in amperes). Generally, in humans and animals the *short-circuit* current flows from head to feet (called body currents) and can be approximated with the following formula: $I_{\text{short-circuit (microamps)}} = 5.4(h^{\text{height(meters)}})(E_{\text{kV/m}})$. Examples of measured *short-circuit* currents in 0.7 kV/m and 2 kV/m electric fields similar to those under 138 kV and 230 kV overhead transmission line are presented below in microamps (μA):

Objects	138 kV Line	230 kV Line
	0.7 kV/m E Field	2 kV/m E Field
Human -1.75 meters tall (5' 9")	12 μA	32 μA
Station wagon	77 μA	220 μA
Large school bus	287 μA	820 μA
Large Trailer Truck	441 μA	1,260 μA

Within elevated *electric fields*, when a grounded person touches an isolated (ungrounded) conductive object, a perceptible current (tingling sensation) or shock may occur. This phenomena also happens when the person is insulated and the conductive object is grounded. There are three basic classifications for shocks: perception and secondary shocks (which are annoying but not harmful) and primary shocks (which are very dangerous and potentially lethal). A safe perception shock (tingling response) for most men and women is 1.0 mA and 0.65 mA, respectively. Secondary shocks invoke involuntary muscle responses (shaking) that are very annoying and possibly painful. However, primary shocks begin at the *let-go current* where 99.5 % of all subjects can still voluntarily *let-go* of an energized conductor: 9.0 mA for men and 6.0 mA for women. Unfortunately, beyond the *let-go current* threshold, a victim's heart may be shocked into ventricular fibrillation resulting in imminent death if not medically treated (defibrillated) within 4-6 minutes. Near transmission lines, the National Electrical Safety Code (N.E.S.C.) specifies 5 mA as the maximum allowable *short-circuit current* from vehicles, trucks, and equipment. And the American National Standards Institute (ANSI) allows up to 0.5 mA leakage current from portable household appliances and 0.75 mA for fixed appliances.

Electromagnetic induction occurs when alternating 60-Hz magnetic fields couple with animate (humans) and inanimate conductive objects (wires, metal beams, HVAC ducts, etc.), thereby inducing circulating currents and voltages. Magnetically induced body currents in human tissues flow primarily in peripheral loops (called eddy currents) perpendicular to the field; however, current at the center is generally near zero. Magnetic fields from transmission lines will normally induce voltages at the open ends of long, partially grounded, parallel conductors (fences, wires, and exposed pipes). So, dangerous and potentially lethal shocks from *electromagnetic induction* are also a serious problem.

Unfortunately, *electromagnetic induction* generates circulating tissue currents in humans near **transformers, network protectors, secondary feeders, switchgears, distribution busways, and electrical panels**. In calculating the *current density* in human tissues due to *electromagnetic induction*, the conductivity of mammalian tissue is assumed to be uniform: $\sigma_{\text{conductivity}} = 0.1 \text{ S/m}$ (siemens/meter). Assuming the human body is within a conducting sphere, the *induced voltage* E_i in volts/meter (V/m) at a defined radius r_{meters} representing a waist of .145 m (36 in.) is defined as: $E_i = (1 \times 10^{-7})(\pi)(r_{\text{meters}})(f_{\text{frequency}})(B_{\text{mG}})$. The *current density* J_{body} in microamps/meter² ($\mu\text{A/m}^2$) for human body tissues around the waist can be calculated by using: $J_{\text{body}} = (\sigma_{\text{conductivity}})(E_i)$. Below there is a list of 60-Hz calculated *electromagnetically induced voltages* E_i and *current densities* J_{body} around a typical waist exposed to various magnetic flux density B_{mG} levels (also equivalent *short-circuit* currents induced within humans from E_{field} *electrostatic induction* in italics):

Magnetic Flux Density	Induced Voltage - E_i	Induced Current Density - J_{body}
5,000 mG	$13.667 \times 10^{-3} \text{ V/m}$	$1,366.7 \mu\text{A/m}^2$ (82.6 kV/m E_{field})
1,000 mG	$2.733 \times 10^{-3} \text{ V/m}$	$273.3 \mu\text{A/m}^2$ (16.5 kV/m E_{field})
500 mG	$1.367 \times 10^{-3} \text{ V/m}$	$136.7 \mu\text{A/m}^2$ (8.2 kV/m E_{field})
100 mG	$.273 \times 10^{-3} \text{ V/m}$	$27.3 \mu\text{A/m}^2$ (1.7 kV/m E_{field})
50 mG	$.137 \times 10^{-3} \text{ V/m}$	$13.7 \mu\text{A/m}^2$ (800 V/m E_{field})
10 mG	$.027 \times 10^{-3} \text{ V/m}$	$2.7 \mu\text{A/m}^2$ (200 V/m E_{field})
3 mG	$.008 \times 10^{-3} \text{ V/m}$	$0.8 \mu\text{A/m}^2$ (50 V/m E_{field})

5.2 ELF Electromagnetic Interference (EMI)

Electromagnetic interference (EMI) occurs when time-varying AC magnetic fields couple with any conductive object, including wires, electronic equipment and people, thereby inducing circulating currents and voltages. In unshielded (susceptible) electronic equipment (computer monitors, video projectors, computers, televisions, LANs, diagnostic instruments, magnetic media, etc.) and signal cables (audio, video, telephone & data), electromagnetic induction generates electromagnetic interference (EMI), which is manifested as visible screen jitter/color shifts in displays and noise, popping sounds, blanking/sync distortions and data errors in signal cables.

