Hawaiian Electric Company

East Oahu Transmission Project

Magnetic Field Evaluation

Prepared for
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NOTICE

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EXECUTIVE SUMMARY

Hawaiian Electric Company (HECO) has proposed the construction of a new transmission system project, entitled the East Oahu Transmission Project. This project involves the installation of several new underground 46 kV subtransmission lines and transformers. As a result of this proposed installation, some existing electrical facilities (such as 12 kV, 25 kV and 46 kV underground and overhead distribution lines) may be eliminated, remain unchanged, or may increase or decrease in loading. Based upon this evaluation, the following conclusions were reached:

Existing magnetic field levels from HECO facilities are typical of levels from similar facilities throughout the State of Hawaii.

Magnetic field measurements were conducted at eleven selected segments along portions of the proposed project to characterize field strengths due to existing electrical facilities. Existing magnetic field levels along these segments range from a few tenths of a mG to over 25 mG, depending upon location. Existing electric facilities surveyed included 12 kV, 25 kV, 46 kV, and 138 kV power line facilities.

The difference in projected magnetic field levels between the existing and proposed power line configurations under 2009 forecasted loading can decrease slightly, remain unchanged, or increase depending upon the project segment.

In addition to field measurements, magnetic field levels were also calculated for 2009 forecasted normal and Pukele outage conditions for eleven different project segments. The difference in projected magnetic field levels between the existing and proposed power line configurations under 2009 forecasted loading can decrease slightly, remain unchanged, or increase depending upon the project segment. For Segment 'I' (where no 46 kV power lines presently exist), the projected magnetic field generally remains unchanged since the proposed underground 46 kV power lines would only be utilized under Pukele outage conditions. For Segment 'E' (east of Kamoku Substation where modifications to an existing overhead 46 kV power line are proposed), the range of projected magnetic field levels decreases slightly since the 2009 forecasted load is somewhat lower for the proposed configuration than for the existing configuration. At all other segment locations, the projected magnetic field increases due to the proposed power line configuration under 2009 forecasted loading conditions. While the largest magnetic field increases typically occur within street locations, projected magnetic field levels can also increase at sidewalk locations. Under proposed 2009 Pukele outage conditions, the projected magnetic field increases at all segment locations.

If the project is implemented, the proposed underground circuits would have little effect on EMF levels at nearby institutions; EMF levels will be in the range of common everyday levels.

A magnetic field assessment was performed to evaluate present and future levels at various institutions along the proposed project. Several institutions are located near portions of the proposed project, including day care centers, pre-schools and schools, hospitals, churches, and retirement homes. Distance measurements were taken to determine the closest building edge to the proposed project. Using these distance measurements, the projected magnetic fields for 2009 loading conditions were evaluated for each of these institutions. Six different institutions are located within 100 feet of the proposed project. The two closest institutions are the Kaplan Test Preparation Center and the Lunalilo Elementary School. For the Kaplan Test Preparation Center, projected 2009 magnetic field levels of 0.0 mG with the existing power line configuration would increase about 1.1 mG with the proposed configuration under normal loading. For the Lunalilo Elementary School, projected 2009 magnetic fields of about 4.0 mG with the existing power line configuration would decrease to about 3.3 mG with the proposed configuration under normal loading (due to some field cancellation). Four other institutions within 100 feet would have no projected magnetic field under normal operating conditions, since the underground power lines are only loaded during Pukele outage conditions (and even then the projected field at the closest building edge is less than 1 mG). There are five additional institutions located within 200 feet of the proposed project. Of these, two institutions have projected magnetic fields of about 0.6 or less under Pukele outage conditions, and three institutions would have no projected magnetic field under normal operating conditions (since the underground power lines are only loaded during Pukele outage conditions and have negligible projected field influence of about 0.1 mG). Beyond 200 feet, the projected magnetic field influence from the proposed project is negligible.

The proposed substations, manholes, and risers of the East Oahu Transmission Project will be similar to existing facilities and have very low EMF levels at a relatively short distance away.

Another aspect of the proposed East Oahu Transmission Project is the installation of new transformers within certain substations, manholes in the streets, and risers on wooden poles at sidewalk locations. The magnetic field from a substation transformer or manhole is typically reduced by about 90% at a distance of about 20 feet away from the facility (for transformers, magnetic fields due to these sources are typically reduced to ambient levels at the substation perimeter). For this project, the closest property line is at least 30 feet away from any proposed substation transformer location. For risers, the magnetic field is typically reduced by over 90% at a distance of about 3 feet away from the riser.

There are a wide variety of EMF levels and sources encountered in everyday life that are comparable to EMF due to electric power facilities.

In addition to measuring and calculating magnetic fields for electrical facilities associated with the proposed project, magnetic field measurements of everyday environments were performed at ten different locations in Honolulu. These measurements were performed to provide a range of magnetic field levels encountered in everyday locations and for comparison with the magnetic field levels associated with the proposed East Oahu Transmission Project. Measured magnetic fields ranged from 0.1 mG to over 99 mG in everyday environments. Many of these magnetic field sources are common appliances and electrical devices, such as refrigeration units in supermarkets, electric stoves in food preparation areas, library security gates, escalators, vending machines, display counters, video games, cash registers, and ATM machines.

There are no Federal or State of Hawaii health standards for 60 Hertz magnetic fields.

Over the past two decades, there has been research investigating exposure to EMF. Although there are no Federal health standards in the United States specifically for 60 Hertz magnetic fields, two organizations have developed guidelines or limits: the International Commission on Non-Ionizing Radiation Protection and the American Conference of Governmental Industrial Hygienists. The measured and projected magnetic field levels associated with the proposed East Oahu Transmission Project are far below these guidelines or limits.

There are at least two states that have adopted "status quo" engineering standards for magnetic fields. The purpose of most of these standards is to make the field levels from new power lines similar to the field levels from existing overhead transmission lines. The measured and projected magnetic field levels associated with the proposed East Oahu Transmission Project are well below these other state standards.

INTRODUCTION

Hawaiian Electric Company (HECO) has proposed the construction of a new power line[1] project, entitled the East Oahu Transmission Project. This project involves the installation of several new underground 46 kV power lines and transformers. This proposed action would allow HECO to transfer electrical loads between substations serving high-demand areas of the island, addressing existing and future transmission problems. As a result of this proposed installation, some existing electrical facilities (such as 12 kV, 25 kV and 46 kV underground and overhead power lines) along portions of the project and beyond may be eliminated, remain unchanged, or may increase or decrease their loading.

HECO retained Enertech Consultants to evaluate the magnetic field levels associated with this proposed project. This evaluation included magnetic field measurements along selected segments of the proposed project line, magnetic field calculations for these segments for both existing and proposed power line configurations, assessment of existing HECO facilities, identification of nearby environments to the proposed project, and magnetic field measurements in common, everyday locations around the Honolulu project area. The results of this evaluation are presented within this report.

PROJECT DESCRIPTION

The East Oahu Transmission Project is comprised of two independent phases of work. The first phase, "Phase 1", involves the installation of 0.5 miles of underground duct line for 46kV subtransmission lines, and related work at eight substations, in order to interconnect three 46kV circuits out of the Pukele Substation, at the end of HECO's Northern 138kV transmission corridor, to four 46kV lines connected to HECO's Southern 138kV transmission corridor. Phase 1 includes: (1) the installation of six underground 46kV lines in the Ala Moana, McCully, Moiliili, and Kapahulu areas, (2) a 138kV/46kV transformer installation at the existing Kamoku Substation with associated protective relaying, (3) a 46kV/12kV transformer installation at the existing Makaloa Substation with associated switchgear, (4) various switching and reconnections on the existing 46kV and 12kV systems near Makaloa and McCully Substations, (5) removal of existing 46kV and 12kV cables between Makaloa and McCully Substations, (6) removal of an existing 46/12kV transformer and associated switchgear from McCully Substation, and (7) modifications of various existing distribution substations in the Honolulu area.

The second phase, "Phase 2", involves the installation of 1.9 miles of underground duct line for 46kV subtransmission lines, and related work at one substation, in order to interconnect four out of the five remaining 46kV circuits out of the Pukele Substation to three other 46kV lines connected to HECO's Southern 138kV transmission corridor. Phase 2 includes: (1) the

[1] The term "power lines" is used generically to describe transmission, subtransmission and distribution lines.

installation of three underground 46kV lines in the Kakaako, Makiki, and McCully areas, and (2) a 138kV/46kV transformer installation at the existing Archer Substation with associated protective relaying.

Phase 1 is proposed for construction beginning in 2006 and is expected to require 12 months to complete, while Phase 2 construction is proposed for 2008 – 2009 and is expected to require 15 months to complete. Eleven different segments along portions of the proposed power line project were selected by HECO to represent the various changes which would result from construction of the project. These locations, identified as segments 'A' thru 'K', designate the following locations and proposed electrical modifications:

Phase 1:

- Segment 'A' – Makaloa Street between Kaheka and Poni Streets: Three existing 46 kV underground power lines would be replaced with two 46 kV power lines (one power line in a new duct), while three existing 12 kV underground power lines would remain.
- Segment 'B' – Fern Street between Punahou and Hauoli Streets: Three existing 46 kV underground subtransmission lines and three 12 kV underground power lines would be replaced with two 46 kV underground power lines within the existing duct, while an existing 12 kV overhead distribution line would remain.
- Segment 'C' – Pumehana Street between Lime and Date Streets: One new 46 kV underground power line would be installed in new duct, while an existing 46 kV overhead and an existing 12 kV overhead power line would remain.
- Segment 'D' – Date Street west of Kamoku Substation: One new 46 kV underground intertie would cross Date Street (from the substation to an existing pole that will be replaced with a thicker pole) and feed an existing 46 kV overhead power line, while one existing 138 kV and two existing 25 kV underground power lines would remain and one existing 12 kV overhead power line would also remain.
- Segment 'E' - Date Street east of Kamoku Substation: One new 46 kV underground intertie would cross and then travel down Date Street (from the substation to an existing pole) and feed an existing 46 kV overhead power line, a segment of the existing 46 kV power line between segments 'D' and 'E' would be removed, and an existing 12 kV overhead power line would remain.
- Segment 'F' – Winam Avenue between Hoolulu and Mooheau Streets: A new 46 kV underground power line in a new duct would connect two existing 46 kV overhead power lines, while an existing 12 kV overhead power line would remain.
- Segment 'G' – Date Street between Pumehana and McCully Streets: An existing 46 kV overhead power line would have increased loading and an existing 12 kV underbuild power line would remain.
- Segment 'H' – Kapiolani Boulevard between Wiliwili and McCully Streets: An existing 46 kV overhead power line would have increased loading, an existing 12 kV underbuild power line would remain, and one existing 138 kV underground power line and two existing 25 kV underground power lines would also remain.

- Segment 'J' – Kapiolani Boulevard between Clayton Street and Ward Avenue: Three existing 46 kV underground power lines would have increased loading and two existing 138 kV underground power lines would remain.
- Segment 'K' – Sheridan Street between Kapiolani Boulevard and Makaloa Street: Three existing 46 kV underground power lines would have increased loading and one existing 12 kV overhead power line would remain.

Phase 2:

- Segment 'I' – King Street between Ward Avenue and Victoria Street: Three new 46 kV underground circuits would be installed in a new duct.

Maps of the various project segments (identified by its respective letter) are presented in Appendix A. A detailed diagram of each segment, showing the existing and proposed electrical facilities at each segment, is also included in Appendix A. The descriptions of Segments 'A','B' and 'C' incorporate two changes in Phase 1 of the project now planned by HECO. Appendix G presents the criteria for HECO's selection of these segments for analysis.

UNITS OF MEASURE

Magnetic field (B) is commonly reported using units of gauss (G). However, it is usually more convenient to report magnetic field using a smaller unit, the milligauss (mG) that is equal to one-thousandth of a gauss (i.e., 1 mG = 0.001 G).

Some technical reports also use units of Tesla (T) or microTesla (μT), where 1 μT = 0.000001 T. The conversion between the magnetic field units is 1 mG = 0.1 μT and 1 μT = 10 mG. Although the term EMF includes both the electric and magnetic field, it is common for EMF to denote only the magnetic field.

DESCRIPTION OF MAGNETIC FIELDS

An electric current flowing in a conductor (e.g. electric equipment, household appliance, power circuits, etc.) creates a magnetic field. The most commonly used magnetic field intensity unit of measure is the milligauss (mG). As a general reference, the earth has a natural static or direct current (DC) magnetic field of about 360 mG in Honolulu (Merrill 1983).

As with electric fields, the magnetic fields from electric power facilities and appliances differ from static (or DC) fields because they are caused by the flow of 60 Hz alternating currents. Power frequency magnetic fields also reverse direction at a rate of 60 cycles per second, corresponding to the 60 Hz operating frequency of the power systems in the United States. The magnetic field is stronger near an electric current source and decreases with distance away from the source.

Since the magnetic field is caused by the flow of an electric current, a device must be operated to create a magnetic field. The Illinois Institute of Technology Research (IITRI) measured magnetic field strengths of a large number of common household appliances for the U.S. Navy (Gauger 1985). Appliance measurements were also conducted by Enertech Consultants for the Electric Power Research Institute or EPRI (Silva 1989). Typical magnetic field values for some appliances are presented in Table 1 to facilitate a better understanding of magnetic field strength values.

Table 1. Magnetic Fields From Household Appliances

	Magnetic Field (mG)	
Appliance	**12" Away**	**Maximum**
Electric Range	3 to 30	100 to 1,200
Electric Oven	2 to 25	10 to 50
Garbage Disposal	10 to 20	850 to 1,280
Refrigerator	0.3 to 3	4 to 15
Clothes Washer	2 to 30	10 to 400
Clothes Dryer	1 to 3	3 to 80
Coffee Maker	0.8 to 1	15 to 250
Toaster	0.6 to 8	70 to 150
Crock Pot	0.8 to 1	15 to 80
Iron	1 to 3	90 to 300
Can Opener	5 to 250	10,000 to 20,000
Mixer	6 to 100	500 to 7,000
Blender, Popper, Processor	6 to 20	250 to 1,050
Vacuum Cleaner	20 to 200	2,000 to 8,000
Portable Heater	1 to 40	100 to 1,100
Fans/Blowers	0.4 to 40	20 to 300
Hair Dryer	1 to 70	60 to 20,000
Electric Shaver	1 to 100	150 to 15,000
Color TV	9 to 20	150 to 500
Fluorescent Fixture	2 to 40	140 to 2,000
Fluorescent Desk	6 to 20	400 to 3,500
Circular Saws	10 to 250	2,000 to 10,000
Electric Drill	25 to 35	4,000 to 8,000

(Gauger 1985 and Silva 1989)

There are many sources of magnetic fields encountered in everyday activities. These everyday sources have variable temporal and spatial characteristics. A major research project has been undertaken to estimate exposure to ambient 60 Hz magnetic fields. This comprehensive study of contemporary magnetic field exposure was performed for the U.S. Department of Energy (Enertech 1998). The objective of this work was to characterize personal magnetic field exposure of the general population. This was accomplished by randomly selecting over 1,000 people throughout the United States and recruiting these people to wear a recording magnetic field meter during a typical 24-hour period, including all activity inside and away from the place of residence (Silva 1999). The study population was selected in a manner to be representative of the general population. The measurement population (both genders) included about 874 adults and 138 children. Some key findings of this unique study included:

- The national average 24-hour exposure: 1.25 mG.
- About 14.3% of the U.S. population is exposed to a 24-hour Avg. exceeding 2 mG.
- About 25% of the U.S. population spend more than one hour in fields > 4 mG.
- About 9% of the U.S. population spend more than one hour in fields > 8 mG.
- About 1.6% of U.S. population experience 1,000 mG (or higher) during a 24-hour period.

Table 2 summarizes the results of "The 1,000 Person Study" (based on a population of 267 million).

Table 2. U.S. Population with Average Field Exposure Exceeding Given Level

		Average	
24-Hr Field	**EST. PORTION**	**95% Confidence Interval**	**POPULATION RANGE**
> 0.5 mG	76.3%	73.8 % - 78.9 %	197 - 211 million
> 1 mG	43.6%	40.9 % - 46.5 %	109 - 124 million
> 2 mG	14.3%	11.8 % - 17.3 %	31.5 - 46.2 million
> 3 mG	6.3%	4.7 % - 8.5 %	12.5 - 22.7 million
> 4 mG	3.6%	2.5 % - 5.2 %	6.7 - 13.9 million
> 5 mG	2.42%	1.65 % - 3.55 %	4.4 - 9.5 million
> 7.5 mG	0.58%	0.29 % - 1.16 %	0.77 - 3.1 million
> 10 mG	0.46%	0.20 % - 1.05 %	0.53 - 2.8 million
> 15 mG	0.17%	0.035 % - 0.83 %	90 thousand - 2.2 million

(Enertech 1998)

MEASUREMENT EQUIPMENT

An EMDEX II Magnetic Field Digital Exposure Meter was used to record power-frequency (60 Hertz) magnetic field levels of the overhead and underground power lines and substation electrical equipment. The EMDEX II is a computer-controlled, three-axis, AC exposure meter. Each of the three-axis sensors measures the magnetic field and the on-board computer calculates a resultant field value (the resultant is comparable to a maximum field value and is calculated as the square root of the sum of the squares for all three orthogonal axes (B_r=SQRT[B_x^2 + B_y^2 + B_z^2]). The data are stored in the computer's memory and downloaded to a personal computer for analysis following the measurement session. In addition, an LCD digital display on the EMDEX II allows the user to see the magnetic field data, as they are stored in the computer's memory. The EMDEX II meter has a range of 0.1 milliGauss (mG) up to 3,000 mG (3 Gauss). The EMDEX II recorded the magnetic field at a sample rate of once every 1.5 seconds. The accuracy of the EMDEX II meters is $\pm$ 2%.
The EMDEX II meter was used in conjunction with a LINear DAta (LINDA) distance measurement wheel to record magnetic field levels as a function of distance. The EMDEX II simultaneously recorded magnetic field and distance data to evaluate field levels across each study segment as lateral profile measurements. Figure 1 presents a photograph of magnetic field measurements being conducted.

An EMDEX SNAP Magnetic Field Meter was used to make general magnetic field survey measurements. The EMDEX SNAP is a computer-controlled, three-axis, AC field meter. An LCD digital display on the meter shows the resultant magnetic field measurement every 0.5 seconds. The EMDEX SNAP meter has a measurement range from 0.1 mG to 1,000 mG (1 Gauss). Typical accuracy of the EMDEX SNAP meter is $\pm$2%.

INSTRUMENTATION CALIBRATION

All magnetic field instruments were calibrated using a 91-centimeter (cm) diameter Helmholtz coil in the Enertech research laboratory. Vertical magnetic fields are generated with magnitudes ranging from 0.5 mG to 1,000 mG and with absolute accuracy of $\pm$2 percent above 10 mG and $\pm$15 percent at 1 mG. Meters were calibrated in accordance with 1994 IEEE/ANSI Standards (IEEE 1994).

MAGNETIC FIELD MEASUREMENTS AT SELECTED PROJECT LOCATIONS

For the proposed East Oahu Transmission Project, eleven different segments along portions of the proposed project were selected to represent the various types of changes which would result from construction of the project. Magnetic field measurements were conducted at each of these locations to characterize existing field strengths due to existing electrical facilities. Measurements were conducted as lateral profile measurements across each location during May 17 – 21, 2004. Appendix B presents graphs of the measured magnetic field as a function of distance for each segment location. Included in Appendix B is a table of the distribution loads for power lines at the time field measurements were performed as recorded by HECO.

Existing magnetic field levels range from a few tenths of a mG to over 25 mG, depending upon location. Existing electric facilities surveyed included overhead and underground 12 kV distribution lines, underground 25 kV distribution lines, overhead and underground 46 kV subtransmission lines, and underground 138 kV transmission lines. For streets and sidewalks where no overhead or underground power lines were immediately present, measured magnetic field levels ranged from a few tenths of a mG to about 2 mG. Sidewalk locations with overhead power lines were measured and typically ranged from about 1 mG to about 5.5 mG. Street and sidewalk locations with underground powerlines typically ranged from about 1 mG to a maximum of over 25 mG directly above the underground power line in the street.

Figure 1. Magnetic Field Measurements Being Conducted on the Sidewalk at King Street

MAGNETIC FIELD CALCULATIONS AT SELECTED PROJECT LOCATIONS

In addition to field measurements, magnetic field calculations were also performed for each of the selected project segments. Transmission line computer models were developed using the software program "ENVIRO", which is a module within EPRI's EMFWorkstation program. ENVIRO models the magnetic fields in and around transmission and distribution lines. The ENVIRO software allows the user to enter transmission line configuration information and other parameters into the program and then calculates lateral profiles for power-frequency magnetic fields at designated locations. Results obtained with computer models have been compared with measurement data for operating power lines and calculation accuracy has been evaluated. Typically, the computer model will calculate field values to within ±5% of actual field measurements.

HECO provided existing power line geometry and loading information as described in Appendix G. Circuit routing for the existing and proposed underground lines were provided as HECO plan and profile drawings. Overhead line geometry was collected in the field and confirmed with HECO standard power line drawings. Magnetic field calculations were performed for the existing power line configuration (if the proposed project were not constructed), as well as for the proposed power line configuration. For the existing power line configuration, calculations were performed using a forecasted 2009 normal loading condition. For the proposed project power line configuration, calculations were performed using two forecasted 2009 loading conditions: normal and Pukele outage condition. As defined by HECO in Appendix G, "normal load" means the power line loads at the time of the forecasted system peak load with the HECO transmission system under normal, all lines in-service, state. "Pukele outage condition" means the power line loads at the time of the forecasted system peak load with the Pukele Substation out of service. Details for determining the loading values for power lines within each segment are presented by HECO in Appendix G. Calculations were performed for each line configuration and load condition at a calculation height of 1 meter above ground level (3.28 feet), in accordance with IEEE Standards (IEEE 1994). Calculations were performed assuming that both Phase 1 and Phase 2 of the proposed project are implemented, and that Change #1 and Change #2 are implemented.

The difference in projected magnetic field levels between the existing and proposed power line configurations under forecasted 2009 normal loading can decrease slightly, remain unchanged, or increase depending upon the project segment. Figures 2 through 12 present the calculated magnetic field results for each segment under normal loading conditions for both the existing and proposed power line configurations. For Segment 'C' (on Pumehana Street near Lunalilo School where a new underground 46 kV circuit is proposed), the range of projected magnetic field levels decreases slightly on one side of the street while increasing on the opposite side of the street. Near the school, the projected magnetic field from the existing overhead power lines decrease slightly with the presence of the proposed underground power line (across the street), due to magnetic field cancellation. However, across the street from the school (where the proposed underground power line is located), the projected magnetic field level increases. For Segment 'E' (east of Kamoku

Substation where modifications to an existing overhead 46 kV circuit are proposed), the range of projected magnetic field levels decreases slightly with the proposed power line configuration since the 2009 forecasted load is somewhat lower for the proposed configuration than for the existing configuration. For Segment 'I' (on King Street, where no power lines presently exist), the projected magnetic field remains unchanged since the proposed underground 46 kV circuits would only be utilized under Pukele outage conditions. At all other segment locations, the projected magnetic field increases due to the proposed power line configuration under 2009 forecasted loading conditions. While magnetic field increases typically occur within street locations, projected magnetic field levels can also increase at sidewalk locations. Under proposed 2009 Pukele outage conditions, the projected magnetic field increases at all segment locations. Appendix C presents graphs of the projected magnetic field as a function of distance for each segment location. Appendix C also contains a summary table of the projected 2009 loading values used for each of the power lines at each segment.