Generally, the minimum EMI threshold level in unshielded electronic equipment and signal cables is 10 mG for ELF sources (transmission & distribution lines, transformers, network

protectors, secondary feeders, switchgears, distribution panels & risers, motors, variable speed controllers, dimmers, etc.). However, actual EMI immunity depends on the PCB and component layout, circuit design (differential verses unbalanced input amplifiers, signal-to-noise ratio, etc.), outer case composition, geometry and shielding factor (SF).

6.0 GROUND & PLUMBING CURRENTS

VitaTech examined the *Foundation, Fence, Conduit & Grounding Plan* of the Orangeburg Substation, which is very similar to the proposed Stony Point substation. It is difficult to predict substation ground current problems before the facility is installed because factors (water table, soil types, grade and ground resistance) influence how the return ground currents travel back to the secondary input of the transform. Ground return currents are a very complex phenomena and the magnetic fields generated along the ground return paths in the earth are just as mystical. Nevertheless, the substation grounding plan is standard and will work as designed.

Finally, plumbing currents were detected on the water main that runs along W. Main Street and Crickettown Road. These emission levels and calculated currents were not outside of the normal range for most suburban and rural neighborhoods, however, O & R should evaluate this problem because there could be a residence with a very serious grounding problem nearby. *Warning to all those who read this report: Do not cut the metal water pipes inside your home before it is inspected by a licensed plumber because potentially lethal plumbing currents can be present on the pipes.*

7.0 RESIDENTIAL PROPERTY DEVALUATION

Perhaps the greatest tragedy in the EMF imbroglio is the issue of residential property value devaluation, especially when homes are adjacent to transmission lines ROWs and substations. This is a real phenomena - the author has surveyed hundreds of residential properties in the Washington, D.C. metropolitan area. Basically, the residential home devaluation (defined as difference between the asking and closing price) is as follows:

<u>Distance To</u> <u>Transmission Lines/Substation</u>	<u>Devaluation</u>
100 feet	25%-30%
200 feet	15%-20%
300 feet	5%-10%

The author contacted Mr. David R. Bolton, who is a licensed Real Estate Property Appraiser in Austin, Texas, and a recognized expert in EMF devaluation issues. Mr. Bolton has been an expert witness in many cases and published a paper, *Properties Near Power Lines and Valuation Issues: Condemnation or Inverse Condemnation?*, in the Southwestern Legal Foundation's 24th Annual Institute proceedings in 1994. On page 13-11 he wrote the following:

"This author conducted a recent study of assessed values of the Harris County Appraisal District (HCAD) on approximately 100 residential properties located near the western portion of the city of Houston. These properties were compared to about the same number of similar residences located within the interior of the subdivisions. The assessed values of properties adjoining the power line easement were 12.8 percent to 30.7 percent less than the average of the interior properties, thus supporting the articles, studies, reports and opinions mentioned above."

Several years ago a New York State case, *Criscuola v. Power Authority of the State of New York*, was decided in favor of the property owners. Again, the author will yield to Mr. Bolton's articulate explanation regarding this decision on page 13-15 of his paper:

"This very recent case is probably the easiest for a layman to understand due to its clarity in explaining EMF issues. The decision stems from eminent domain litigation involving numerous property owners and a line running from near Utica of Dutchess County, north of New York City. Reversing an appellate court, this opinion relied on many of the other cases that have been discussed here. Adopting the language of *Willsey v. Kansas Power and Light Co.*, the opinion states "evidence of fear in the market place is admissible with respect to the value of property taken without proof of the reasonableness of the fear."

"Particularly of interest to real estate appraisers, the following excerpt from the opinion should be welcome:

Whether the damage is a scientifically genuine or verifiable fact should be irrelevant to the central issue of its market value impact. Genuineness and proportionate dollar effects are relevant factors, to be sure, but in the usual evidentiary frame work. Such factor should be left to the contest between the parties' market value experts, not magnified and escalated by the whole new battery of electromagnetic power engineers, scientists or medical experts. **Adverse health effect *vel non* is not the issue in eminent domain proceedings: full compensation to the landowner for property taken is."**

VitaTech has attempted over the last several years to contact the *National Association of Realtors* and discuss the devaluation issue - they do not want to talk about it, period. Local real estate agents have told the author (off-the-record) that most realtors do not take listings of homes near transmission lines and substations -- they are too difficult to sell.

In conclusion, the homeowners near the proposed Stony Point distribution substation will probably suffer 20%-30% property devaluation (both the author and Mr. Bolton concur) upon the sale of their residence due to the proximity to the transmission lines. However, the proposed substation would only increase the devaluation by a small incremental amount because the transmission lines are more visible and imposing (perceived threat) at the site. Therefore, an earthen wall 8-10 feet high should be erected on the open side of the substation, except at the maintenance gate, to basically hide the

substation from view. An earthen wall would essentially surround the substation, providing additional sound isolation and protection from any catastrophic events (exploding equipment, fuses, transformer, etc.).

8.0 CONCLUSION & RECOMMENDATIONS

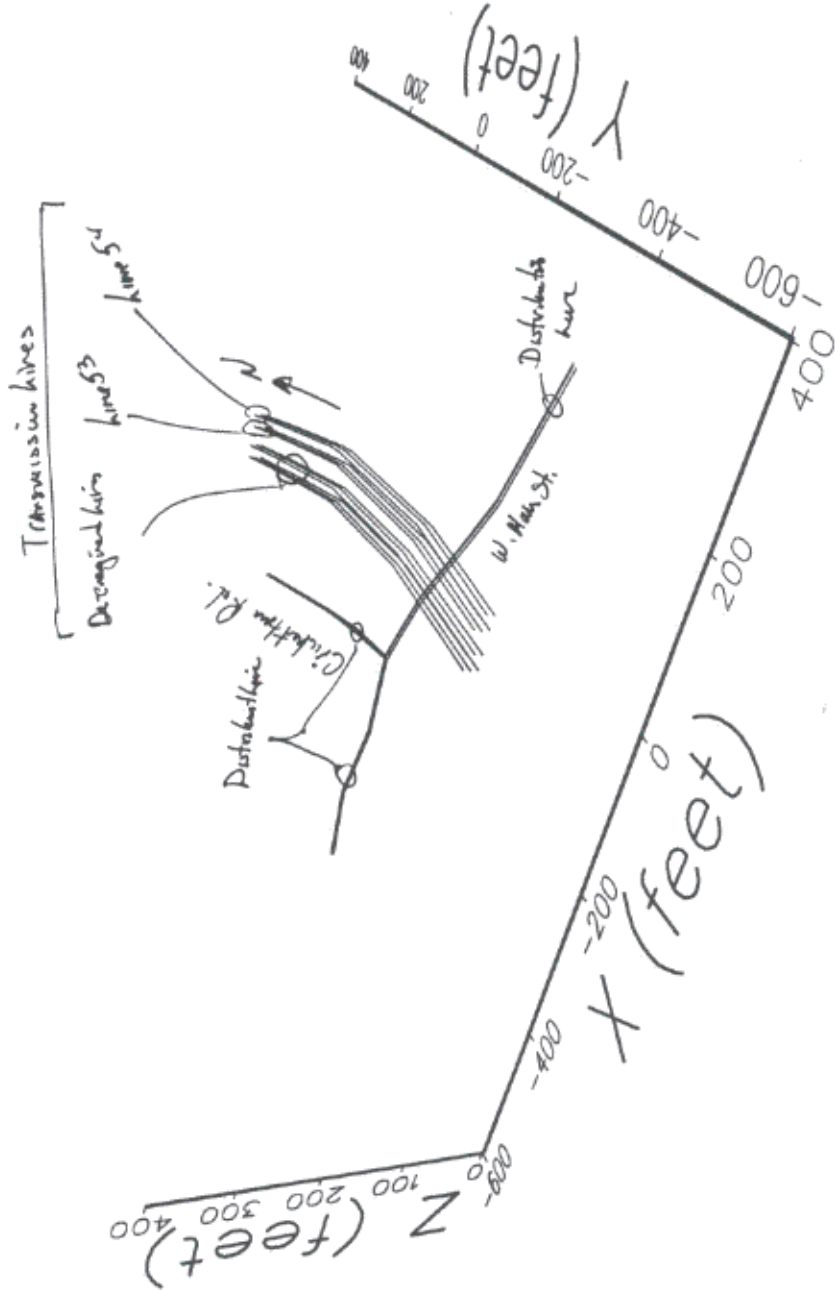
The proposed Stony Point distribution substation only produces a slight increased magnetic field profile at the site compared to the transmission line emissions, and therefore does not pose a potential EMF health risk to the neighborhood, especially since most of the homes will be at least 200 feet from the substation fence. Furthermore, the proposed substation will only have an incremental impact on the residential property values, compared to the transmission line impact, which is between 20%-30% for those properties within 100-feet of the ROW. Therefore, the impact (EMF and property devaluation) of the proposed Stony Point distribution substation on this site is minimal: as it would be at any other site along the transmission line ROW in the Town of Stony Point. However, the following recommendations must be implemented to protect the safety and welfare of those who live near the proposed substation site and along the transmission line ROW:

- 1) Reverse phase the active transmission lines #53 and #54 to significantly reduce the ELF magnetic emissions to within the limits of the ROW boundaries as shown in the Reverse Phase Contour Maps in Appendix D.
- 2) Seek a written guarantee from O & R that states the other two transmission lines will be reverse phased, if energized, to limit magnetic emissions within the ROW limits.
- 3) No homes should be built within 100 feet of the substation fence line.
- 4) Erect an earthen wall 8-10 feet high on the open side of the substation, except at the maintenance gate, to basically hide the substation from view. An earthen wall would essentially surround the substation, providing additional sound isolation and protection from any catastrophic events (exploding equipment, fuses, transformer, etc.).
- 5) Install an *induced current* monitoring system around the gas pipe to reduce any potential problems since the substation will be in close proximity. Another alternative would be to log the induced current inspections at the town hall to insure proper preventative maintenance by O & R.
- 6) Install reinforced protective cement barriers around the gas pipeline valve and regulator sections. Also, install a muffler or sound wall to reduce the regulator noise level by 20-30 dB.