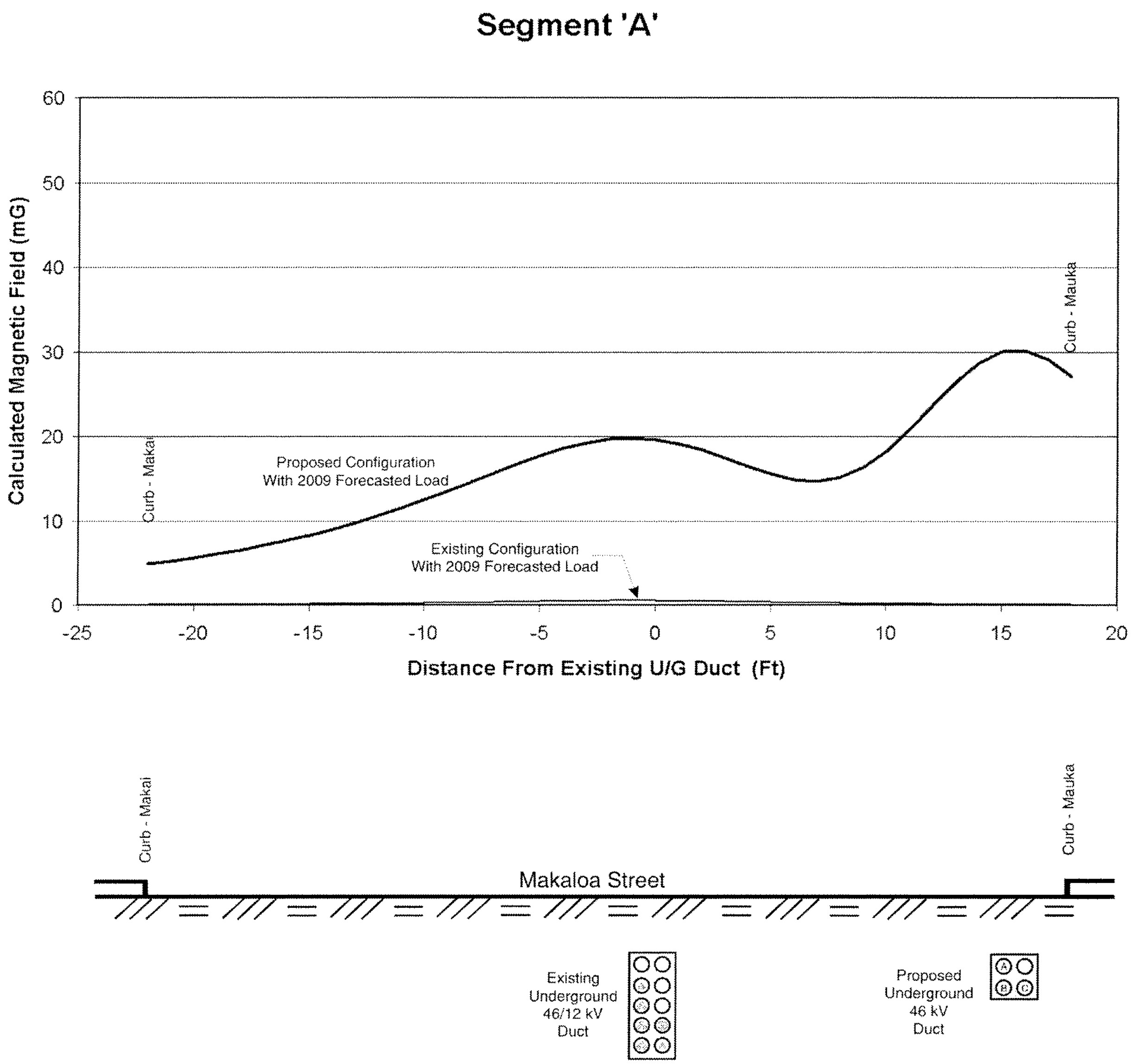

Figure 2. Projected Magnetic Field for Segment 'A' Under 2009 Forecasted Normal Loading (Makaloa Street between Kaheka and Poni Streets)

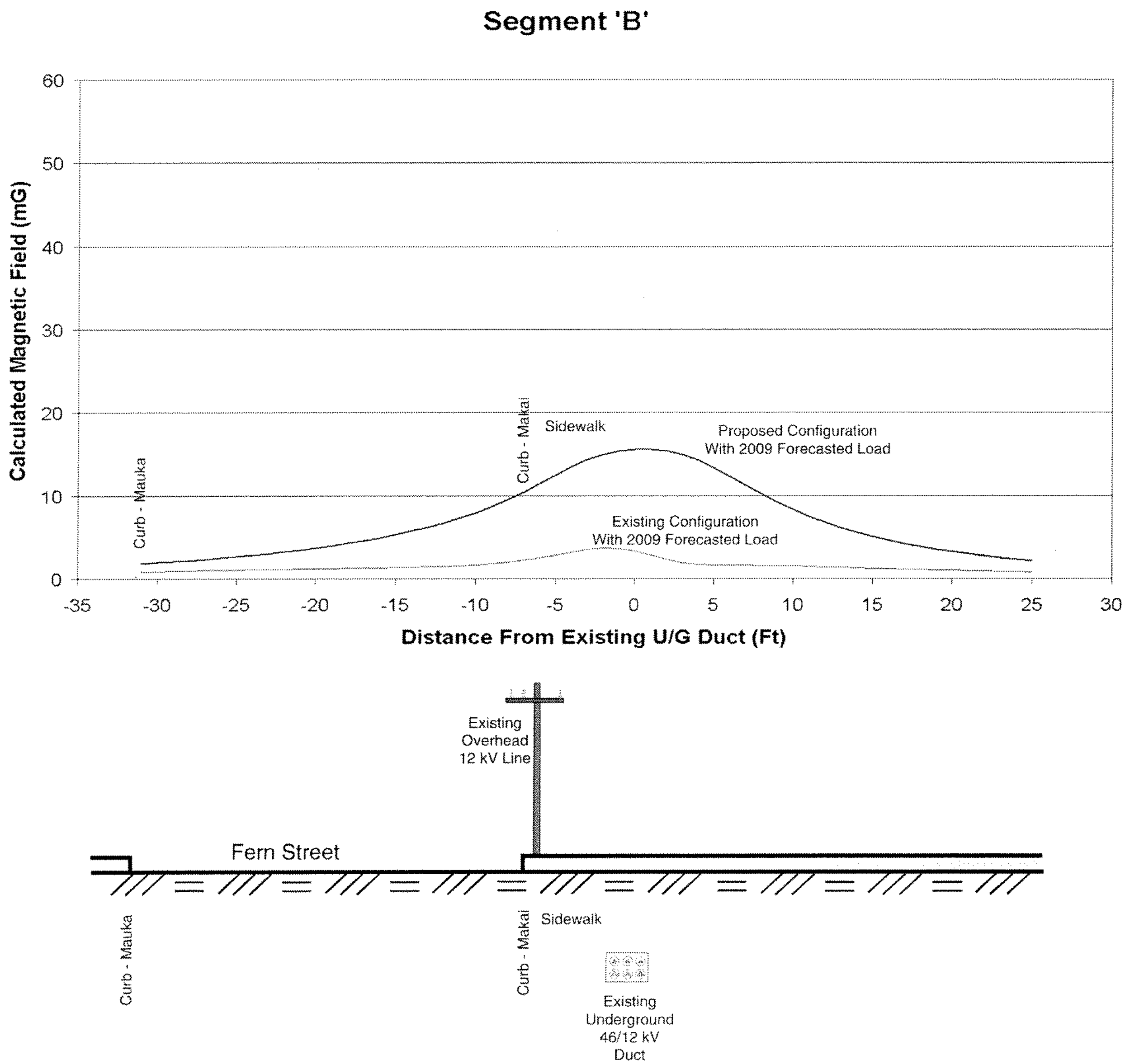

Figure 3. Projected Magnetic Field for Segment 'B' Under 2009 Forecasted Normal Loading (Fern Street between Punahou and Hauoli Streets)

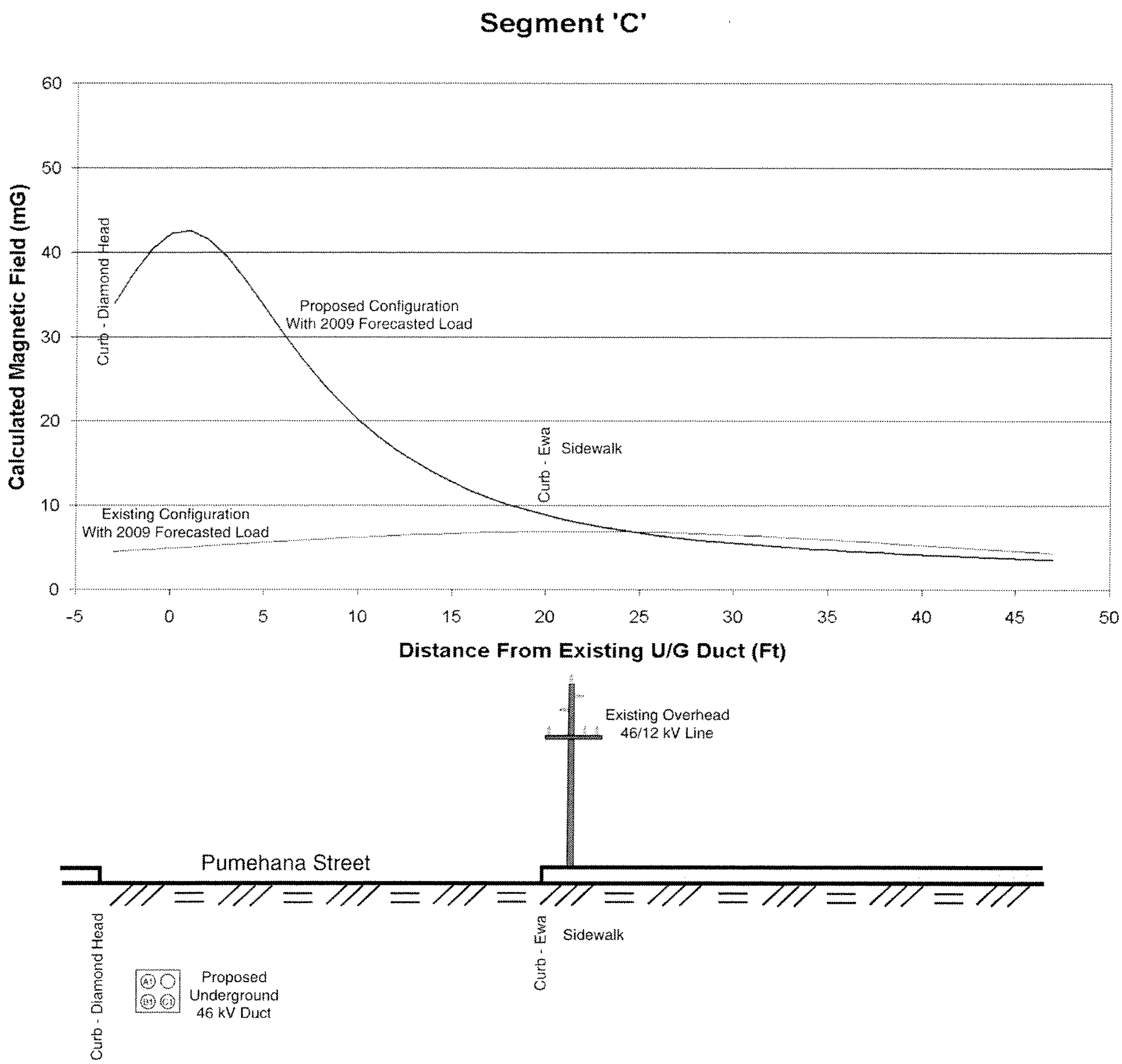

Figure 4. Projected Magnetic Field for Segment 'C' Under 2009 Forecasted Normal Loading (Pumehana Street between Lime and Date Streets)

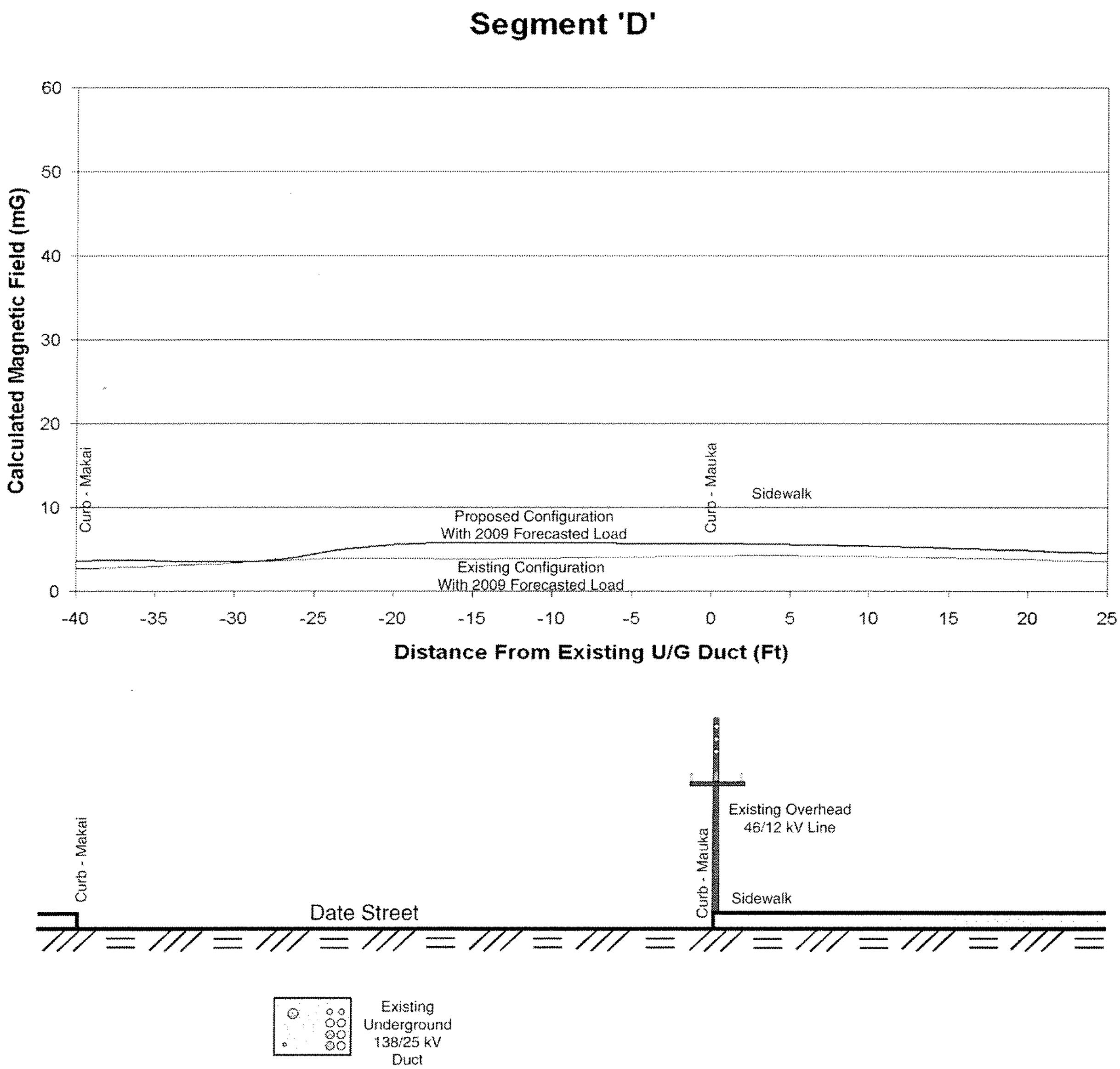

Figure 5. Projected Magnetic Field for Segment 'D' Under 2009 Forecasted Normal Loading (Date Street west of Kamoku Substation)

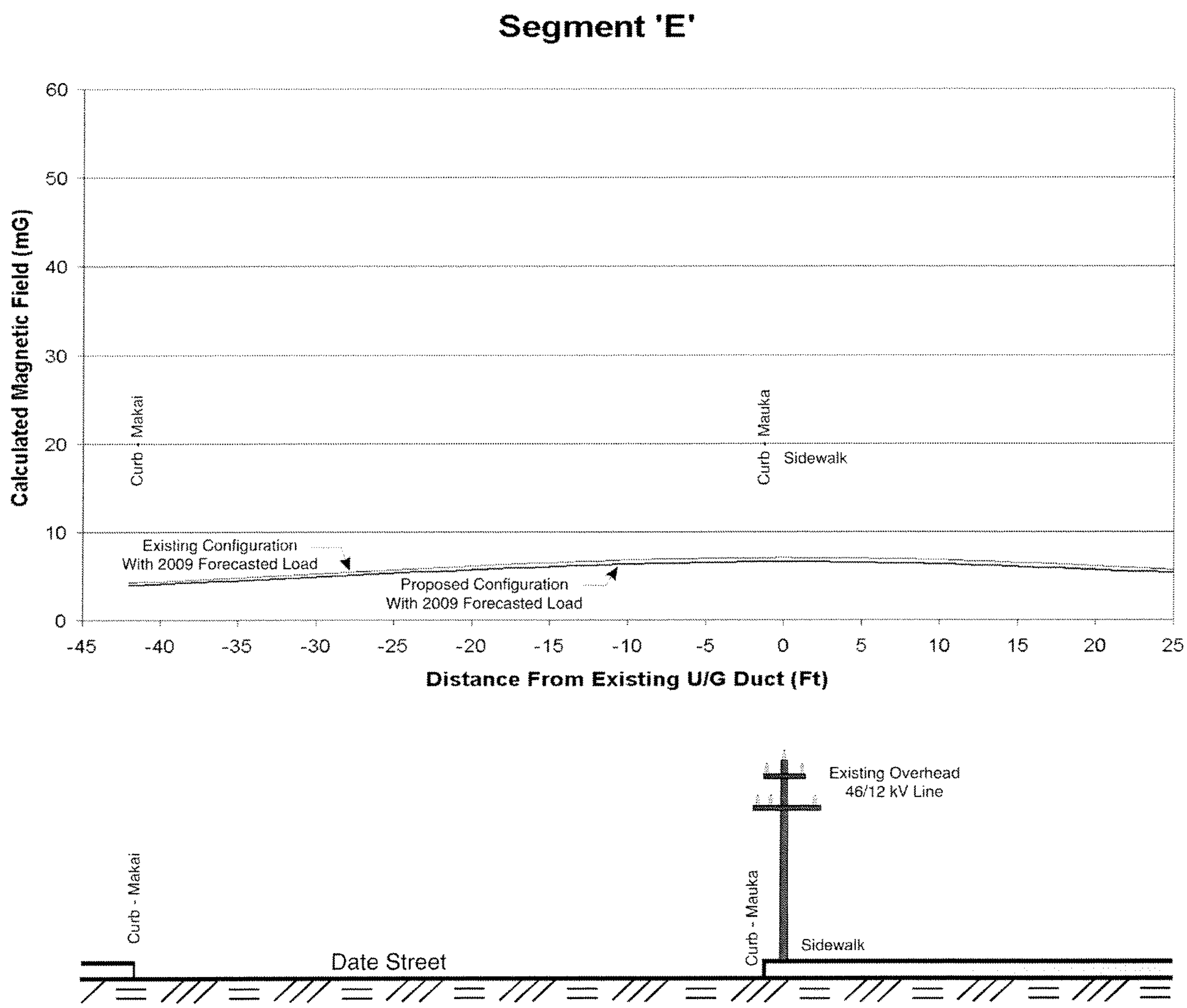

Figure 6. Projected Magnetic Field for Segment ‘E’ Under 2009 Forecasted Normal Loading (Date Street east of Kamoku Substation)

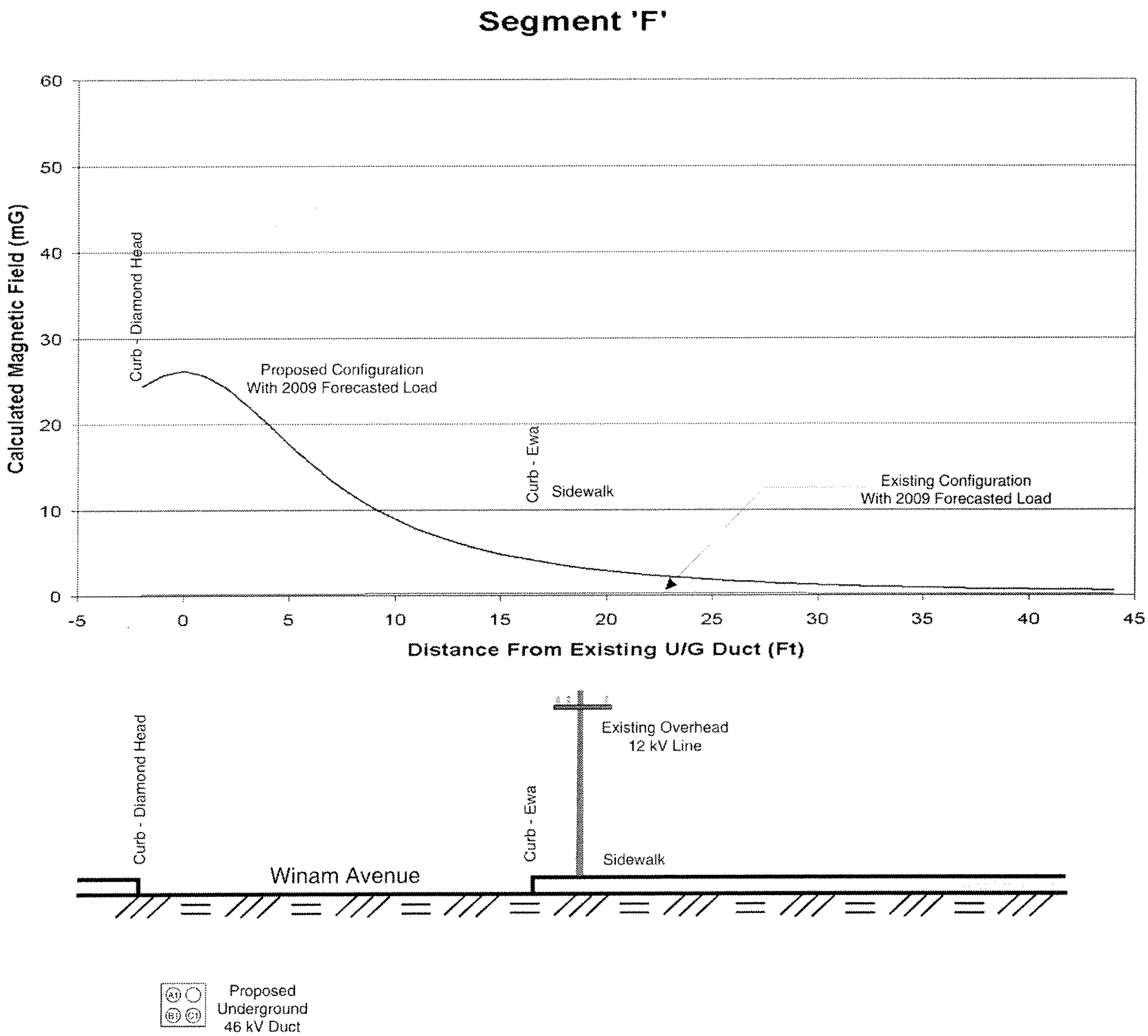

Figure 7. Projected Magnetic Field for Segment 'F' Under 2009 Forecasted Normal Loading (Winam Avenue between Hoolulu and Mooheau Streets)

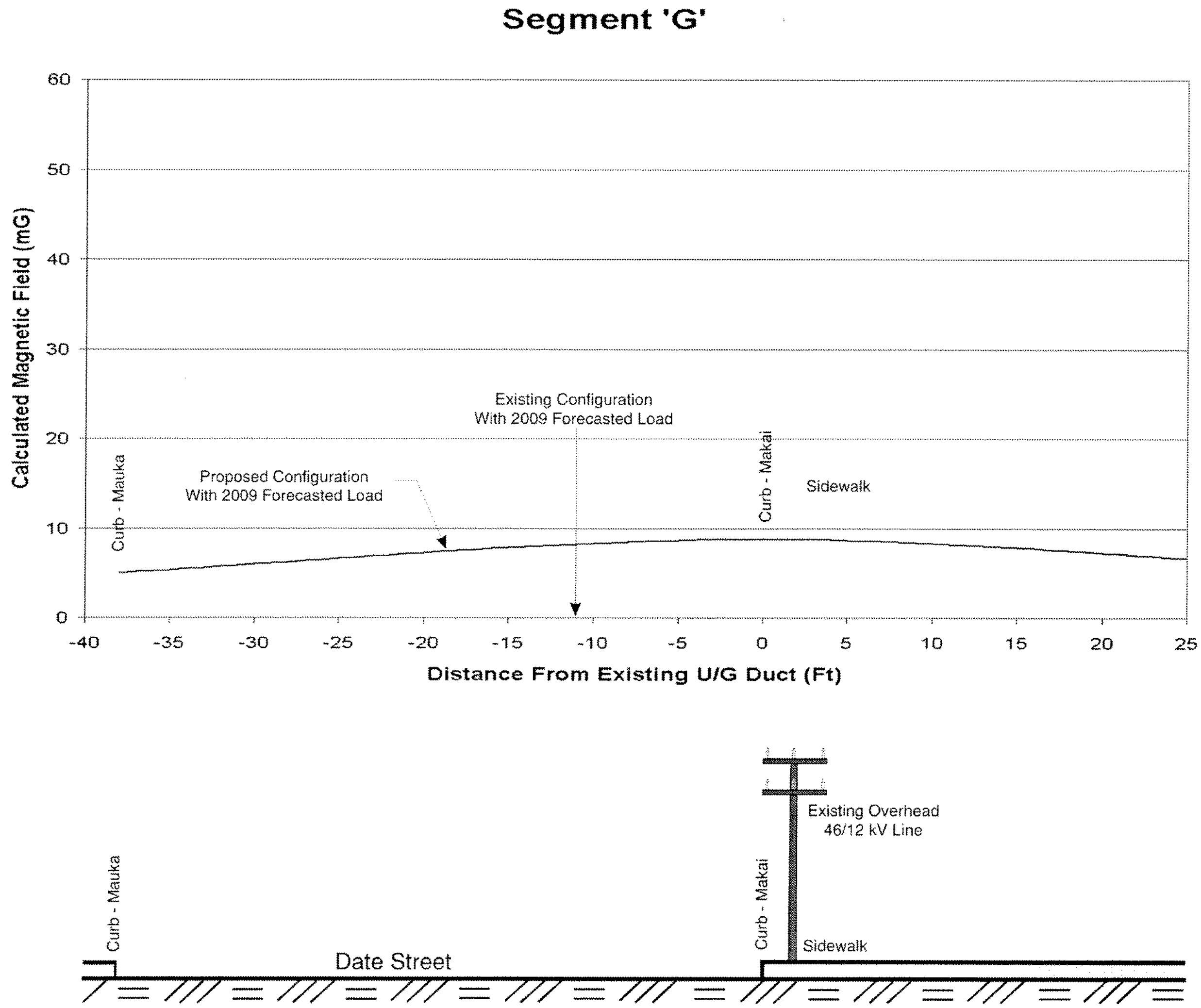

Figure 8. Projected Magnetic Field for Segment 'G' Under 2009 Forecasted Normal Loading (Date Street between Pumehana and McCully Streets)

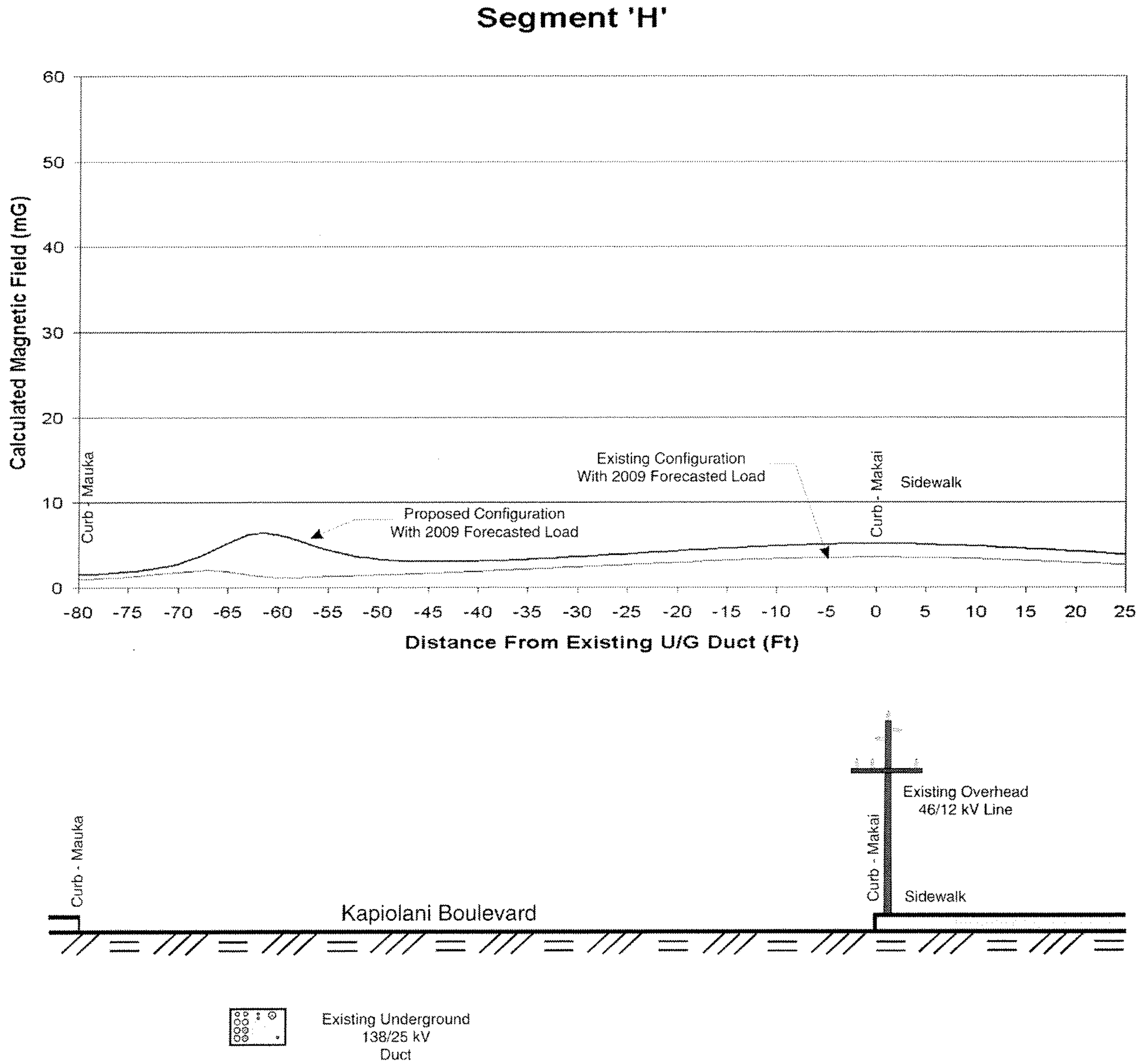

Figure 9. Projected Magnetic Field for Segment 'H' Under 2009 Forecasted Normal Loading (Kapiolani Boulevard between Wiliwili and McCully Streets)

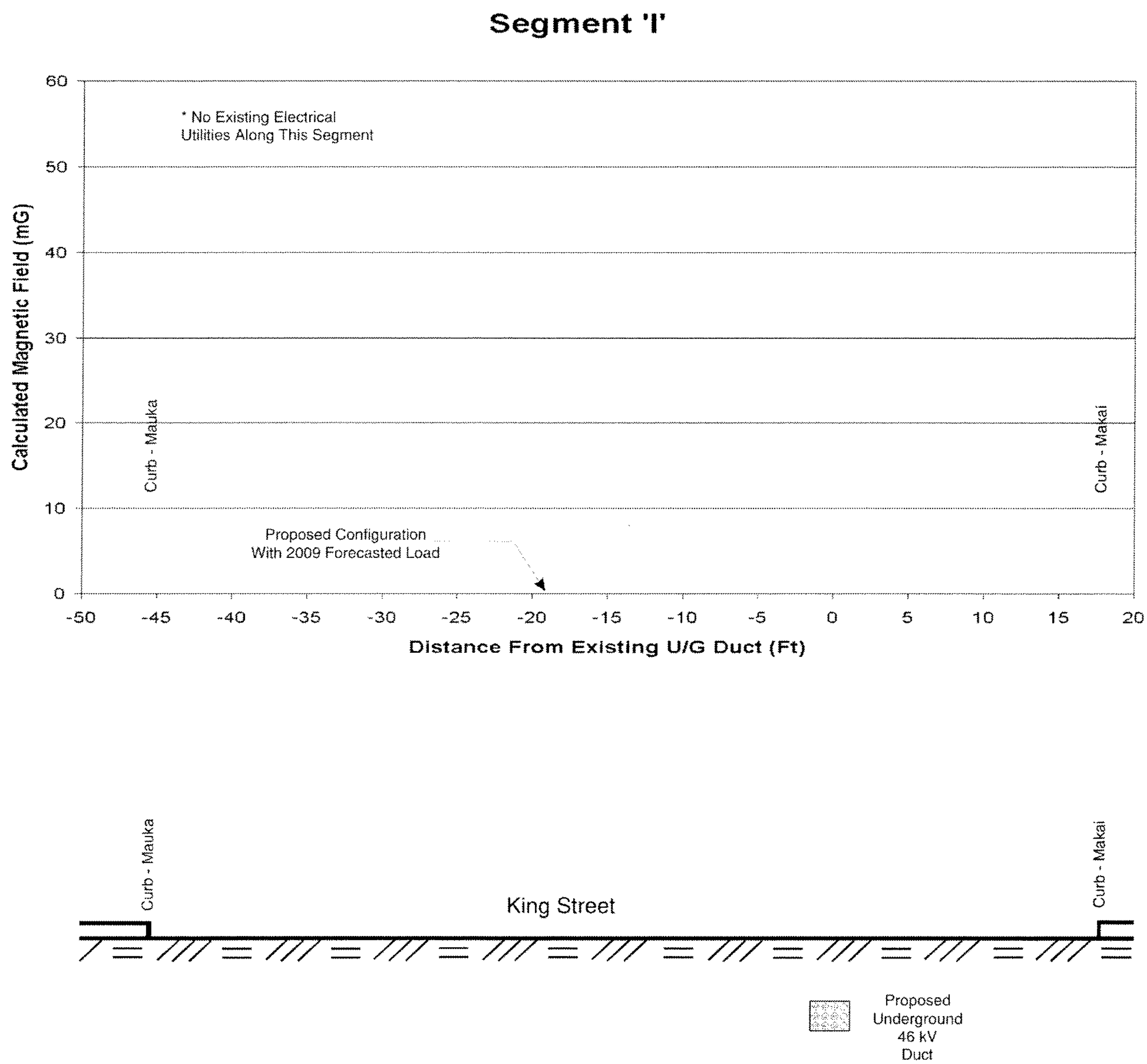

Figure 10. Projected Magnetic Field for Segment 'I' Under 2009 Forecasted Normal Loading (King Street between Ward Avenue and Victoria Street)

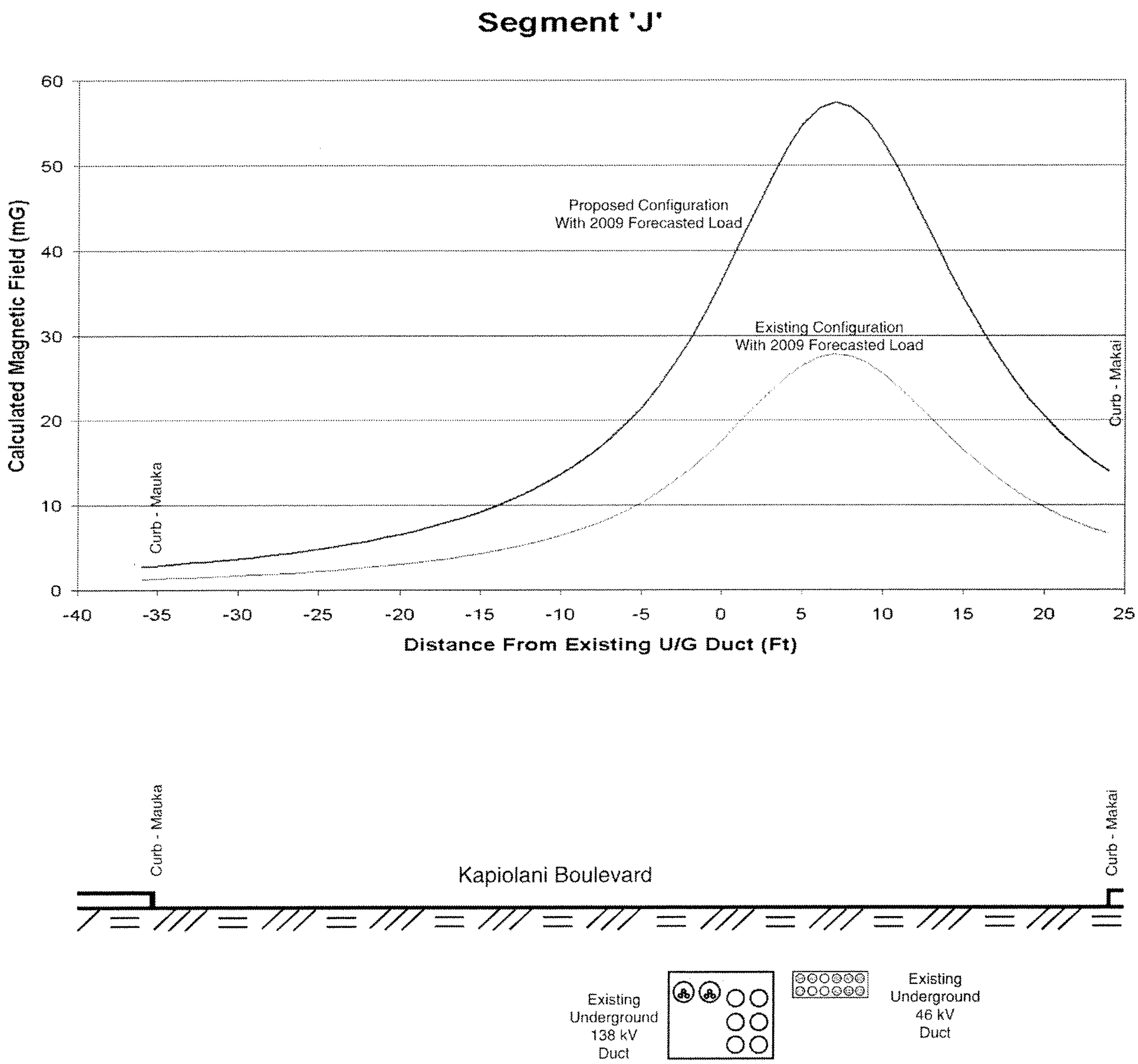

Figure 11. Projected Magnetic Field for Segment 'J' Under 2009 Forecasted Normal Loading (Kapiolani Boulevard between Clayton Street and Ward Avenue)

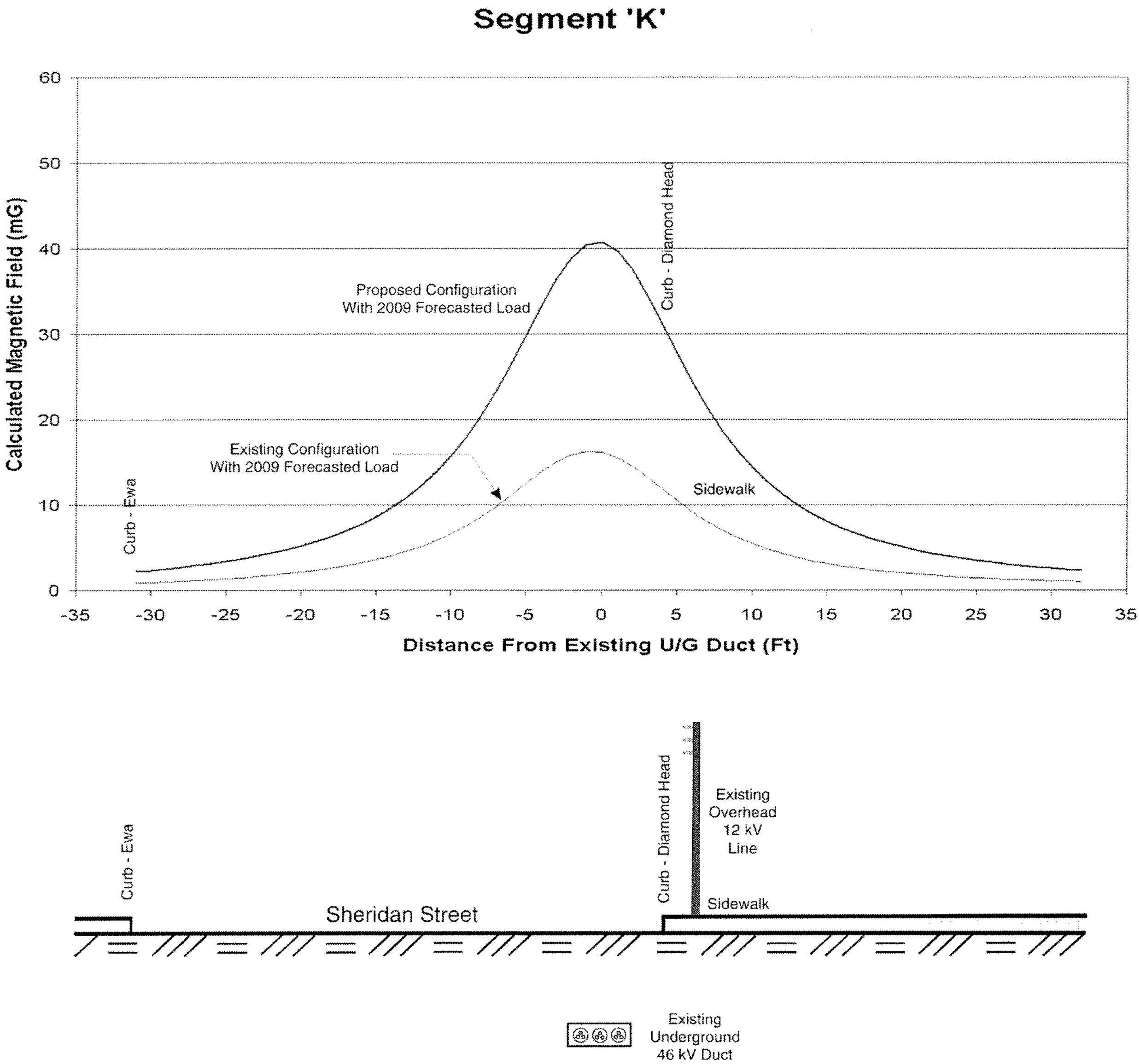

Figure 12. Projected Magnetic Field for Segment 'K' Under 2009 Forecasted Normal Loading (Sheridan Street between Kapiolani Boulevard and Makaloa Street)

For Segment 'J', HECO could not provide the phasing arrangement for two of the three 46 kV underground circuits (Archer #43 and #41). Therefore, computer calculations were performed for "day of measurement" loading to identify the phasing arrangement which most closely matches measured magnetic field levels directly above the 46 kV underground duct (as shown in Appendix B – Figure B-10). All thirty-six possible phasing combinations were modeled, and the phasing arrangement which most closely matched the measured magnetic field level above the underground 46 kV circuits was selected for subsequent field calculations (as presented in Appendix C). As shown in Appendix C, the projected magnetic fields for Segment 'J' at the northern and southern sidewalk curbs respectively are about 1.3 mG and 6.6 mG under existing normal load, 2.8 mG and 14.0 mG under forecasted normal load, and 3.4 mG and 17.5 mG under forecasted Pukele outage condition. If a phasing configuration that results in the highest magnetic field level is assumed (rather than the phasing that most closely matches the measured field level), then these projected magnetic field levels for Segment 'J' at the northern and southern sidewalk curbs respectively would increase to about 1.6 mG and 8.1 mG under existing normal load, 3.4 mG and 16.7 mG under forecasted normal load, and 4.1 mG and 20.2 mG under proposed Pukele outage condition. Appendix D presents the results of this phasing analysis.

COMPUTER MODELING ASSUMPTIONS

Projected magnetic field levels are based upon computer modeling of the line design for the existing and proposed HECO electrical equipment which simulate a real world environment. Enertech has assumed that both Phase 1 and Phase 2 of the East Oahu Transmission Project will be implemented.

While computer modeling is very accurate in calculating magnetic field levels, the computer model contains certain assumptions. For example, the computer model assumes balanced three-phase currents on all of the underground and overhead transmission and distribution circuits. However, there may be some load unbalance or net current on a circuit. An unbalanced current (or net current) can create higher magnetic field levels than projected, and can attenuate much more slowly than magnetic fields from balanced sources. Ground currents can also exist, where electrical current can flow along metallic objects, such as underground steel conduits or pipes. Specific magnitudes for phase angles on a circuit are assumed to be exactly 120-degrees out of phase from each other, and are also assumed to be uniform across circuits. Many of these parameters can vary or are unknown (such as the presence of small load-carrying underground conductors), and therefore may not be included within the computer model. The methods used for the computer modeling are reasonable for a practical characterization of magnetic field levels.

HECO ELECTRICAL FACILITY CHARACTERIZATION

Another aspect of the proposed East Oahu Transmission Project is the installation of new transformers within certain substations, manholes in the streets, and risers on wooden poles at sidewalk locations. To characterize magnetic fields from these types of facilities, magnetic field measurements were conducted at similar existing facilities during May 17 – 21, 2004. Magnetic field measurements were conducted as a function of distance away from each of these types of facilities. Measurement data from these facilities were then normalized to characterize the attenuation rate of the magnetic field versus distance away from each of these facilities. Appendix E provides tables of the actual measurement data used to create these normalized attenuation profiles.

Figure 13 presents the average normalized magnetic field data versus distance graph for 46 kV transformers. Because other magnetic field sources (such as overhead and underground power lines, buswork, and other types of substation equipment) are typically present near substation transformers, it is difficult to characterize magnetic field attenuation strictly from the transformer itself. As shown in Figure 13, other nearby magnetic field sources can influence the actual field measurements and the resulting attenuation rate. The magnetic field from a substation transformer is reduced by over 90% at a distance of about 20 feet away from the transformer housing. Typically, magnetic fields from transformers are reduced to ambient levels at the perimeter of the substation (since transformers are usually centrally located within the substation). For this project, the closest property line is at least 30 feet away from any proposed substation transformer location.

Figure 14 presents the average normalized magnetic field versus distance graph for underground power line manholes. At manhole locations, power line circuit conductors are usually separated for installation or splices. Separating the conductors reduces magnetic field cancellation and creates elevated magnetic fields at these manhole locations. Again, other magnetic field sources (such as other nearby underground power lines) may be present near manhole locations, thereby complicating the characterization of magnetic field attenuation strictly from the manhole itself. As shown in Figure 14, the magnetic field from a manhole is reduced by almost 90% at a distance of about 20 feet away.