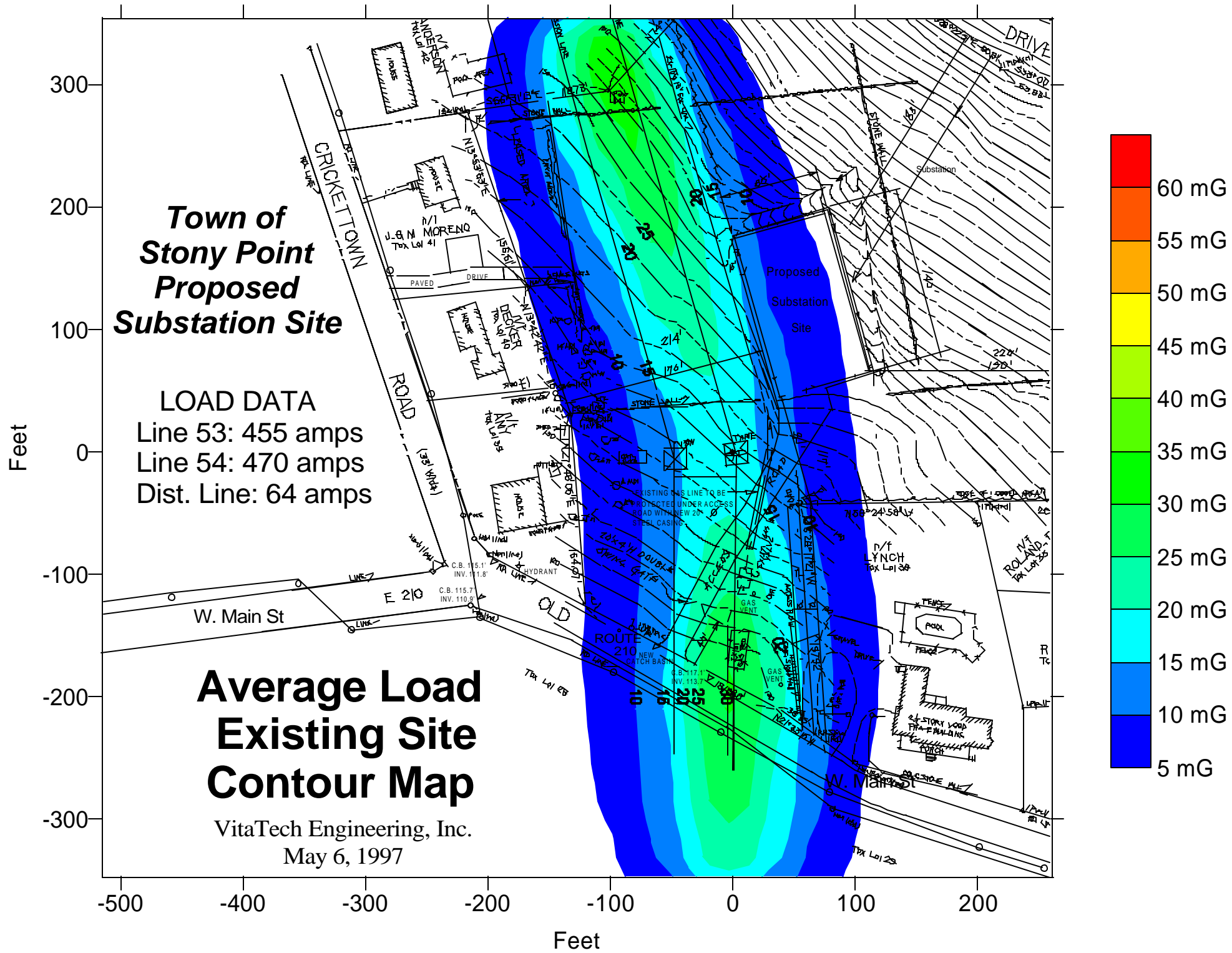
Appendix B:

Existing Site ELF Simulated Magnetic Field Emissions

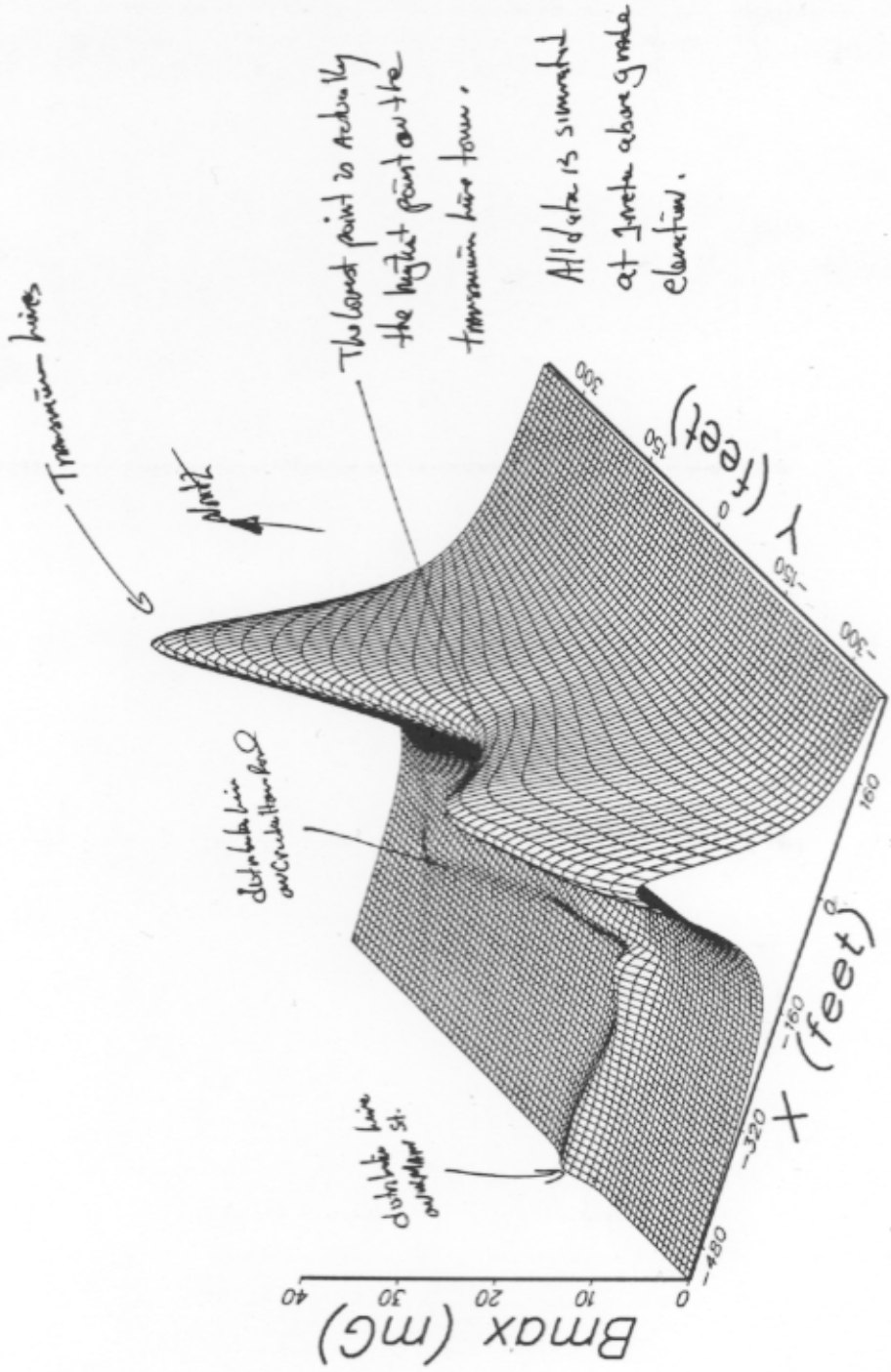
Existing Site Conductor Diagram



Viewing Angle
x = 300
z = 70