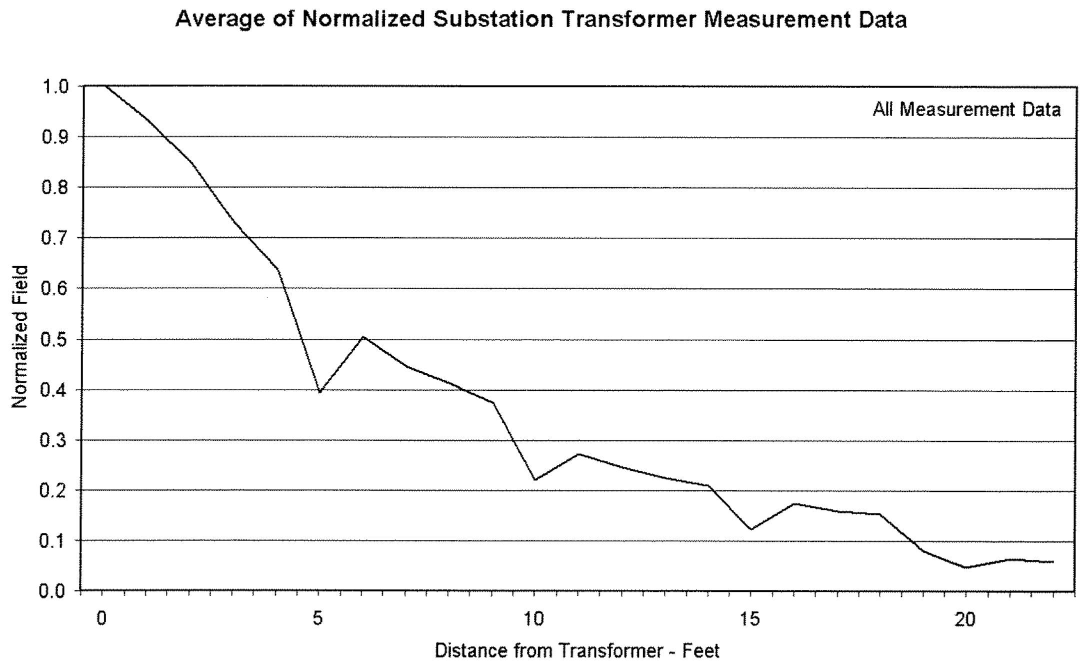

Figure 13. Average Normalized Magnetic Field Attenuation Rate for Substation Transformers

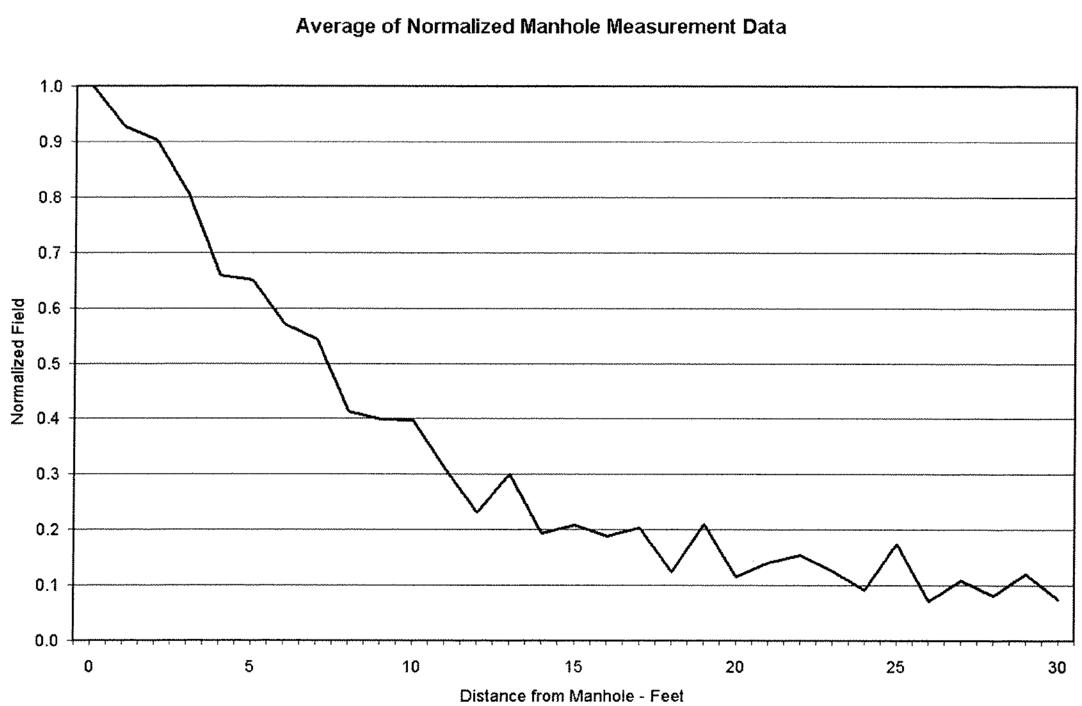

Figure 14. Average Normalized Magnetic Field Attenuation Rate for HECO Manholes

Figure 15 presents the average normalized magnetic field versus distance graph for risers (where overhead circuits transition to underground circuits) mounted to wooden support poles. Some risers are enclosed within steel pipes (which can provide some magnetic field shielding), while other risers are enclosed in plastic pipes (which do not provide any type of shielding). Again, other magnetic field sources (such as the overhead and underground portions of the power line) are present at riser pole locations, thereby complicating the characterization of magnetic field attenuation strictly from the riser itself. As shown in Figure 15, the magnetic field from an average normalized riser attenuates very quickly with distance away from the riser – the average normalized magnetic field is reduced by over 90% at a distance of about 3 feet away from the riser. This attenuation rate is much faster than for substation transformers and manholes, due to the close configuration of the circuit conductors.

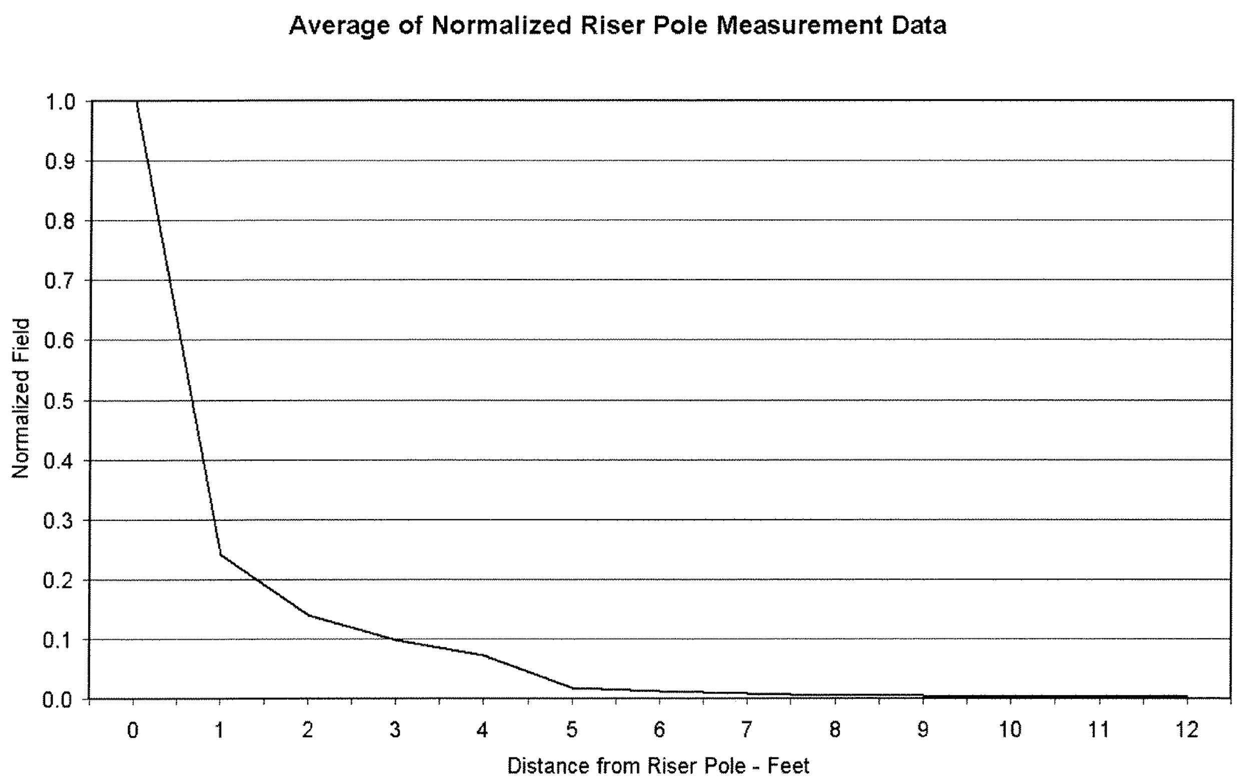

Figure 15. Average Normalized Magnetic Field Attenuation Rate for HECO Riser Poles

MAGNETIC FIELD MEASUREMENTS AT EVERYDAY ENVIRONMENTS IN HONOLULU

In addition to electrical facilities, magnetic field measurements of everyday environments were performed to provide a range of magnetic field levels encountered in everyday locations and for comparison with the magnetic field levels associated with the proposed East Oahu Transmission Project. Magnetic field measurements were conducted at selected locations within Honolulu on May 19 - 21, 2004. Eleven different areas were selected for measurements:

- Ala Moana Shopping Mall
- Daiei Department Store
- Ward Shopping Center
- McCully Shopping Center
- State Capitol Building
- McCully – Moiliili Public Library
- Straub Hospital
- Central Pacific Bank
- U.S. Post Office
- Jack-In-The-Box Restaurant

Tables 3 through 12 present summaries of the magnetic field measurements at these selected locations. Appendix F presents the magnetic field versus time graphs recorded at these locations. As shown in Tables 3 through 12, measured magnetic fields can typically range from 0.1 mG to over 99 mG in everyday environments. Many of these magnetic field sources are common appliances and electrical devices, such as refrigeration units in supermarkets, electric stoves in food preparation areas, library security gates, escalators, vending machines, display counters, video games, and ATM machines. In several cases, magnetic field levels were due to larger area sources which could not easily be identified.

Table 3. Summary of Magnetic Field Measurements at the Ala Moana Shopping Mall

Ala Moana Shopping Mall		
Location	**Measured Magnetic Field (mG)**	**Notes**
Overall Measurement Visit	0.1 - 76.5	Average Field = 3.7 mG
Food Court	0.3 - 18.1	Refrigeration Unit = 18.1 mG
Speed Gear Auto Store	0.8 - 20.5	
Jungle Fun Video Arcade	0.9 - 46.3	Arcade Games and Area Source
Just a Second Clock Kiosk	3.3 - 6.2	
Apple Computer Store	0.8 - 3.7	Computer Systems and Monitors
Shirokiya Department Store	0.3 - 23.3	Camera Display = 16 mG, Grill Area = 23 mG
Macy's Department Store	0.1 - 42.9	Godiva Chocolates Cart = 42.9 mG Make-Up Counter = 37.5 mG
Starbuck's Coffee Shop	0.3 - 22.7	Counter Area = 22 mG
Nieman Marcus Department Store	0.1 - 5.3	
Waldenbooks	0.9 - 20.9	Children's Section = 6.7 - 20.9 mG
Thinker Toy Store	0.5 - 7.3	Wood Train Play Area = 5 - 6 mG
Satellite City Hall	0.4 - 2.6	
Open Mall Area	0.2 - 76.5	Base of Escalator = 76.5 mG

Table 4. Summary of Magnetic Field Measurements at the Daiei Department Store

Location	Daiei Department Store Measured Magnetic Field (mG)	Notes
Overall Measurement Visit	0.1 - 42.3	Average Field = 2.2 mG
Florist Section	0.3 - 8.2	Refrigeration Unit = 8.2 mG
Produce Section	0.3 - 17.9	
Bakery Section	1.0 - 13.7	Refrigeration Unit = 13.7
Dairy Section	0.5 - 13.7	Refrigeration Unit = 13.7
Frozen Food Section	0.4 - 7.7	Refrigeration Units
Meat Counter	0.8 - 4.6	Freezer = 4.6 mG
Seafood Section	0.6 - 16.9	Freezer = 16.9 mG
Electronics Section	0.1 - 6.1	Soft Drink Machine = 6.1 mG
Greeting Card Section	0.1 - 2.0	
Key Making Area	0.3 - 7.0	Counter Area = 7.0 mG
Young Art Children's Store	0.5 - 3.7	
Newspaper Stand	0.5 - 14.0	ATM Machine = 14.0 mG
Party Supply Section	0.6 - 12.9	
Jewelry Department	0.2 - 18.9	Display Case = 18.9 mG
Blimpies Sandwich Stand	0.5 - 42.3	Counter Area = 42.3 mG
Cajun Grill Food Stand	0.5 - 4.7	
Sunkyu Bakery Stand	0.2 - 7.7	
Café Brew Coffee Stand	0.1 - 13.3	Counter Area = 13.3 mG

Table 5. Summary of Magnetic Field Measurements at the Ward Shopping Center

Ward Shopping Center		
Location	**Measured Magnetic Field (mG)**	**Notes**
Overall Measurement Visit	0.1 - 37.1	Average Field = 3.5 mG
Dave and Busters Recreation Center	0.1 - 15.8	Arcade Area = 0.2 - 15.8 mG
Executive Chef Kitchen Store	0.8 - 35.3	Cash Register Counter = 35.3 mG
Honolulu Cookie Company	1.3 - 3.8	Check Out Counter = 3.8 mG
Snakalicious Novelty Store	0.5 - 13.8	Display Case = 13.8 mG
Food Court Eating Area	0.9 - 26.3	
Old Spaghetti Factory Restaurant	1.0 - 10.0	Eating Area in Restaurant = 3.6 mG Average
Outside of Linea Clothing Store	0.2 - 37.1	
Outdoor Mall Areas	0.1 - 26.3	

Table 6. Summary of Magnetic Field Measurements at the McCully Shopping Center

McCully Shopping Center		
Location	**Measured Magnetic Field (mG)**	**Notes**
Overall Measurement Visit	0.3 - 11.9	Average Field = 1.7 mG
7-11 Convenience Store	0.7 - 11.9	Ice Machine = 11.9 mG
Aji Ichiban Candy Store	0.4 - 5.1	Cash Register = 5.1 mG
T-Mobile Cellular Telephone Store	0.5 - 1.5	Counter Area = 1.5 mG

Table 7. Summary of Magnetic Field Measurements at the State Capitol Building

State Capitol Building		
Location	**Measured Magnetic Field (mG)**	**Notes**
Overall Measurement Visit	0.1 - 20.7	Average Field = 1.0 mG
Third Floor Office	0.2 - 10.6	Aquarium = 10.6 mG
Third Floor Hallways	0.1 - 2.9	Electrical Panel = 2.9 mG
Second Floor Hallways	0.1 - 0.7	
Basement Hallways	0.2 - 20.7	Walking by Electrical Vault = 20.7

Table 8. Summary of Magnetic Field Measurements at the McCully – Moiliili Public Library

McCully - Moiliili Public Library		
Location	**Measured Magnetic Field (mG)**	**Notes**
Overall Measurement Visit	0.2 - 99.5	Average Field = 2.6 mG
Entering Library	0.4 - 99.5	Security Gate = 99.5 mG
Children's Section	1.0 - 16.9	Story Telling Area = 2.0 mG Study Area = 1.5 mG
Main Counter Area	0.5 - 11.8	
Adult Section Upstairs	0.3 - 6.1	Internet Computer Area = 0.7 mG Drinking Fountain = 6.1 mG
Computer Reference Area	0.9 - 7.3	Computer Terminals
Leaving Library	0.2 - 2.7	

Table 9. Summary of Magnetic Field Measurements at the Straub Hospital

Straub Hospital		
Location	**Measured Magnetic Field (mG)**	**Notes**
Overall Measurement Visit	0.2 - 16.5	Average Field = 1.7 mG
Hallways	0.2 - 9.5	Pediatric Waiting Area = 5.6 mG
Emergency Waiting Room	2.6 - 3.5	
Cafeteria	0.4 - 16.5	Salad Bar = 16.5 mG
Gift Shop	0.2 - 0.7	
Pharmacy Waiting Area	0.2 - 1.1	

Table 10. Summary of Magnetic Field Measurements at the Central Pacific Bank

Central Pacific Bank		
Location	**Measured Magnetic Field (mG)**	**Notes**
Overall Measurement Visit	0.4 - 8.8	Average Field = 3.2 mG
Reception Area	0.4 - 2.9	
Teller Counter	3.8 - 8.8	

Table 11. Summary of Magnetic Field Measurements at the U.S. Post Office

U.S. Post Office		
Location	**Measured Magnetic Field (mG)**	**Notes**
Overall Measurement Visit	0.1 - 2.4	Average Field = 0.4 mG
Waiting in Line	0.1 - 0.2	
Clerk Counter	0.5 - 1.2	
Stamp Vending Machines	0.2 - 2.4	Vending Machine = 2.4 mG

Table 12. Summary of Magnetic Field Measurements at the Jack-In-The-Box Restaurant

Jack-in-the-Box Restaurant		
Location	**Measured Magnetic Field (mG)**	**Notes**
Overall Measurement Visit	0.4 - 17.9	Average Field = 1.3 mG
Waiting at Counter	0.5 - 3.6	
Food Pick-Up Counter Area	17.9	
Seated at Eating Area	0.5 - 0.6	
Restroom Area	1.1 - 12.4	Hand Dryer = 12.4 mG

REVIEW OF SELECTED INSTITUTIONS NEAR PROPOSED PROJECT

Several institutions are located near portions of the proposed project. These institutions include day care centers, pre-schools and schools, hospitals, churches, and retirement homes. Distance measurements were taken to determine the closest building edge to the proposed project. Using these distance measurements, the projected magnetic field for 2009 loading conditions were evaluated for each of these institutions. Table 13 presents the results for this evaluation.

Six different institutions are located within 100-feet of the proposed project. Four of these institutions would have no projected magnetic field under normal operating conditions, since the underground power lines along this segment will be only loaded during Pukele outage conditions (and even then the projected field at the closest building edge is less than 1 mG).

The institution closest to the project is the Kaplan Test Preparation Center, which is located on the fifth floor of a multi-story downtown office building. Projected 2009 magnetic field levels (at an elevation of 50 feet above ground level + 1 meter height) of 0.0 mG with the existing power line configuration would increase to about 1.1 mG with the proposed configuration under normal loading at the closest building edge. Under projected 2009 Pukele outage conditions, the projected magnetic field on the fifth floor level of the closest building edge is 1.6 mG. Projected field levels farther into the building would continue to decrease with distance away from the project.

The Lunalilo Elementary School has one corner of the school property near one portion of the proposed project (Segment 'C') and also has another side of the school property near another portion of the proposed project (Segment 'B'); so it appears twice in the table listing. As shown in Table 13, the closest edge of the school building along Segment 'C' has a maximum projected magnetic field of 4 mG under normal loading conditions in 2009 if the project is not implemented. If the proposed project is implemented, the projected magnetic field at the closest edge of Lunalilo Elementary School building to Segment 'C' will be 3.3 mG under normal loading conditions and 2.8 mG under Pukele outage conditions. This demonstrates that the proposed underground circuit would cancel some existing magnetic field from the existing overhead power lines, resulting in some lower magnetic fields at Lunalilo Elementary School if the project is implemented. In 2009, the projected magnetic field at the closest edge of the Lunalilo Elementary School building to Segment 'B' is about 0.3 mG or less whether or not the project is implemented. Projected field levels farther into the school building would continue to decrease with distance away from the project.

There are five additional institutions located within 200-feet of the proposed project. Of these, three institutions would have no projected magnetic field under normal operating conditions (since the underground power lines are only loaded during Pukele outage conditions) and have negligible projected field influence under Pukele outage conditions (0.1 mG). The two other institutions within 200-feet of the proposed project have projected magnetic fields of about 0.6 or less, even under Pukele outage conditions.

Four more institutions are located within 300-feet of the proposed project. However, at these distances, the projected magnetic field influence from the proposed project is less than 0.1 mG.

Table 13. Summary of Selected Institutions Near Proposed Project and Projected Magnetic Field in 2009

Public Institution	Address	Segment	Distance from Center of Power Line to Closest Building Edge	2009 Existing Configuration with Normal Loading Projected Magnetic Field (mG)	2009 Proposed Configuration with Normal Loading Projected Magnetic Field (mG)	2009 Proposed Configuration with Pukele Outage Loading Projected Magnetic Field (mG)
Kaiser Honolulu Clinic	1010 Pensacola Street	I	61'	0.0	0.0	0.7
Kaplan Test Preparation Center	1580 Makaloa, Suite 500	A	39'	0.0	1.1	1.6
Lunalilo Elementary School	810 Pumehana Street	C	50'	4.0	3.3	2.8
Lunalilo Elementary School	810 Pumehana Street	B	87'	0.2	0.2	0.3
Straub Hospital	888 South King Street	I	67'	0.0	0.0	0.6
Tenrikyo Honolulu Church	1902 South King Street	I	60'	0.0	0.0	0.7
Washington Middle School	1663 South King Street	I	82'	0.0	0.0	0.3
Enshrined Deity of Ishizuchi Shrine	2020-2038 South King Street	I	147'	0.0	0.0	0.1
First Chinese Church of Christ - Church	1054 South King Street	I	129'	0.0	0.0	0.1
Kaimuki High School	2705 Kaimuki Avenue	H	123'	0.4	0.6	0.6
Lamb of God Church	612 Isenberg Street	H	179'	0.2	0.3	0.3
McKinley High School	1039 South King Street	I	154'	0.0	0.0	0.1
First Chinese Church of Christ - Preschool	1061 Young Street	I	267'	0.0	0.0	0.0
Kupono Learning Center	2038 South King Street	I	247'	0.0	0.0	0.0
Shingon Buddhism Center	915 Sheridan Street	I	268'	0.0	0.0	0.0
Small Church / Chapel	910 Cooke Street	I	231'	0.0	0.0	0.0
Ala Wai Elementary School	503 Kamoku Street	H	Over 300'	0.0	0.0	0.0
Angels at Play Pre-School (St. Mary's Episcopal Church)	2062 South King Street	I	Over 300'	0.0	0.0	0.0
Bodaiji Mission Church	1251 Elm Street	I	Over 300'	0.0	0.0	0.0
Honolulu Church of God	822 Coolidge Street	G	Over 300'	0.0	0.0	0.1
Iolani School	563 Kamoku Street	H	Over 300'	0.0	0.0	0.0
Lokahi Montessori	1506 Piikoi Street	I	Over 300'	0.0	0.0	0.0
Makiki Christian Church & Pre-School	829 Pensacola Street	I	Over 300'	0.0	0.0	0.0
Mildred Martin Day Care Center	3122 Williams Street	F	Over 300'	0.0	0.0	0.0
Yoshimi Ueki Day Care Center	2630 Nahaka Place	H	Over 300'	0.0	0.0	0.0

MAGNETIC FIELD STANDARDS

There are at least two states that have adopted "status quo" engineering standards for magnetic fields (NIEHS 2002). The purpose of most of these standards is to make the field levels from new power lines similar to the field levels from existing overhead transmission lines. The following Table 14 presents a summary of these standards. The measured and projected magnetic field levels associated with the proposed East Oahu Transmission Project are well below these standards.

Table 14. Summary of State Transmission Line Standards and Guidelines for Magnetic Fields

State Transmission Line Standards and Guidelines

State	Magnetic Field	
	On R.O.W. *	Edge R.O.W.
Florida	---	150 mG (a) (max. load) 200 mG (b) (max. load) 250 mG (c) (max. load)
New York	---	200 mG (max. load)

* - R.O.W. = right-of-way (or in the Florida standard, certain additional areas adjoining the right-of-way).
(a) - For lines of 69 - 230 kV.
(b) - For 500 kV lines.
(c) - For 500 kV lines on certain existing R.O.W.

Source: NIEHS, 2002.

Although there are no Federal health standards in the United States specifically for 60 Hertz magnetic fields, two organizations have developed guidelines or limits: the International Commission on Non-Ionizing Radiation Protection (ICNIRP 1998) and the American Conference of Governmental Industrial Hygienists (ACGIH 2003). The following Tables 15 and 16 present a summary of the magnetic field levels of these guidelines for ICNIRP and ACGIH, respectively. The measured and projected magnetic field levels associated with the proposed East Oahu Transmission Project are far below the guidelines or limits of Tables 15 and 16.

Table 15. Summary of ICNIRP Exposure Guidelines
For Magnetic Fields

ICNIRP Guidelines for EMF Exposure

Exposure (60 Hz)	Magnetic Field
Occupational	4.2 G (4,200 mG)
General Public	0.833 G (833 mG)

International Commission on Non-Ioning Radiation Protection (ICNIRP) is an organization of 15,000 scientists from 40 nations who specialize in radiation protection.

Source: ICNIRP, 1998.

Table 16. Summary of ACGIH 60 Hz Exposure Guidelines
For Magnetic Fields

ACGIH Occupational Threshold Limit Values for 60-Hz EMF

	Magnetic Field
Occupational exposure should not exceed	10 G (10,000 mG)
Exposure of workers with cardiac pacemakers should not exceed	1 G (1,000 mG)

American Conference of Governmental Industrial Hygienists (ACGIH) is a professional organization that facilitates the exchange of technical information about worker health protection. It is not a governmental regulatory agency.

Source: ACGIH, 2003.

SUMMARY AND CONCLUSIONS

HECO has proposed the construction of a new transmission system project, entitled the East Oahu Transmission Project. This project involves the installation of several new underground 46 kV subtransmission lines and transformers. As a result of this proposed installation, some existing electrical facilities (such as 12 kV, 25 kV and 46 kV underground and overhead distribution lines) may be eliminated, remain unchanged, or may increase or decrease in loading. Based upon this evaluation, the following conclusions were reached:

Existing magnetic field levels from HECO facilities are typical of levels from similar facilities throughout the State of Hawaii.

> Magnetic field measurements were conducted at eleven selected segments along portions of the proposed project to characterize field strengths due to existing electrical facilities. Existing magnetic field levels along these segments range from a few tenths of a mG to over 25 mG, depending upon location. Existing electric facilities surveyed included 12 kV, 25 kV, 46 kV, and 138 kV power line facilities.

The difference in projected magnetic field levels between the existing and proposed power line configurations under 2009 forecasted loading can decrease slightly, remain unchanged, or increase depending upon the project segment.

> In addition to field measurements, magnetic field levels were also calculated for 2009 forecasted normal and Pukele outage conditions for eleven different project segments. The difference in projected magnetic field levels between the existing and proposed power line configurations under 2009 forecasted loading can decrease slightly, remain unchanged, or increase depending upon the project segment. For Segment 'I' (where no 46 kV power lines presently exist), the projected magnetic field generally remains unchanged since the proposed underground 46 kV power lines would only be utilized under Pukele outage conditions. For Segment 'E' (east of Kamoku Substation where modifications to an existing overhead 46 kV power line are proposed), the range of projected magnetic field levels decreases slightly since the 2009 forecasted load is somewhat lower for the proposed configuration than for the existing configuration. At all other segment locations, the projected magnetic field increases due to the proposed power line configuration under 2009 forecasted loading conditions. While the largest magnetic field increases typically occur within street locations, projected magnetic field levels can also increase at sidewalk locations. Under proposed 2009 Pukele outage conditions, the projected magnetic field increases at all segment locations.

If the project is implemented, the proposed underground circuits would have little effect on EMF levels at nearby institutions; EMF levels will be in the range of common everyday levels.

A magnetic field assessment was performed to evaluate present and future levels at various institutions along the proposed project. Several institutions are located near portions of the proposed project, including day care centers, pre-schools and schools, hospitals, churches, and retirement homes. Distance measurements were taken to determine the closest building edge to the proposed project. Using these distance measurements, the projected magnetic fields for 2009 loading conditions were evaluated for each of these institutions. Six different institutions are located within 100 feet of the proposed project. The two closest institutions are the Kaplan Test Preparation Center and the Lunalilo Elementary School. For the Kaplan Test Preparation Center, projected 2009 magnetic field levels of 0.0 mG with the existing power line configuration would increase about 1.1 mG with the proposed configuration under normal loading. For the Lunalilo Elementary School, projected 2009 magnetic fields of about 4.0 mG with the existing power line configuration would decrease to about 3.3 mG with the proposed configuration under normal loading (due to some field cancellation). Four other institutions within 100 feet would have no projected magnetic field under normal operating conditions, since the underground power lines are only loaded during Pukele outage conditions (and even then the projected field at the closest building edge is less than 1 mG). There are five additional institutions located within 200 feet of the proposed project. Of these, two institutions have projected magnetic fields of about 0.6 or less under Pukele outage conditions, and three institutions would have no projected magnetic field under normal operating conditions (since the underground power lines are only loaded during Pukele outage conditions and have negligible projected field influence of about 0.1 mG). Beyond 200 feet, the projected magnetic field influence from the proposed project is negligible.

The proposed substations, manholes, and risers of the East Oahu Transmission Project will be similar to existing facilities and have very low EMF levels at a relatively short distance away.

Another aspect of the proposed East Oahu Transmission Project is the installation of new transformers within certain substations, manholes in the streets, and risers on wooden poles at sidewalk locations. The magnetic field from a substation transformer or manhole is typically reduced by about 90% at a distance of about 20 feet away from the facility (for transformers, magnetic fields due to these sources are typically reduced to ambient levels at the substation perimeter). For this project, the closest property line is at least 30 feet away from any proposed substation transformer location. For risers, the magnetic field is typically reduced by over 90% at a distance of about 3 feet away from the riser.

There are a wide variety of EMF levels and sources encountered in everyday life that are comparable to EMF due to electric power facilities.

In addition to measuring and calculating magnetic fields for electrical facilities associated with the proposed project, magnetic field measurements of everyday environments were performed at ten different locations in Honolulu. These measurements were performed to provide a range of magnetic field levels encountered in everyday locations and for comparison with the magnetic field levels associated with the proposed East Oahu Transmission Project. Measured magnetic fields ranged from 0.1 mG to over 99 mG in everyday environments. Many of these magnetic field sources are common appliances and electrical devices, such as refrigeration units in supermarkets, electric stoves in food preparation areas, library security gates, escalators, vending machines, display counters, video games, cash registers, and ATM machines.

There are no Federal or State of Hawaii health standards for 60 Hertz magnetic fields.

Over the past two decades, there has been research investigating exposure to EMF. Although there are no Federal health standards in the United States specifically for 60 Hertz magnetic fields, two organizations have developed guidelines or limits: the International Commission on Non-Ionizing Radiation Protection and the American Conference of Governmental Industrial Hygienists. The measured and projected magnetic field levels associated with the proposed East Oahu Transmission Project are far below these guidelines or limits.

There are at least two states that have adopted "status quo" engineering standards for magnetic fields. The purpose of most of these standards is to make the field levels from new power lines similar to the field levels from existing overhead transmission lines. The measured and projected magnetic field levels associated with the proposed East Oahu Transmission Project are well below these other state standards.

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APPENDICES

APPENDIX A

Diagram of Electrical Facilities
at Segment Locations

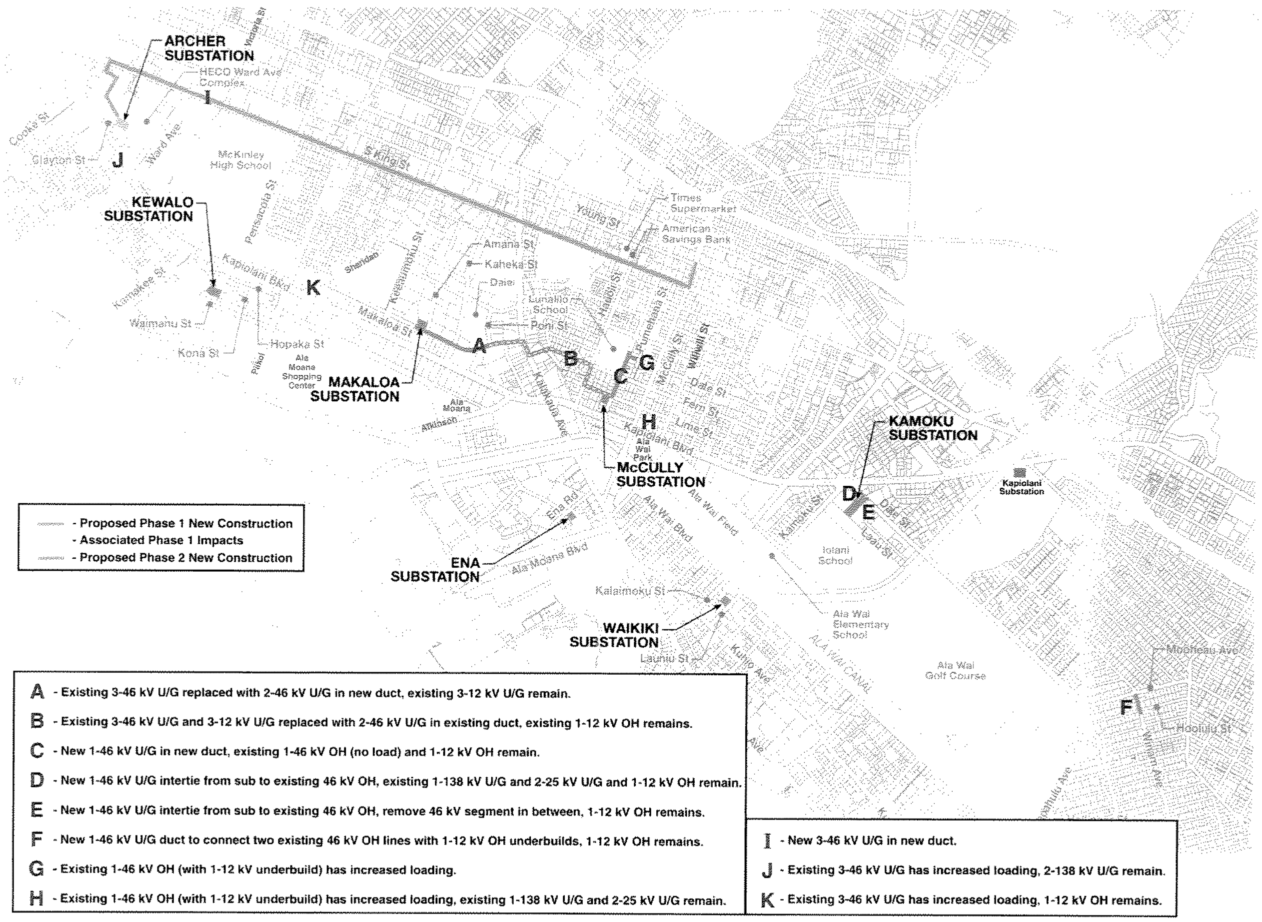


Figure A-1. Diagram for the HECO East Oahu Transmission Project With Associated Segment Locations

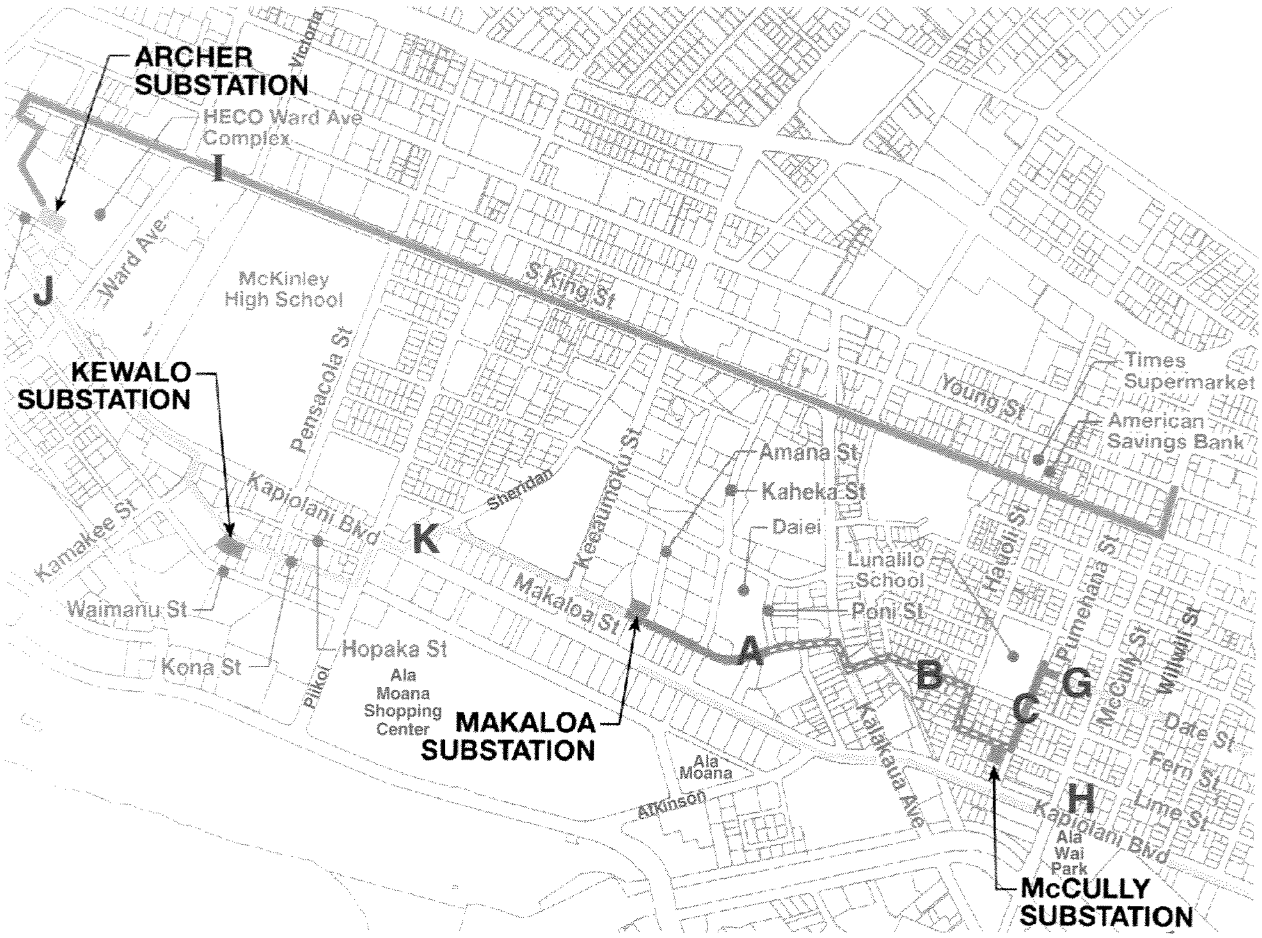


Figure A-2. Detailed Diagram for the HECO East Oahu Transmission Project
Ewa Side With Associated Segment Locations
(Segments 'A' – 'C' and 'G' – 'K')

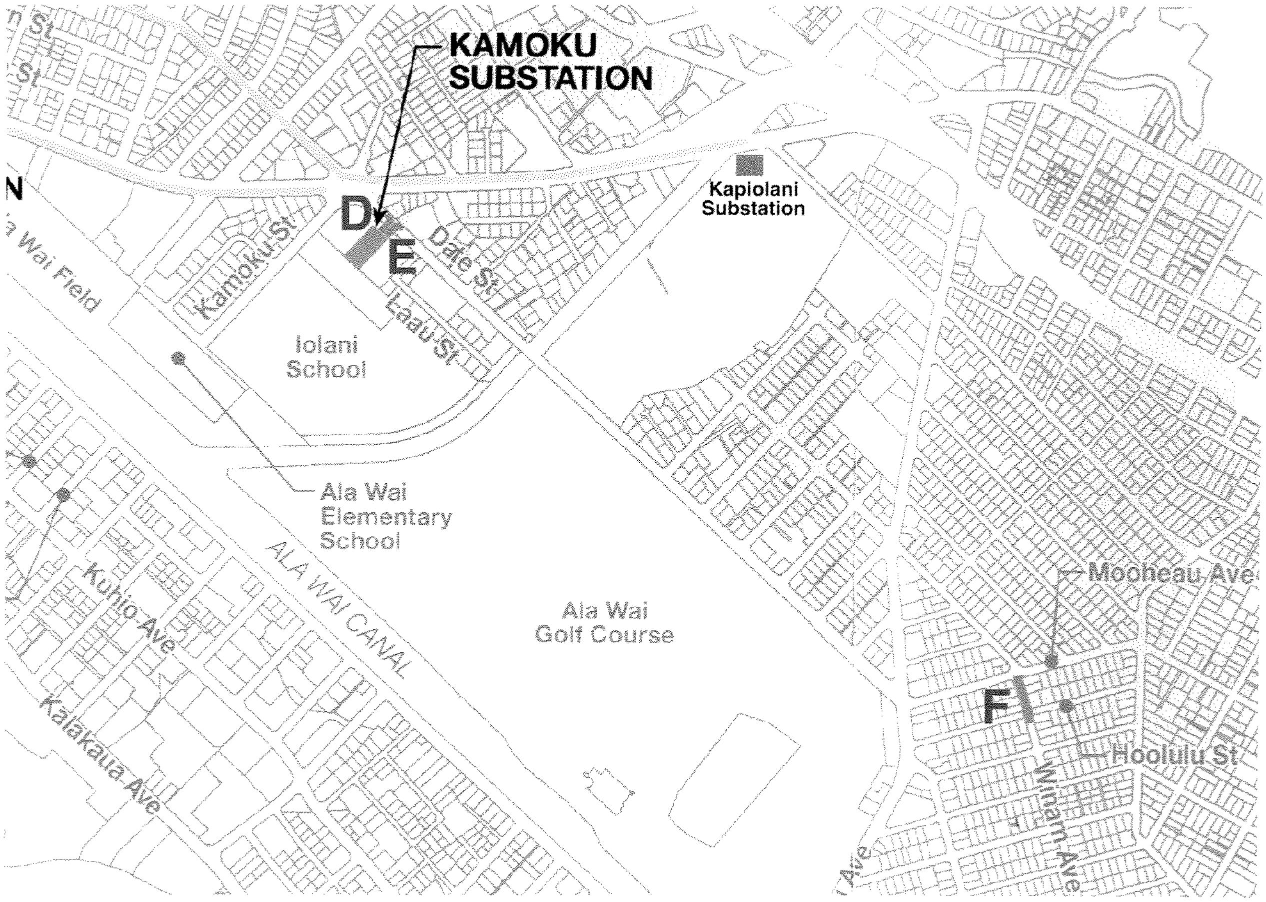


Figure A-3. Detailed Diagram for the HECO East Oahu Transmission Project
Diamond Head Side With Associated Segment Locations
(Segments 'D' – 'F')

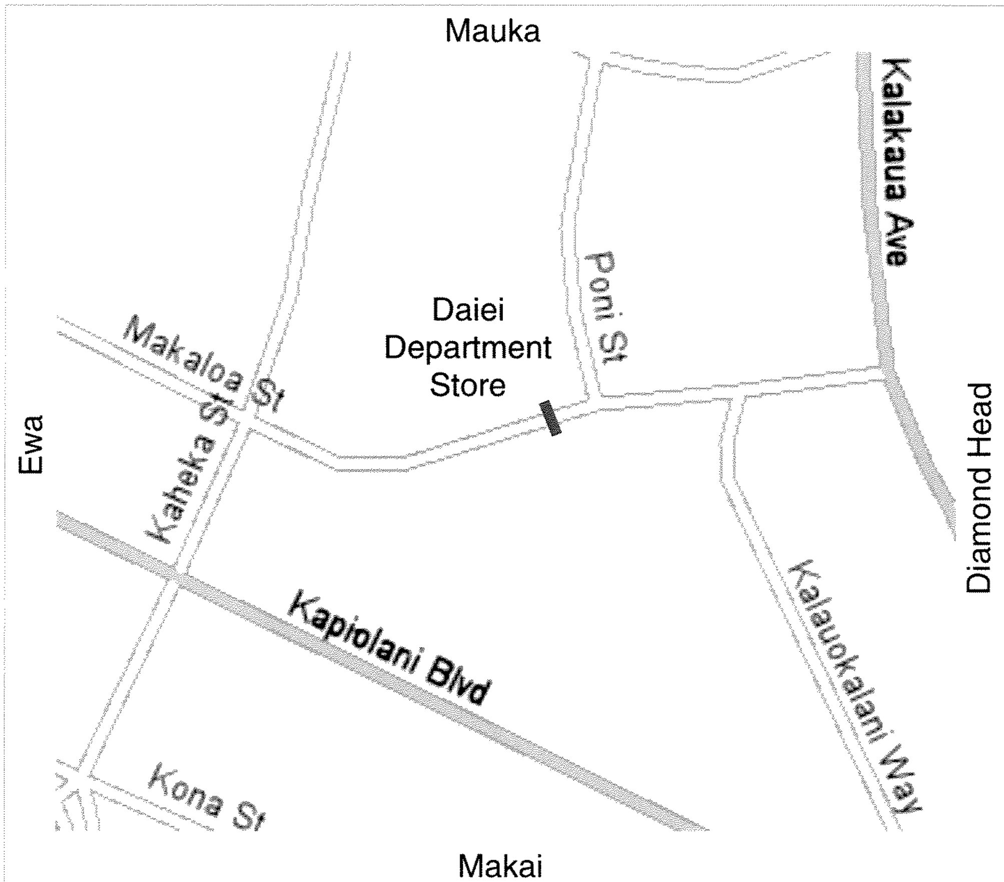
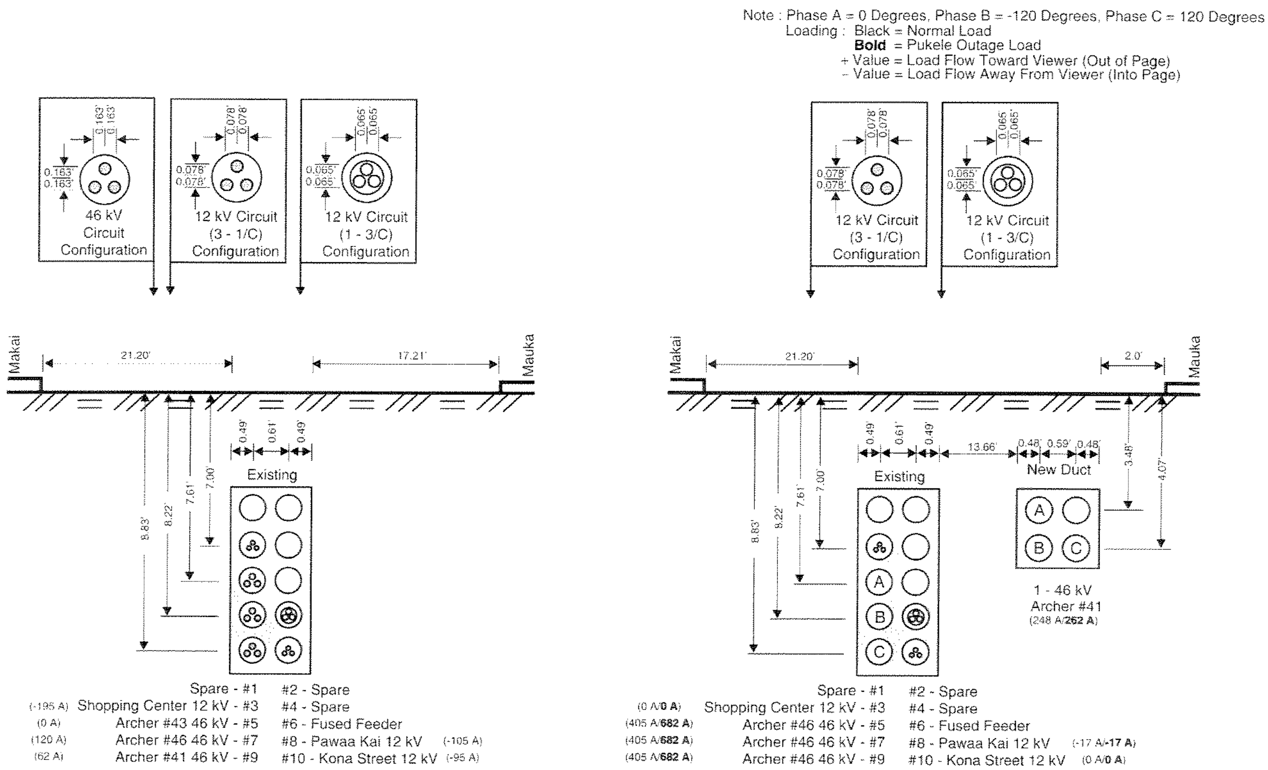


Figure A-4. Measurement Location at Segment 'A'
(Makaloa Street between Kaheka and Poni Streets)



EXISTING **PROPOSED**

SEGMENT 'A'

Makaloa Street between Kaheka & Poni Streets

Figure A-5. Diagram of Electrical Facilities at Segment 'A'
(Makaloa Street between Kaheka and Poni Streets)