Average Load Bmax - Existing Site



Minimum: 0.15 mG
Maximum: 33.05 mG

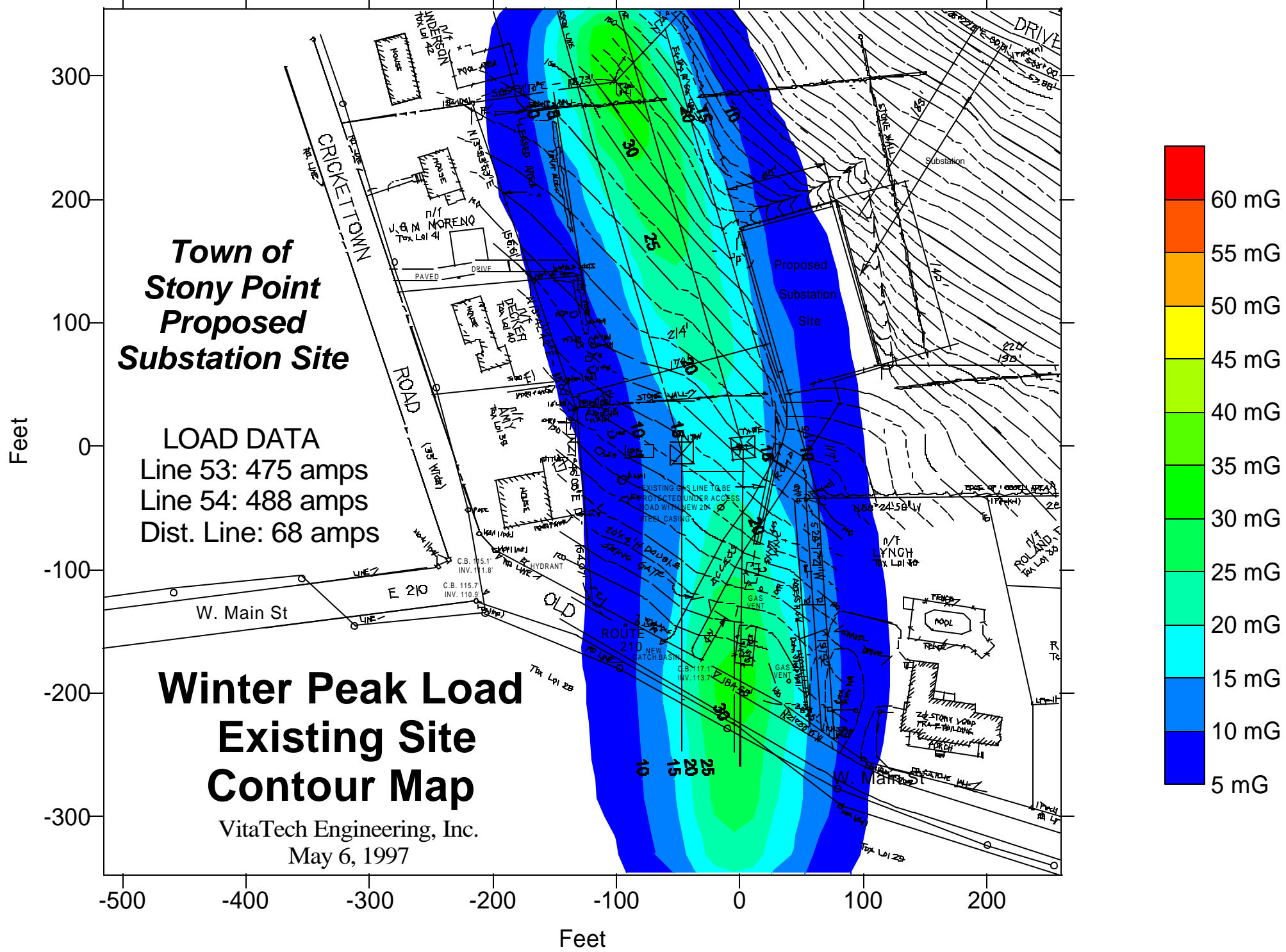
Viewing Angle
x = 300
z = 55

Average Load Bmax - Existing Site



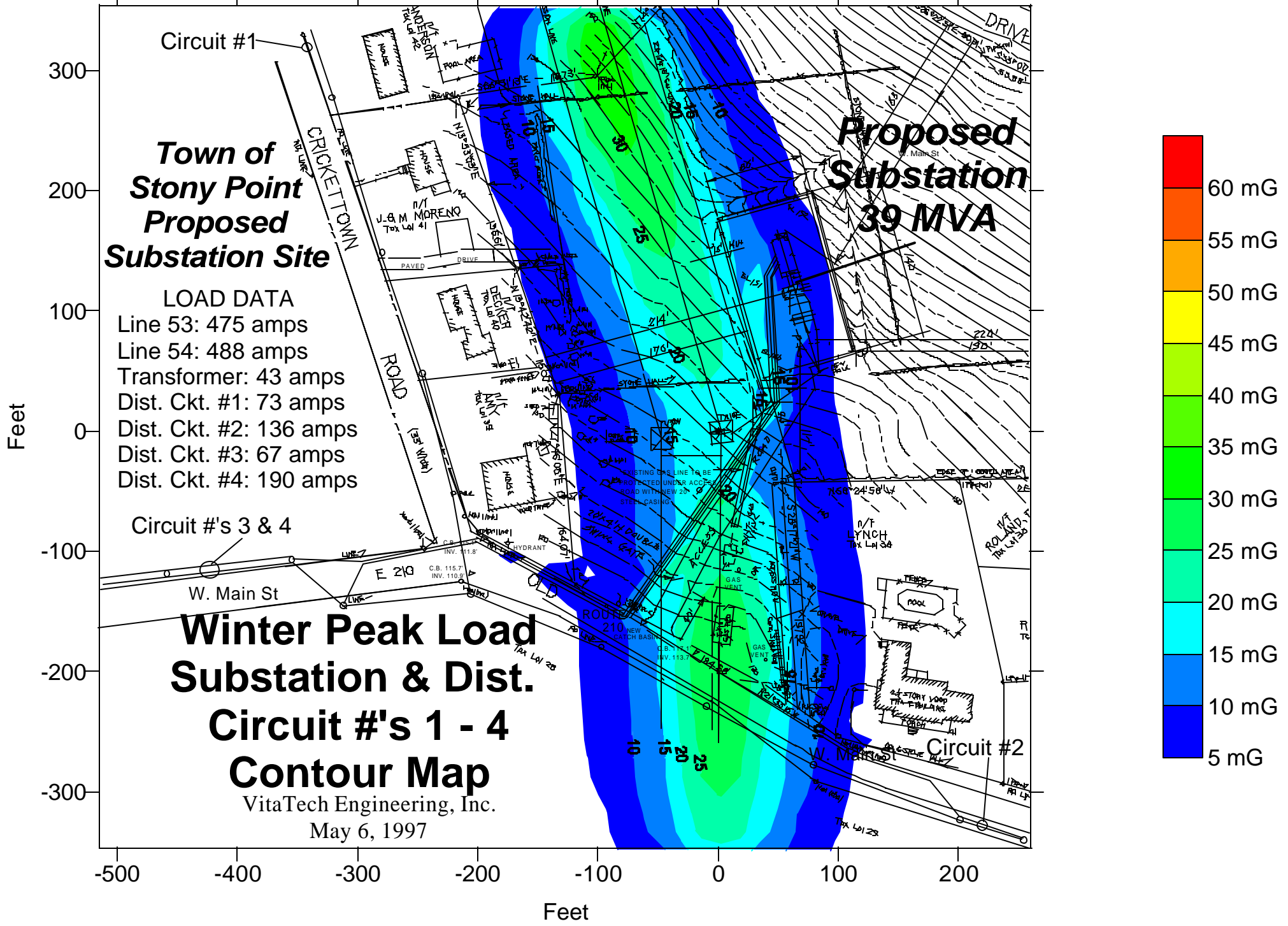
Minimum: 0.15 mG
Maximum: 33.05 mG

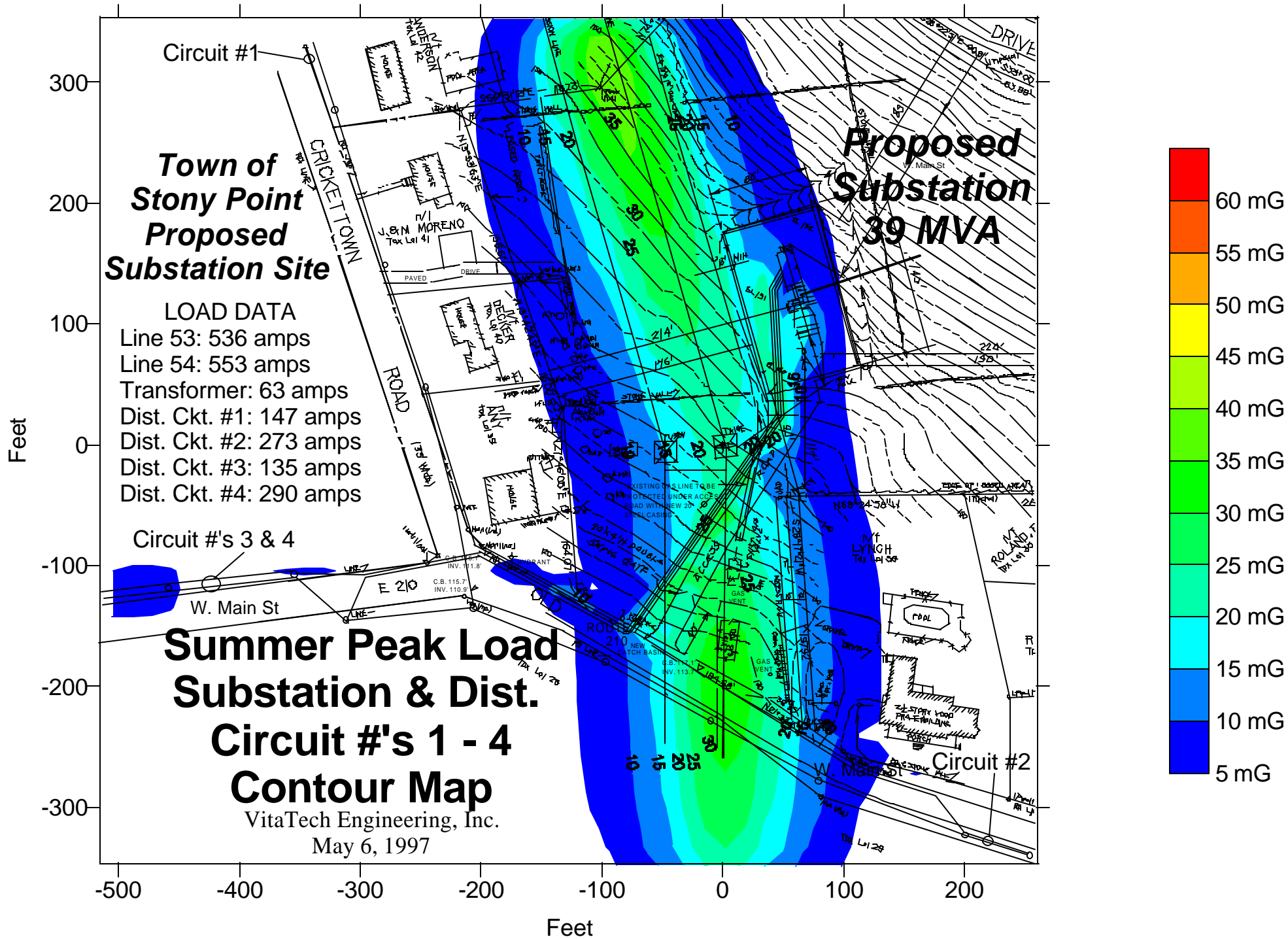
Viewing Angle
x = 300
z = 90



Appendix C:

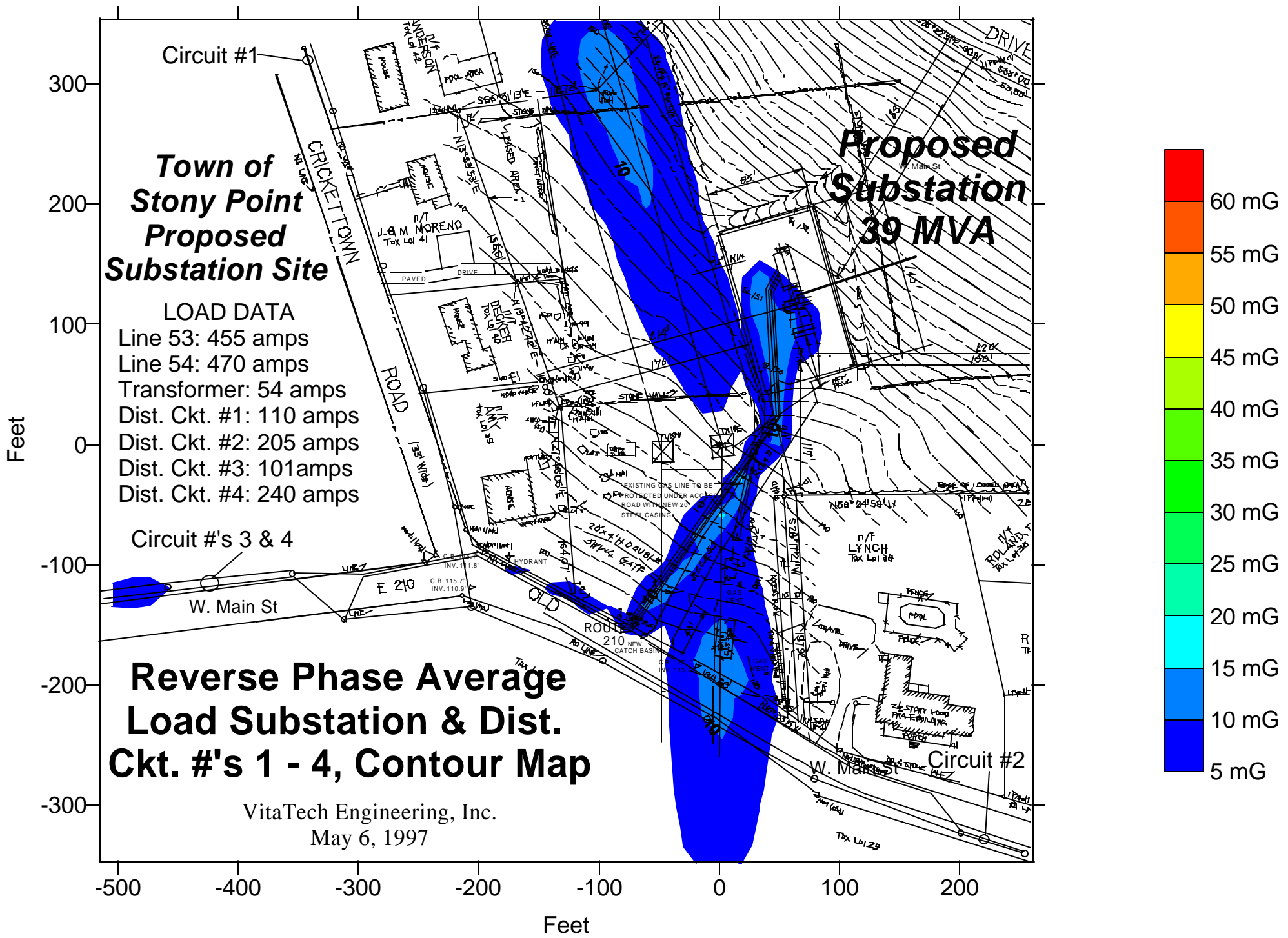
Substation & Distribution ELF Simulated Magnetic Field Emission





Appendix D:

Reverse Phase Substation & Distribution ELF Simulated Magnetic Field Emissions



**Town of Stony Point
Proposed
Substation Site**

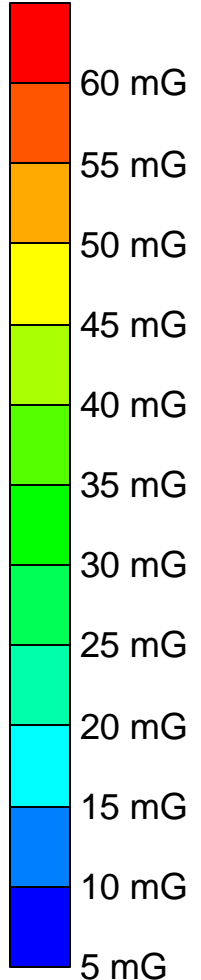
**Proposed
Substation
39 MVA**

LOAD DATA
 Line 53: 455 amps
 Line 54: 470 amps
 Transformer: 54 amps
 Dist. Ckt. #1: 110 amps
 Dist. Ckt. #2: 205 amps
 Dist. Ckt. #3: 101amps
 Dist. Ckt. #4: 240 amps

Circuit #'s 3 & 4

**Reverse Phase Average
Load Substation & Dist.
Ckt. #'s 1 - 4, Contour Map**

VitaTech Engineering, Inc.
May 6, 1997



-500 -400 -300 -200 -100 0 100 200

Feet

300
200
100
0
-100
-200
-300

Feet