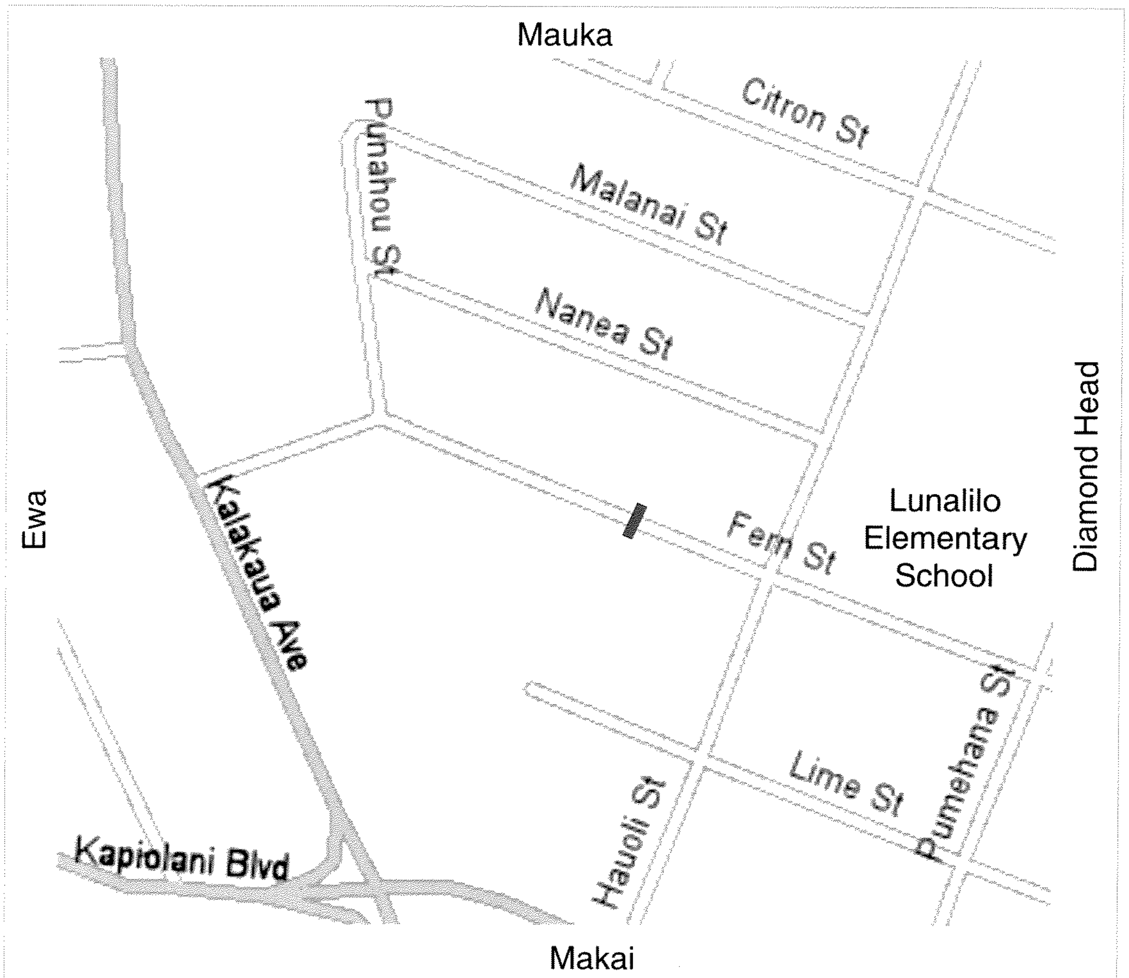
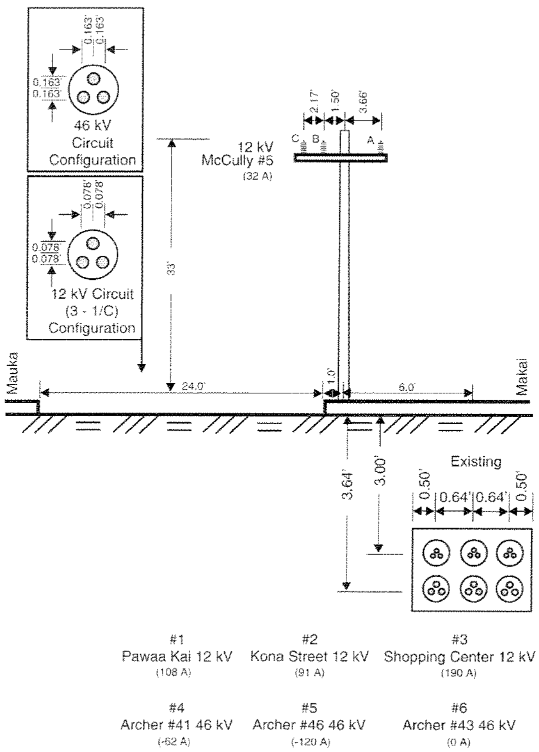
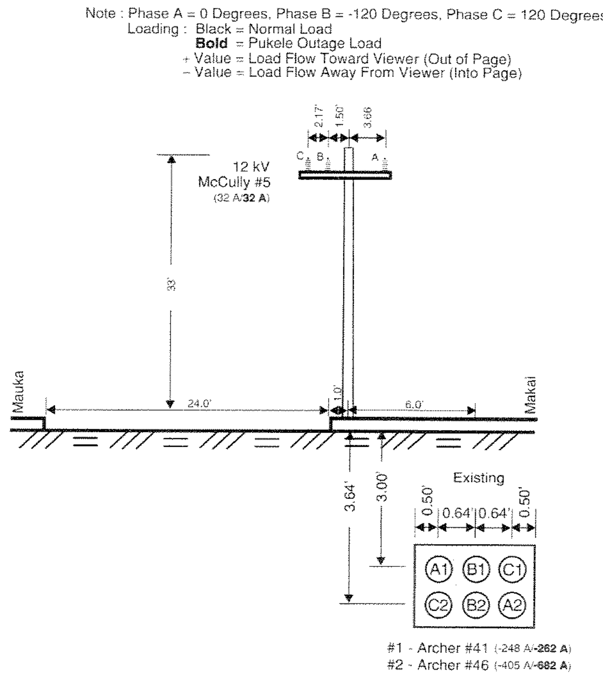


Figure A-6. Measurement Location at Segment 'B'
(Fern Street between Punahou and Hauoli Streets)





EXISTING **PROPOSED**

SEGMENT 'B'

Fern Street between Punahou and Hauoli Streets

Figure A-7. Diagram of Electrical Facilities at Segment 'B'
(Fern Street between Punahou and Hauoli Streets)

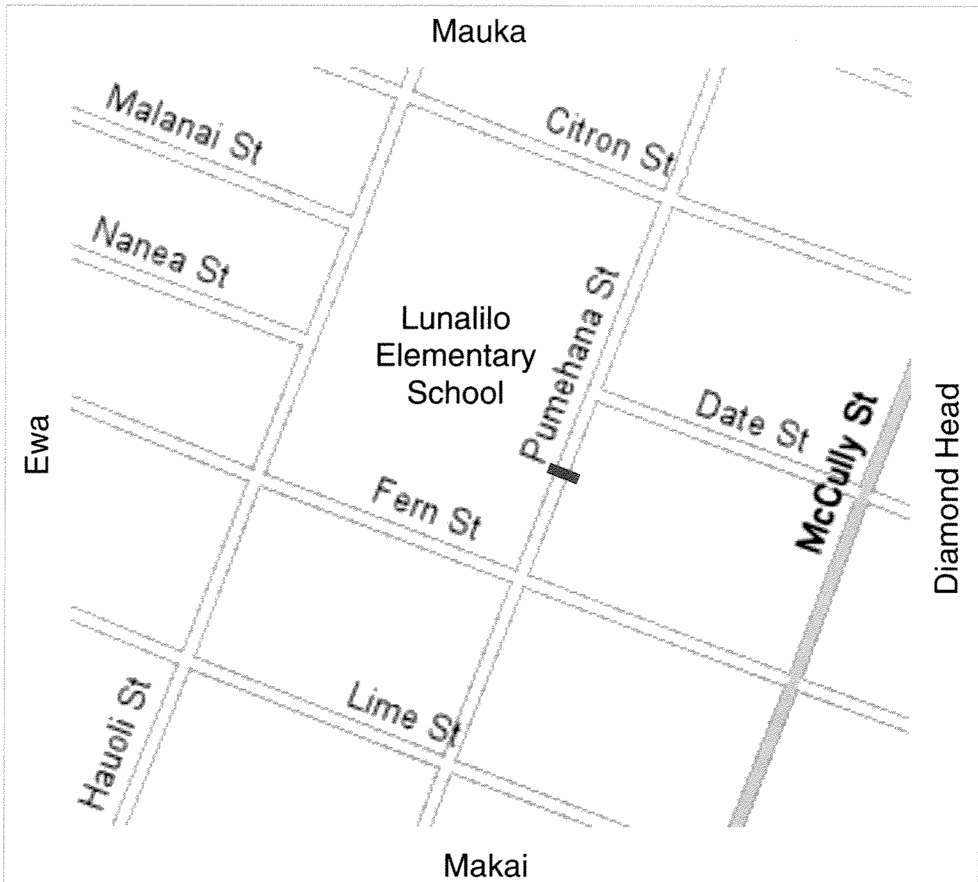
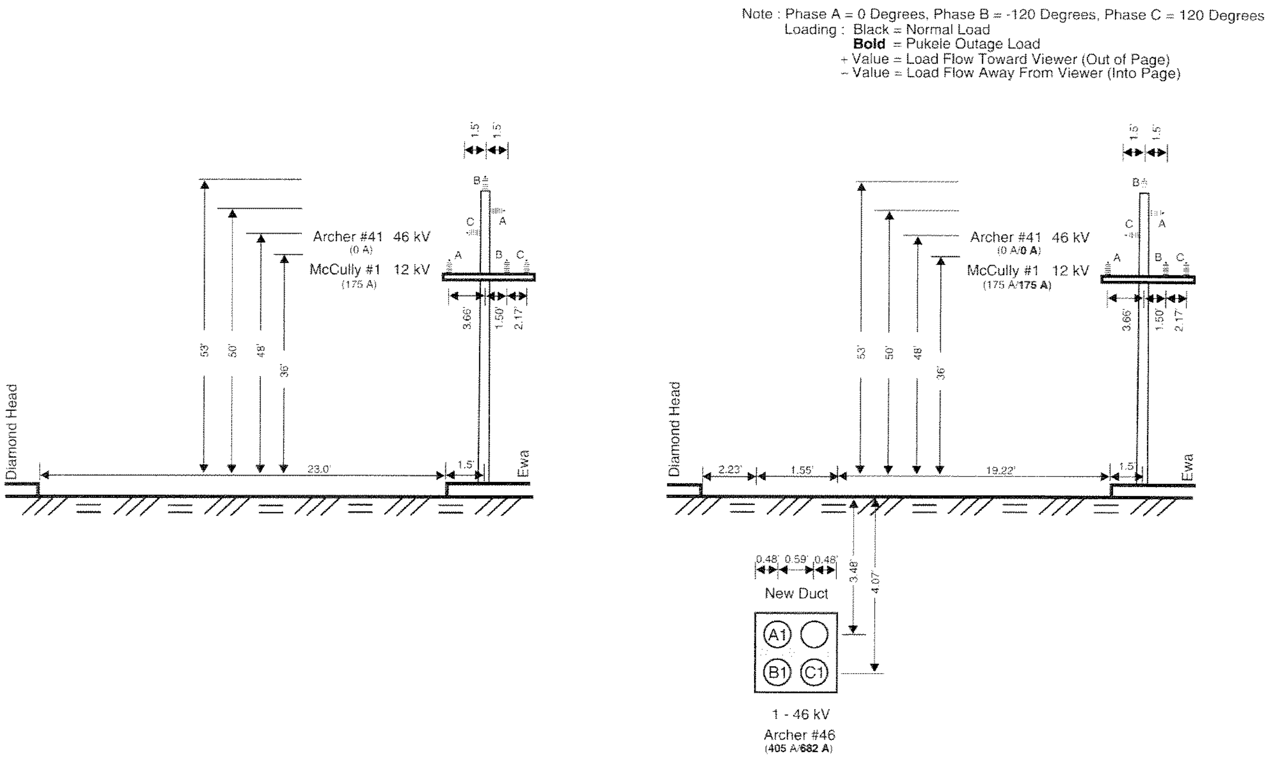


Figure A-8. Measurement Location at Segment 'C'
(Pumehana Street between Lime and Date Streets)



EXISTING **PROPOSED**

SEGMENT 'C'

Pumehana Street between Lime and Date Streets

Figure A-9. Diagram of Electrical Facilities at Segment 'C'
(Pumehana Street between Lime and Date Streets)

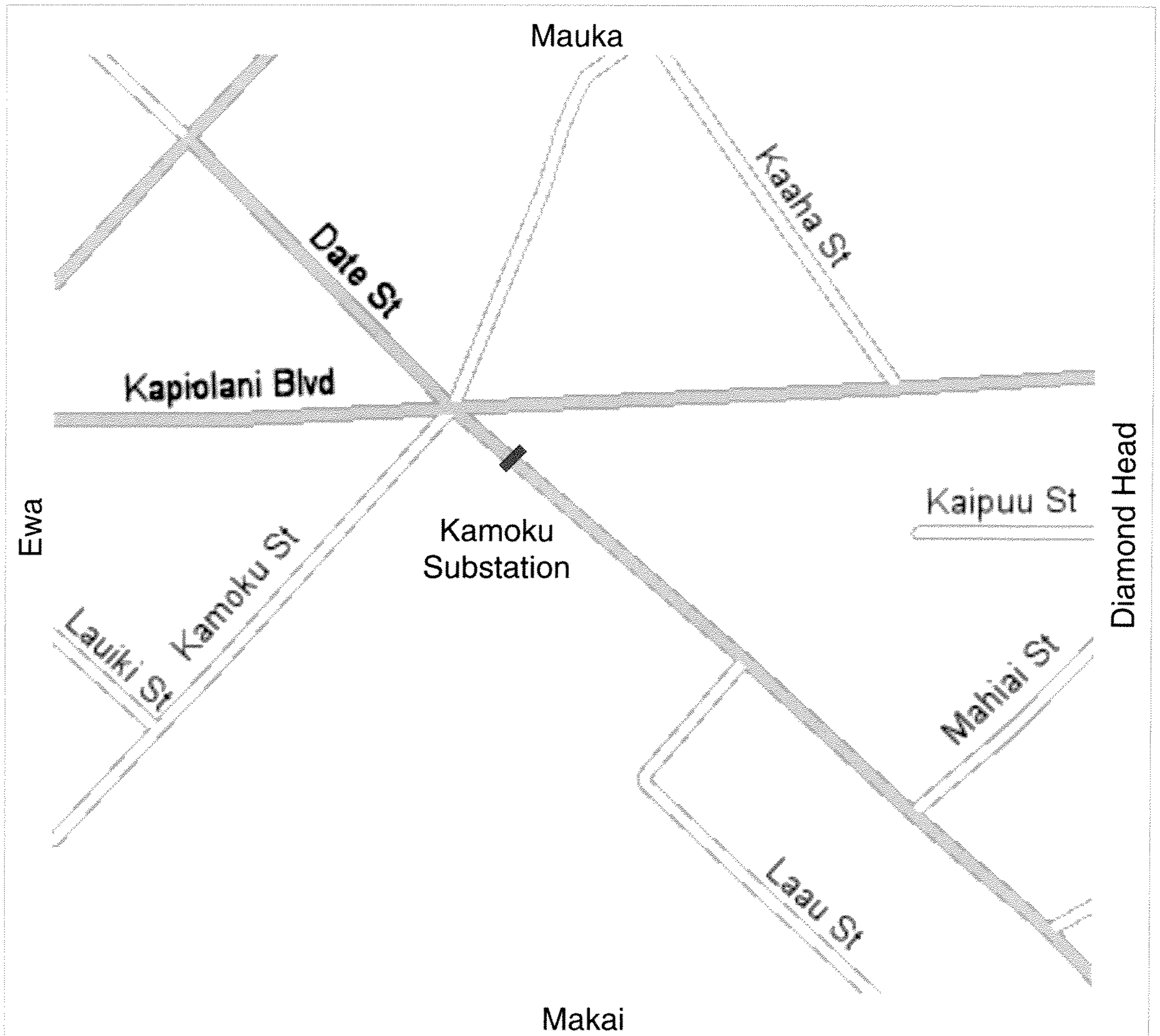
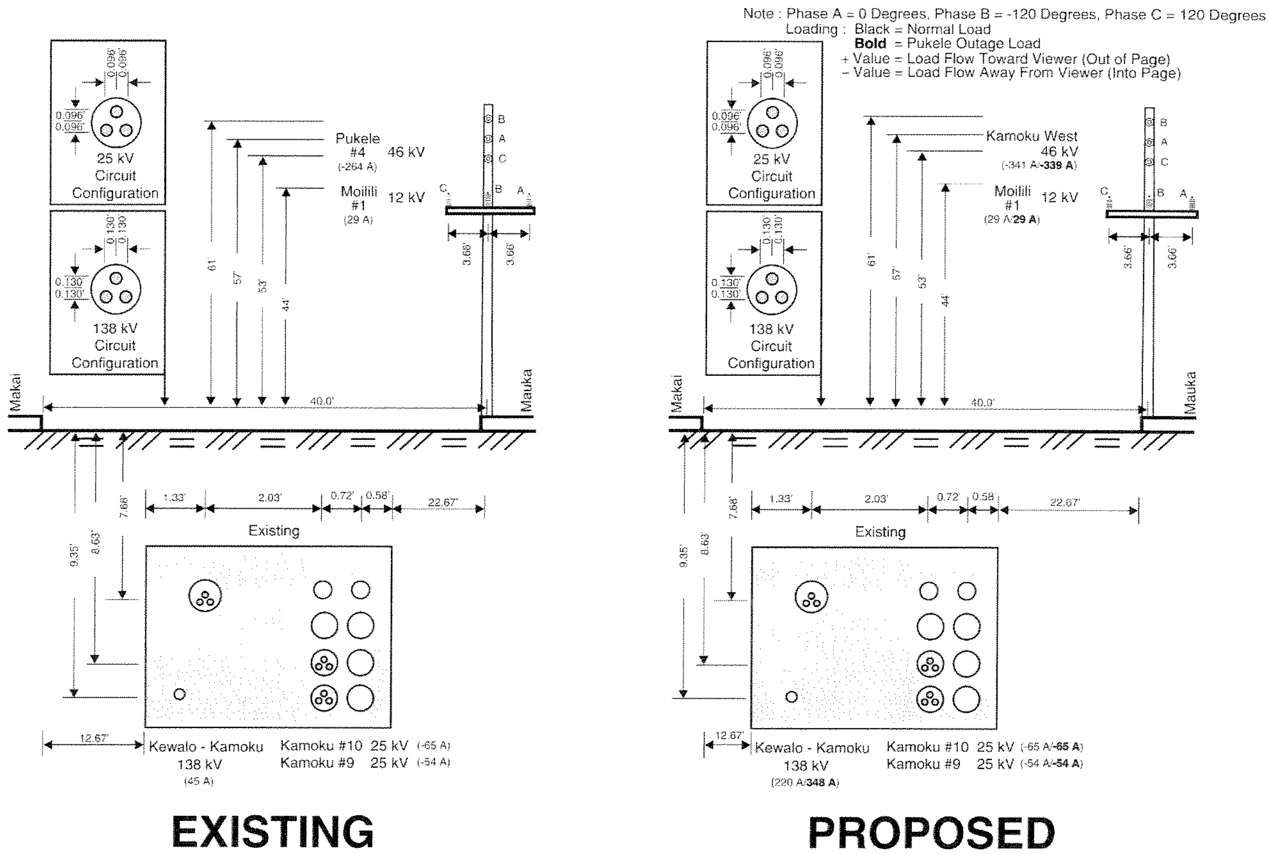


Figure A-10. Measurement Location at Segment 'D'
(Date Street west of Kamoku Substation)



SEGMENT 'D'

Date Street west of Kamoku Substation

Figure A-11. Diagram of Electrical Facilities at Segment 'D'
(Date Street west of Kamoku Substation)

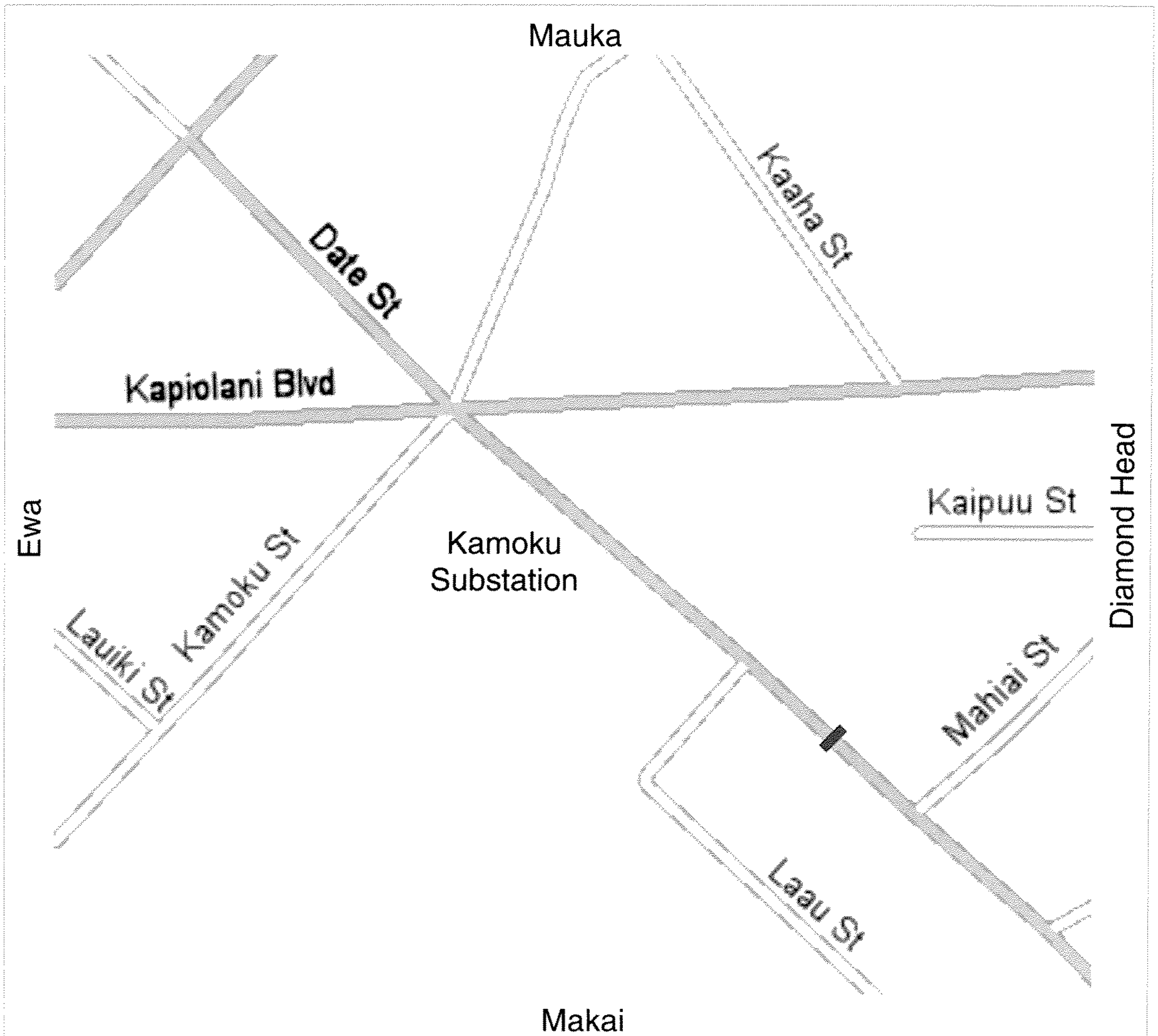
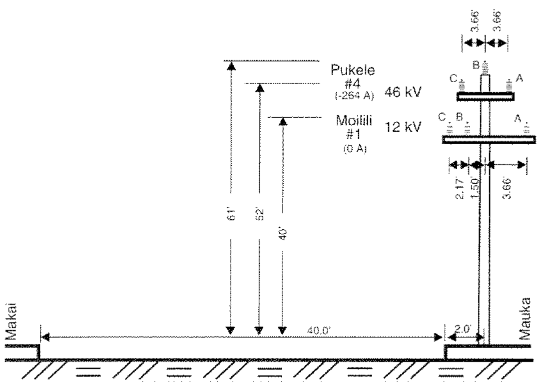
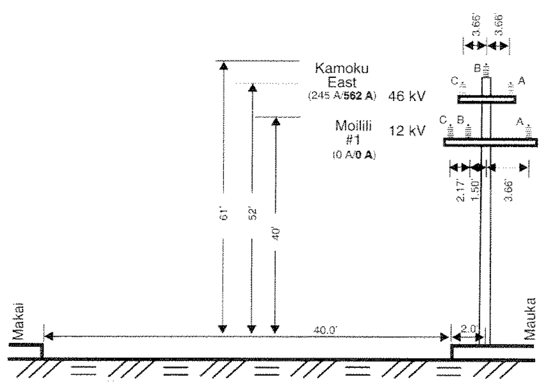


Figure A-12. Measurement Location at Segment 'E'
(Date Street east of Kamoku Substation)

Note : Phase A = 0 Degrees, Phase B = -120 Degrees, Phase C = 120 Degrees
Loading : Black = Normal Load
Bold = Pukele Outage Load
+ Value = Load Flow Toward Viewer (Out of Page)
– Value = Load Flow Away From Viewer (Into Page)





EXISTING

PROPOSED

SEGMENT 'E'

Date Street east of Kamoku Substation

Figure A-13. Diagram of Electrical Facilities at Segment 'E'
(Date Street east of Kamoku Substation)

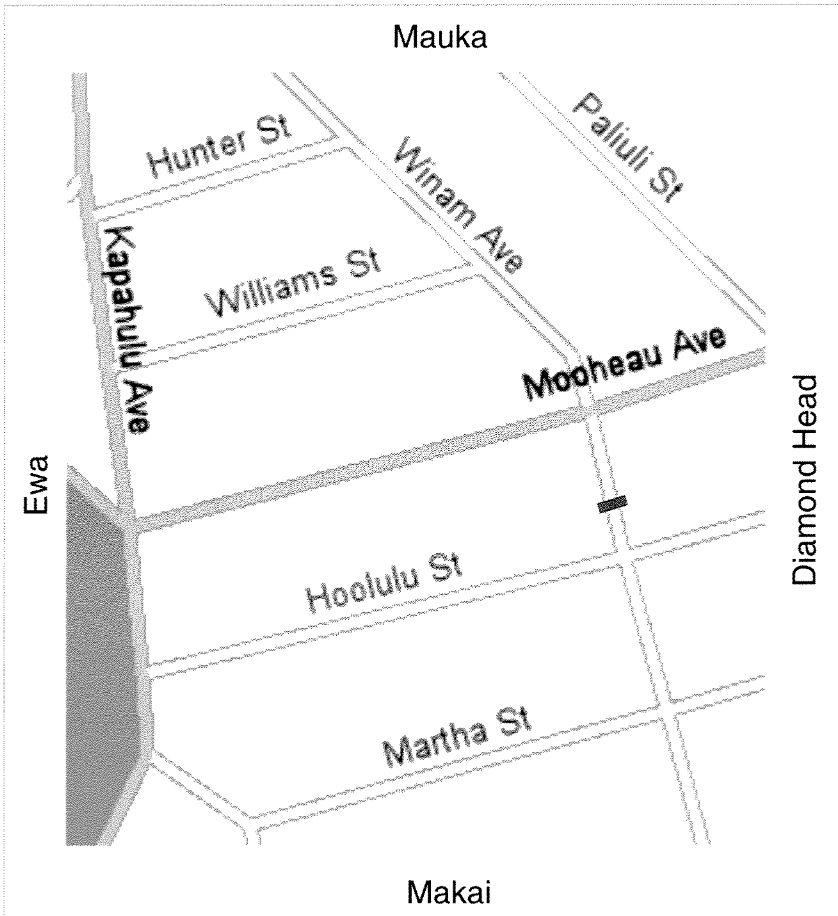
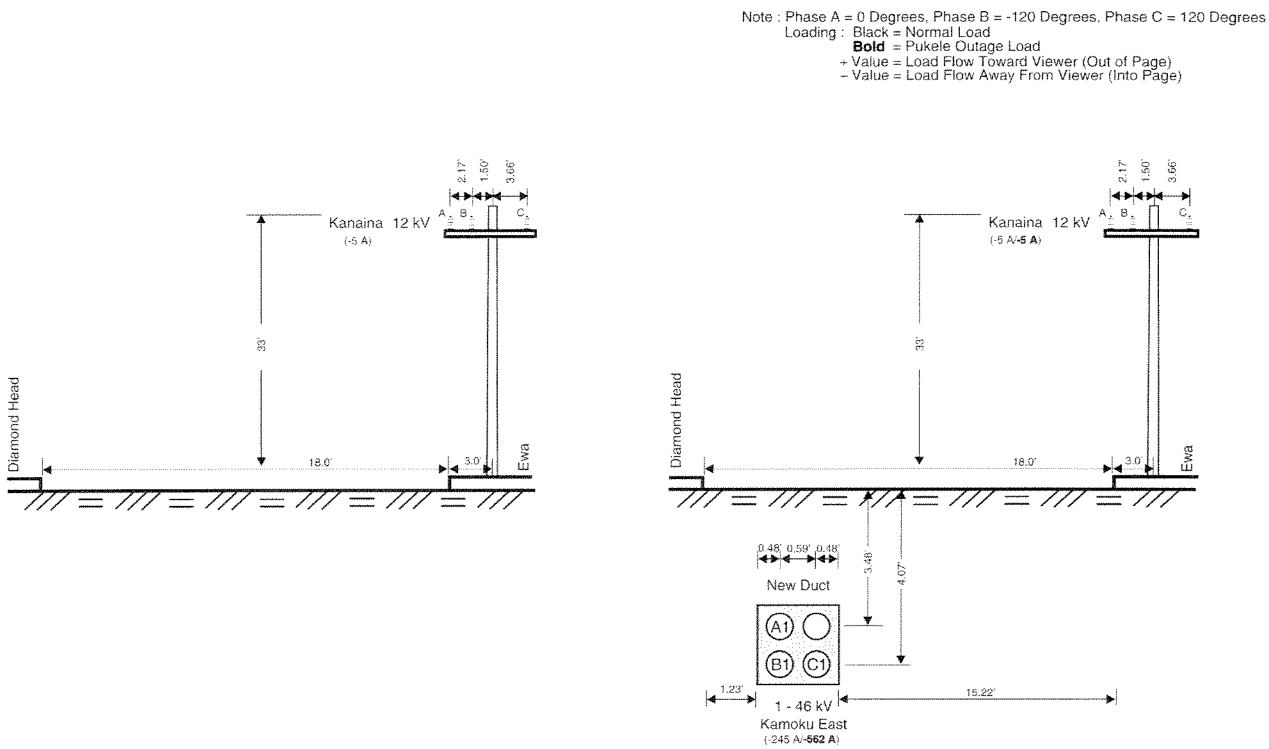


Figure A-14. Measurement Location at Segment 'F'
(Winam Avenue between Hoolulu and Mooheau Streets)



EXISTING PROPOSED

SEGMENT 'F'

Winam Avenue between Hoolulu and Mooheau Streets

Figure A-15. Diagram of Electrical Facilities at Segment 'F'
(Winam Avenue between Hoolulu and Mooheau Streets)

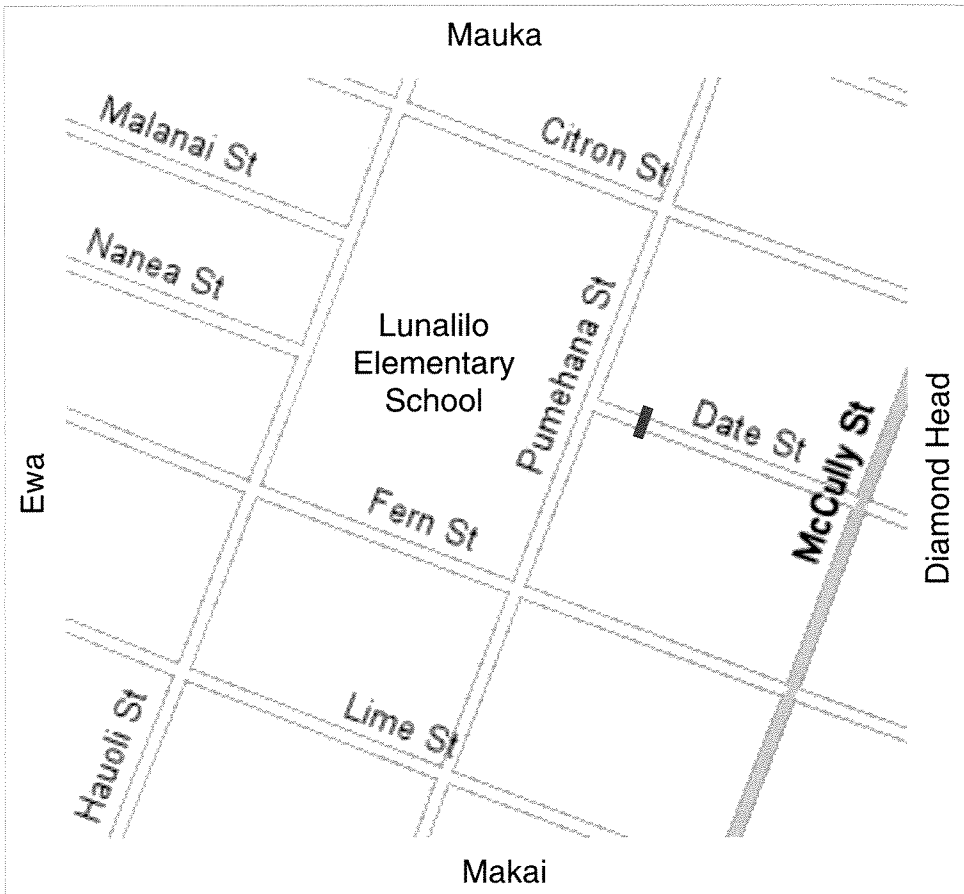
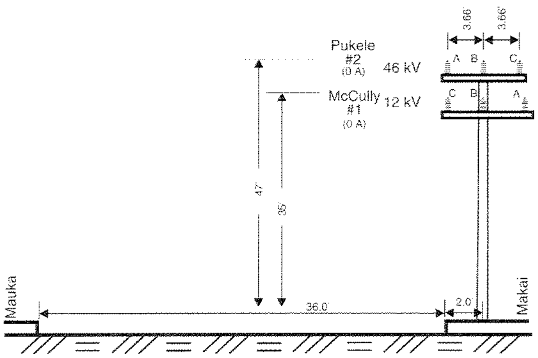
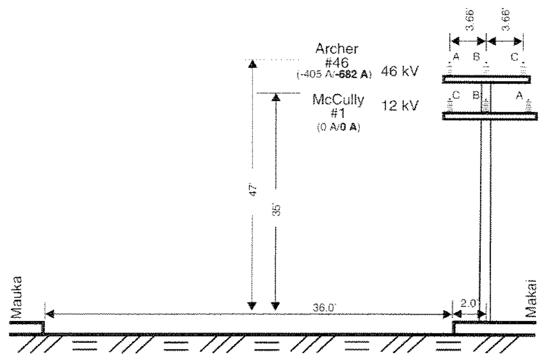


Figure A-16. Measurement Location at Segment 'G'
(Date Street between Pumehana and McCully Streets)

Note : Phase A = 0 Degrees, Phase B = -120 Degrees, Phase C = 120 Degrees
Loading : Black = Normal Load
Bold = Pukele Outage Load
+ Value = Load Flow Toward Viewer (Out of Page)
− Value = Load Flow Away From Viewer (Into Page)





EXISTING **EXISTING - NEW LOADS**

SEGMENT 'G'

Date Street between Pumehana and McCully Streets

Figure A-17. Diagram of Electrical Facilities at Segment 'G'
(Date Street between Pumehana and McCully Streets)

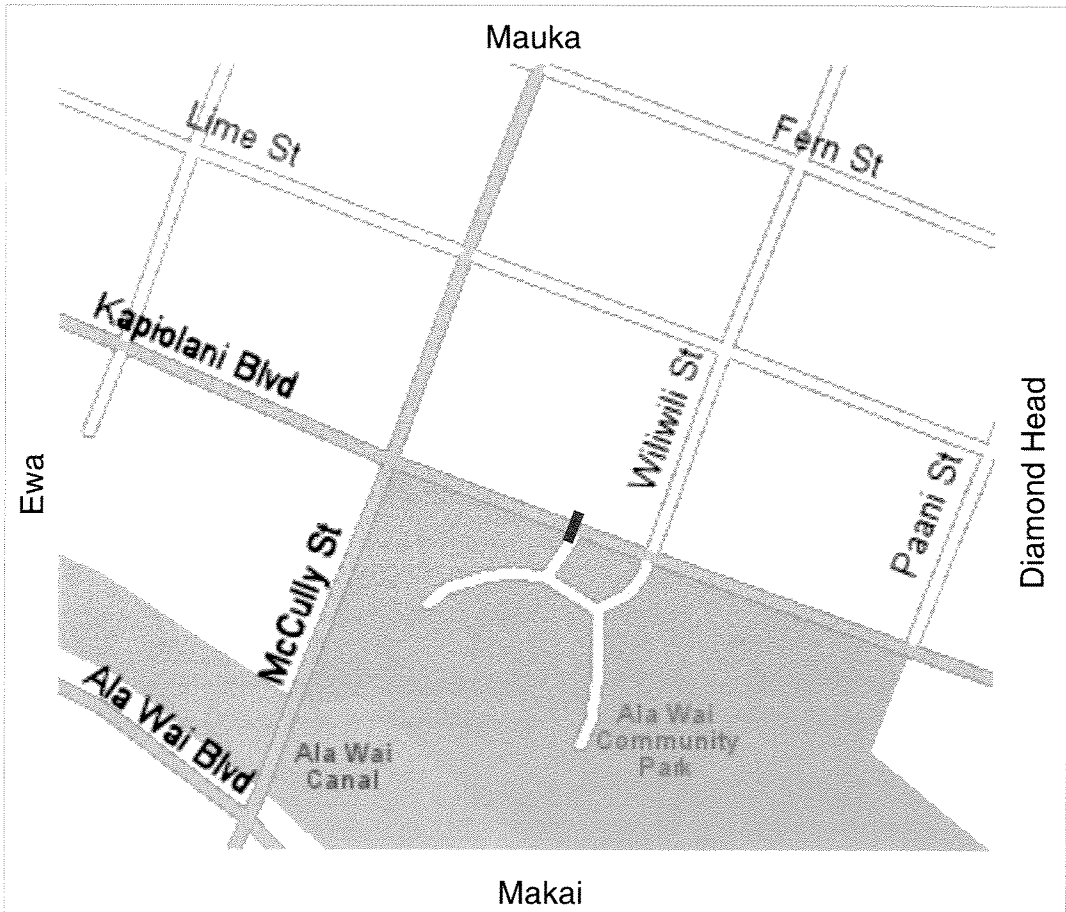
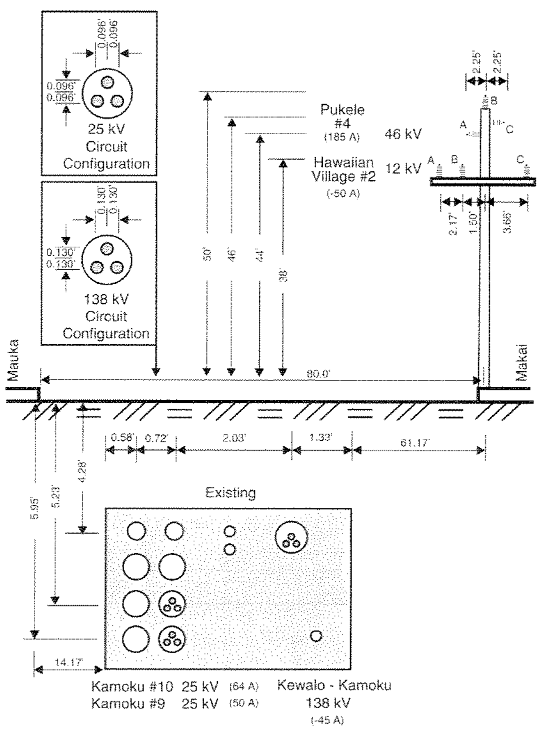
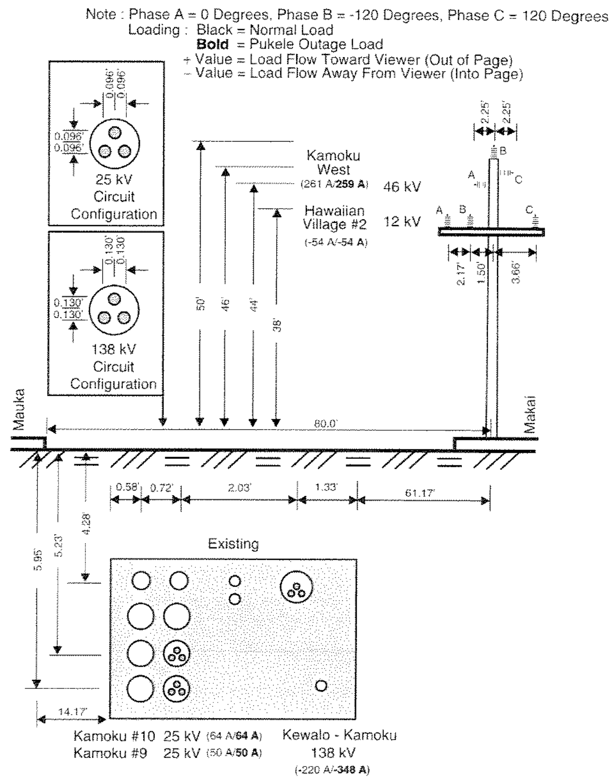


Figure A-18. Measurement Location at Segment 'H'
(Kapiolani Boulevard between Wiliwili and McCully Streets)



EXISTING



EXISTING - NEW LOADS

SEGMENT 'H'

Kapiolani Boulevard between Wiliwili and McCully Streets

Figure A-19. Diagram of Electrical Facilities at Segment 'H' (Kapiolani Boulevard between Wiliwili and McCully Streets)

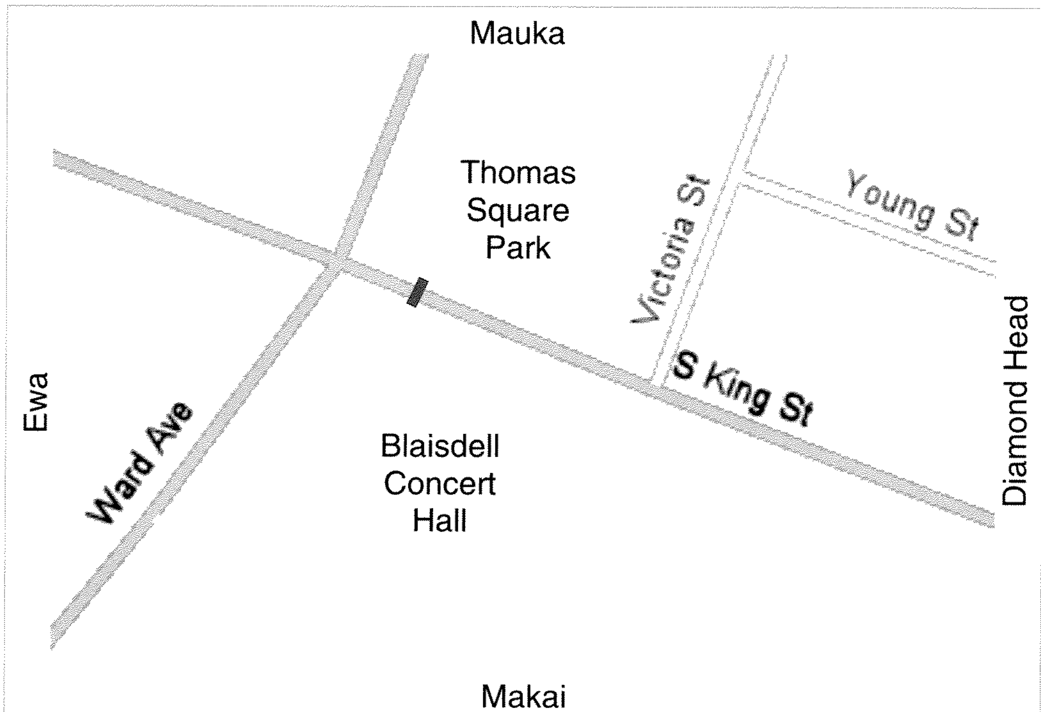
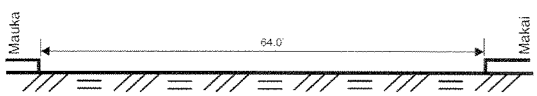
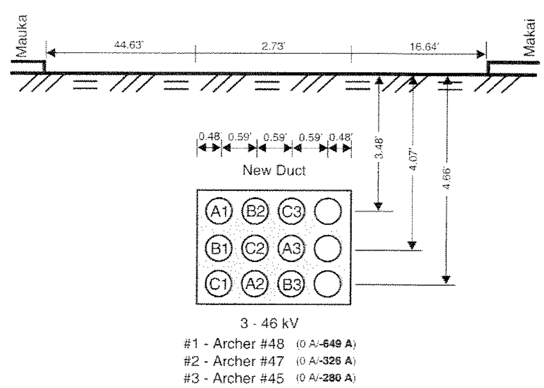


Figure A-20. Measurement Location at Segment 'I'
(King Street between Ward Avenue and Victoria Street)

Note : Phase A = 0 Degrees, Phase B = -120 Degrees, Phase C = 120 Degrees
Loading : Black = Normal Load
Bold = Pukele Outage Load
+ Value = Load Flow Toward Viewer (Out of Page)
- Value = Load Flow Away From Viewer (Into Page)





EXISTING **PROPOSED**

SEGMENT 'I'

King Street between Ward Avenue and Victoria Street

Figure A-21. Diagram of Electrical Facilities at Segment 'I'
(King Street between Ward Avenue and Victoria Street)

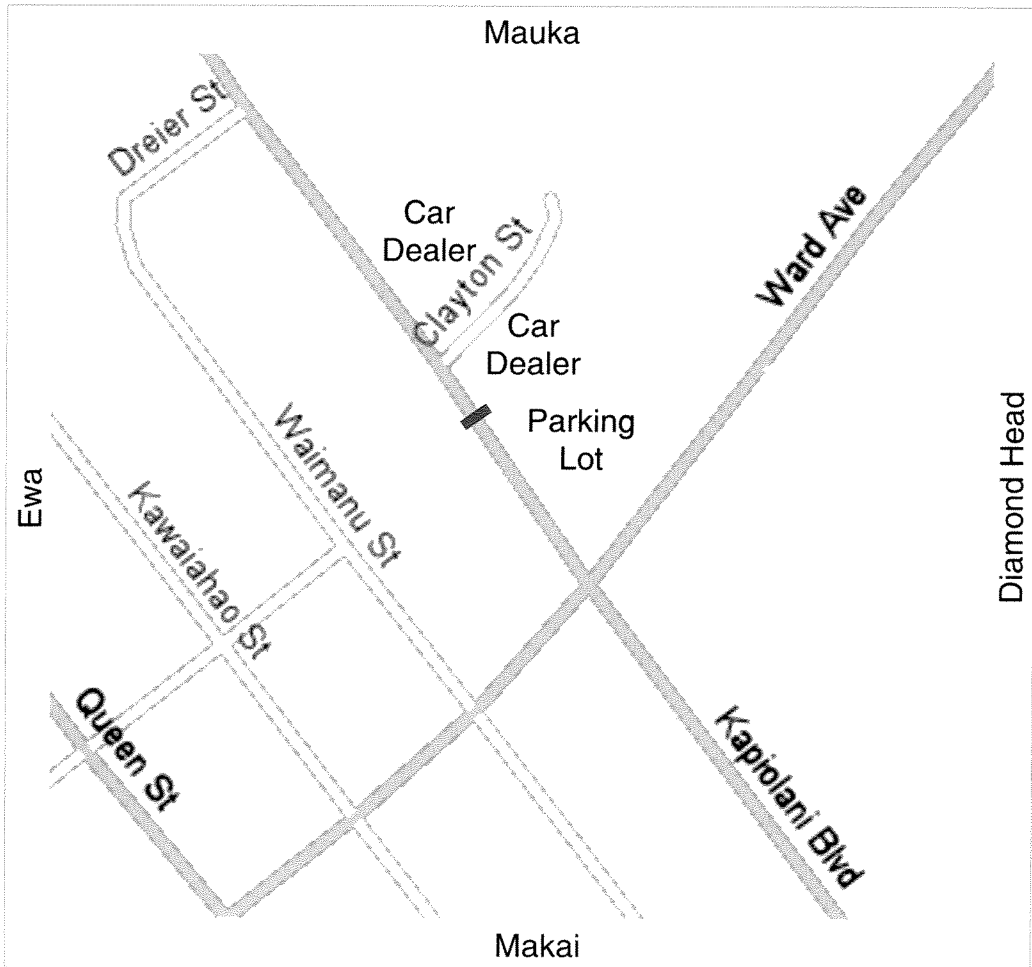
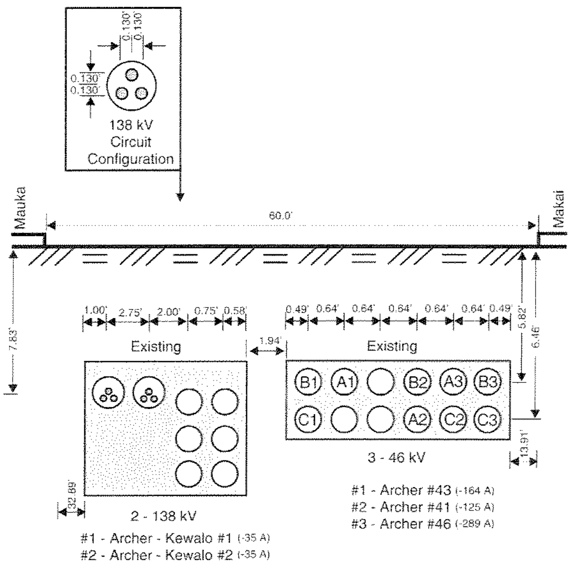
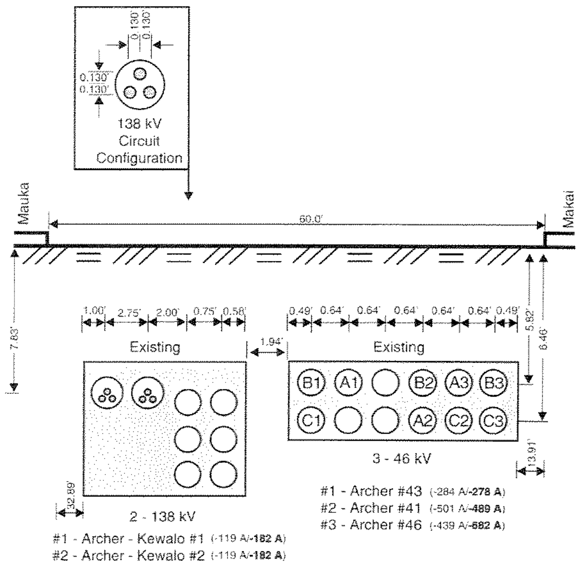


Figure A-22. Measurement Location at Segment 'J'
(Kapiolani Boulevard between Clayton Street and Ward Avenue)

Note : Phase A = 0 Degrees, Phase B = -120 Degrees, Phase C = 120 Degrees
Loading : Black = Normal Load
Bold = Pukele Outage Load
+ Value = Load Flow Toward Viewer (Out of Page)
– Value = Load Flow Away From Viewer (Into Page)





EXISTING

EXISTING - NEW LOADS

SEGMENT ‘J’

Kapiolani Boulevard between Clayton Street and Ward Avenue

Figure A-23. Diagram of Electrical Facilities at Segment ‘J’
(Kapiolani Boulevard between Clayton Street and Ward Avenue)

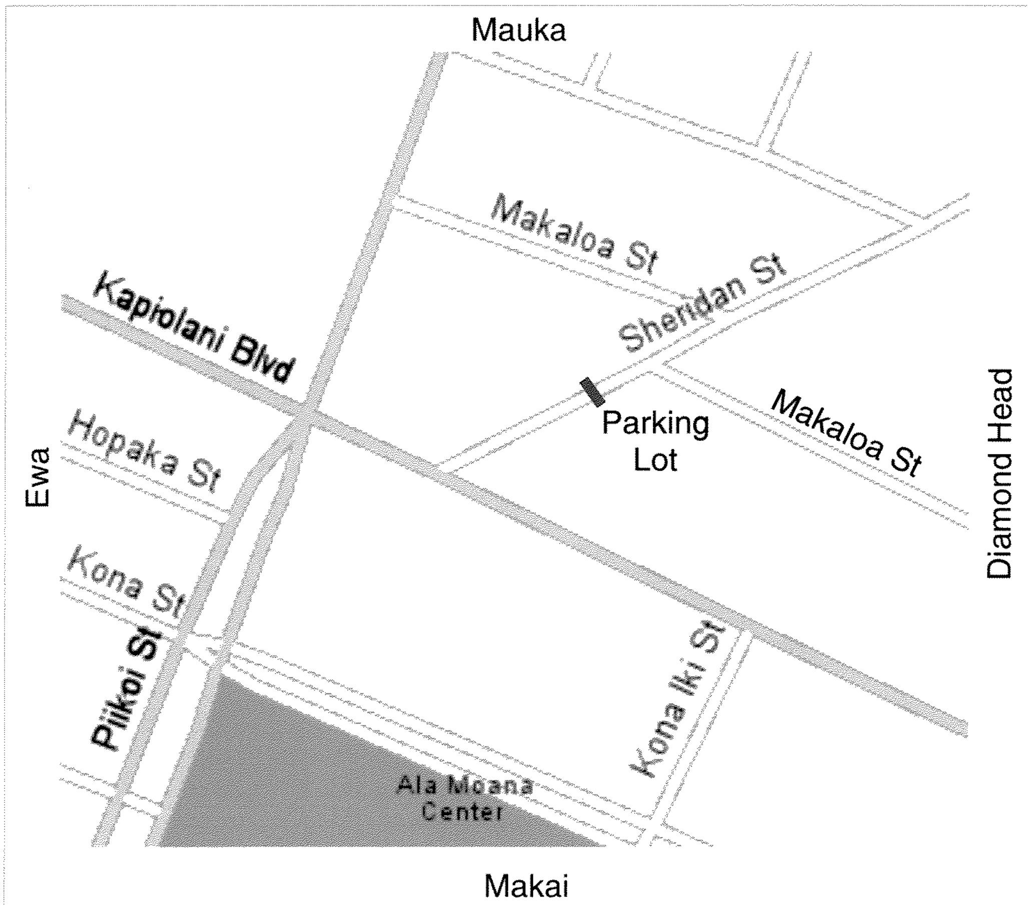
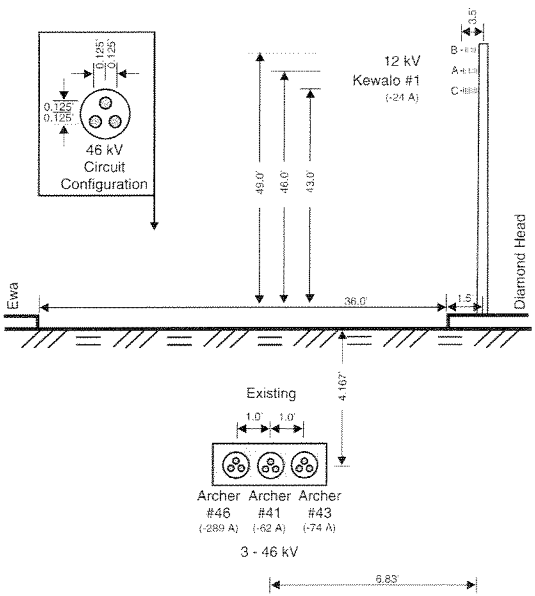
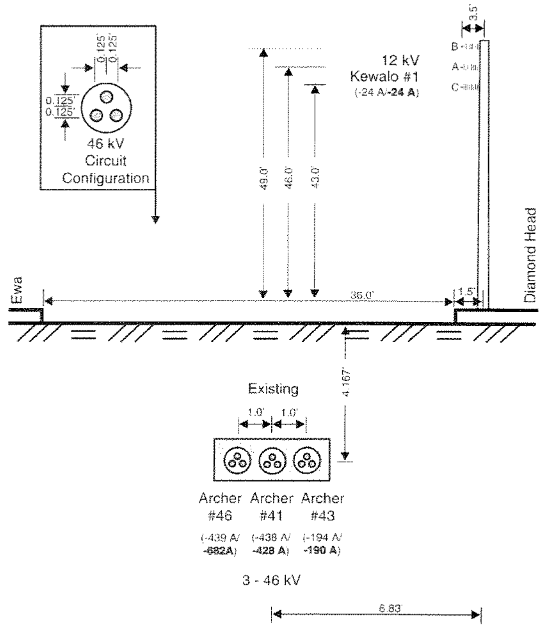


Figure A-24. Measurement Location at Segment 'K'
(Sheridan Street between Kapiolani Boulevard and Makaloa Street)

Note : Phase A = 0 Degrees, Phase B = -120 Degrees, Phase C = 120 Degrees
Loading : Black = Normal Load
Bold = Pukele Outage Load
+ Value = Load Flow Toward Viewer (Out of Page)
- Value = Load Flow Away From Viewer (Into Page)



EXISTING



EXISTING - NEW LOADS

SEGMENT 'K'

Sheridan Street between Kapiolani Boulevard and Makaloa Street

Figure A-25. Diagram of Electrical Facilities at Segment 'K'
(Sheridan Street between Kapiolani Boulevard and Makaloa Street)

Table A-1. Summary of Existing Transmission Line Facilities and Loading Information for Each Segment of the Proposed Project

HECO : EAST OAHU TRANSMISSION PROJECT - 46 kV PHASED PROJECT

					Existing Line Configuration				
Filename	Phase	Segment	Segment Location/Description	Specific Location	Line Type	Line Voltage	Circuit Name	Amp	Conductor Size
HECO_1AE	1	A	Makaloa Substation to Poni Street	Between Kaheka and Poni Streets	U/G	46 kV	Archer 41	62	600 kcm
HECO_1AP					U/G	46 kV	Archer 43	0	600 kcm
					U/G	46 kV	Archer 46	120	600 kcm
					U/G	12 kV	Pawaa Kai	-105	750 PILC-PJ
					U/G	12 kV	Shopping Center	-195	750 PILC-PJ
					U/G	12 kV	Kona Street	-95	750 PILC-PJ
HECO_1BE	1	B	Poni Street to McCully Substation	Fern Street between Punahou and Hauoli Streets	U/G	46 kV	Archer 41	-62	600 kcm
HECO_1BP					U/G	46 kV	Archer 43	0	600 kcm
					U/G	46 kV	Archer 46	-120	600 kcm
					U/G	12 kV	Pawaa Kai	108	750 PILC-PJ
					U/G	12 kV	Shopping Center	190	750 PILC-PJ
					U/G	12 kV	Kona Street	91	750 PILC-PJ
					O/H	12 kV	McCully 5	32	336 Al
HECO_1CE	1	C	McCully Substation Along Pumehana St.	Between Lime and Date Streets	O/H	46 kV	Archer 41	0	556 AAC
HECO_1CP			to Date Street		O/H	12 kV	McCully 1	175	336 Al
			(Connects Pukele #2 to Archer #41)						
HECO_1DE	1	D	Kamoku Substation at Date Street	Date Street West of Kamoku Sub	U/G	138 kV	Kewalo-Kamoku	45	3000 CU HPFF
HECO_1DP					O/H	46 kV	Pukele 4	-264	556 AAC
					O/H	12 kV	Moilili 1	29	336 Al
					U/G	25 kV	Kamoku 9	-54	1000 PEICN
					U/G	25 kV	Kamoku 10	-65	1000 PEICN
HECO_1EE	1	E	Kamoku Substation at Date Street	Date Street East of Kamoku Sub	O/H	46 kV	Pukele 4	-264	556 AAC
HECO_1EP					O/H	12 kV	Moilili 1	0	336 Al
HECO_1FE	1	F	Winam Avenue	Winam Avenue	O/H	12 kV	Kanaina	-5	#4
HECO_1FP			(Between Hoolulu St.and Mooheau -	between Hoolulu and Winam Streets					
			Connects Pukele #4 to Kamoku East)						
HECO_1GE	1	G	Date Street	Between Pumehana and McCully Streets	O/H	46 kV	Pukele 2	0	556 AAC
HECO_1GP			(Near Pumehana St to McCully)		O/H	12 kV	McCully 1	0	336 Al
HECO_2HE	1	H	Kapiolani Blvd	Between McCully & Wiliwili Streets	U/G	138 kV	Kewalo-Kamoku	-45	3000 CU HPFF
HECO_2HP			(At Ala Wai Park - Pukele #4)		O/H	46 kV	Pukele 4	185	556 AAC
					O/H	12 kV	Hawaiian Village #2	-50	336 Al
					U/G	25 kV	Kamoku 9	50	1000 PEICN
					U/G	25 kV	Kamoku 10	64	1000 PEICN
HECO_2IE	2	I	Archer Substation Along King Street	Between Ward Avenue and Victoria Street			None		
HECO_2IP									
HECO_2JE	2	J	Archer Substation Along Kapiolani	Between Clayton Street and Ward Avenue	U/G	138 kV	Archer-Kewalo #1	-35	3000 CU HPFF
HECO_2JP			(to Kamakee Street - Circuits #41, 43, 46)		U/G	138 kV	Archer-Kewalo #2	-35	3000 CU HPFF
					U/G	46 kV	Archer 41	-125	1500 kcm
					U/G	46 kV	Archer 43	-164	1500 kcm
					U/G	46 kV	Archer 46	-289	1500 kcm
HECO_2KE	2	K	Along Kapiolani from Piikoi to Makaloa Sub	Sheridan Street	U/G	46 kV	Archer 41	-62	1500 kcm
HECO_2KP			(Circuits #41, 43, 46)	between Kapiolani and Makaloa Streets	U/G	46 kV	Archer 43	-74	1500 kcm
					U/G	46 kV	Archer 46	-289	1500 kcm
					O/H	12 kV	Kewalo 1	-24	336 Al

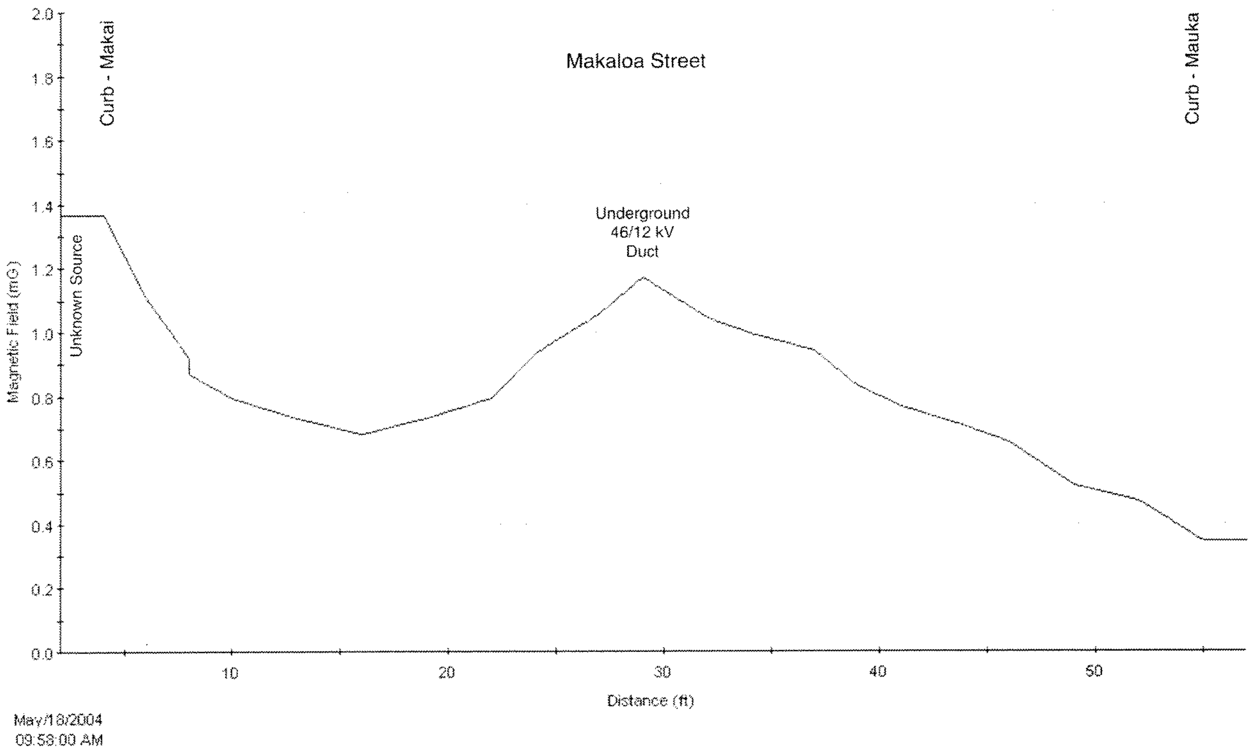
Table A-2. Summary of Proposed Transmission Line Facilities and Loading Information for Each Segment of the Proposed Project

HECO : EAST OAHU TRANSMISSION PROJECT - 46 kV PHASED PROJECT

					Proposed Line Configuration					
Filename	Phase	Segment	Segment Location/Description	Specific Location	Line Type	Line Voltage	Circuit Name	Amp	**Pukele Outage Amp**	Conductor Size
HECO_1AE	1	A	Makaloa Substation to Poni Street	Between Kaheka and Poni Streets	U/G	46 kV	Archer 41	248	**262**	1500 kcm
HECO_1AP					U/G	46 kV	Archer 46	405	**682**	1500 kcm
					U/G	12 kV	Pawaa Kai	-17	**-17**	750 PILC-PJ
					U/G	12 kV	Shopping Center	0	**0**	750 PILC-PJ
					U/G	12 kV	Kona Street	0	**0**	750 PILC-PJ
HECO_1BE	1	B	Poni Street to McCully Substation	Fern Street between Punahou and Hauoli Streets	U/G	46 kV	Archer 41	-248	**-262**	1500 kcm
HECO_1BP					U/G	46 kV	Archer 46	-405	**-682**	1500 kcm
					O/H	12 kV	McCully 5	32	**32**	336 Al
HECO_1CE	1	C	McCully Substation Along Pumehana St.	Between Lime and Date Streets	O/H	46 kV	Archer 41	0	**0**	556 AAC
HECO_1CP			to Date Street		O/H	12 kV	McCully 1	175	**175**	336 Al
			(Connects Pukele #2 to Archer #41)		U/G	46 kV	Archer 46	405	**682**	1500 kcm
HECO_1DE	1	D	Kamoku Substation at Date Street	Date Street West of Kamoku Sub	U/G	138 kV	Kewalo-Kamoku	220	**348**	3000 CU HPFF
HECO_1DP					O/H	46 kV	Kamoku West	-341	**-339**	1500 kcm
					O/H	12 kV	Moilili 1	29	**29**	336 Al
					U/G	25 kV	Kamoku 9	-54	**-54**	1000 PEICN
					U/G	25 kV	Kamoku 10	-65	**-65**	1000 PEICN
HECO_1EE	1	E	Kamoku Substation at Date Street	Date Street East of Kamoku Sub	O/H	46 kV	Kamoku East	245	**562**	1500 kcm
HECO_1EP					O/H	12 kV	Moilili 1	0	**0**	336 Al
HECO_1FE	1	F	Winam Avenue	Winam Avenue	U/G	46 kV	Kamoku East	-245	**-562**	1500 kcm
HECO_1FP			(Between Hoolulu St.and Mooheau -	between Hoolulu and Winam Streets	O/H	12 kV	Kanaina	-5	**-5**	#4
			Connects Pukele #4 to Kamoku East)							
HECO_1GE	1	G	Date Street	Between Pumehana and McCully Streets	O/H	46 kV	Archer 46	-405	**-682**	556 AAC
HECO_1GP			(Near Pumehana St to McCully)		O/H	12 kV	McCully 1	0	**0**	336 Al
HECO_2HE	1	H	Kapiolani Blvd	Between McCully & Wiliwili Streets	U/G	138 kV	Kewalo-Kamoku	-220	**-348**	3000 CU HPFF
HECO_2HP			(At Ala Wai Park - Pukele #4)		O/H	46 kV	Kamoku West	261	**259**	1500 kcm
					O/H	12 kV	Hawaiian Village #2	-54	**-54**	336 Al
					U/G	25 kV	Kamoku 9	50	**50**	1000 PEICN
					U/G	25 kV	Kamoku 10	64	**64**	1000 PEICN
HECO_2IE	2	I	Archer Substation Along King Street	Between Ward Avenue and Victoria Street	U/G	46 kV	Archer 45	0	**-280**	1500 kcm
HECO_2IP					U/G	46 kV	Archer 47	0	**-326**	1500 kcm
					U/G	46 kV	Archer 48	0	**-649**	1500 kcm
HECO_2JE	2	J	Archer Substation Along Kapiolani	Between Clayton Street and Ward Avenue	U/G	138 kV	Archer-Kewalo #1	-119	**-182**	3000 CU HPFF
HECO_2JP			(to Kamakee Street - Circuits #41, 43, 46)		U/G	138 kV	Archer-Kewalo #2	-119	**-182**	3000 CU HPFF
					U/G	46 kV	Archer 41	-501	**-489**	1500 kcm
					U/G	46 kV	Archer 43	-284	**-278**	1500 kcm
					U/G	46 kV	Archer 46	-439	**-682**	1500 kcm
HECO_2KE	2	K	Along Kapiolani from Piikoi to Makaloa Sub	Sheridan Street	U/G	46 kV	Archer 41	-438	**-428**	1500 kcm
HECO_2KP			(Circuits #41, 43, 46)	between Kapiolani and Makaloa Streets	U/G	46 kV	Archer 43	-194	**-190**	1500 kcm
					U/G	46 kV	Archer 46	-439	**-682**	1500 kcm
					O/H	12 kV	Kewalo 1	-24	**-24**	336 Al

APPENDIX B

Magnetic Field Measurements at Segment Locations



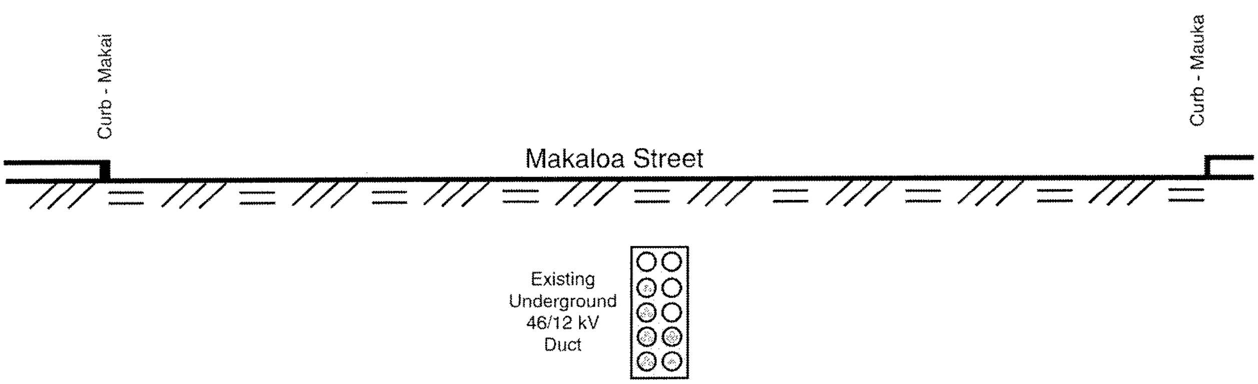


Figure B-1. Magnetic Field Measurements at Segment 'A'
(Makaloa Street between Kaheka and Poni Streets)

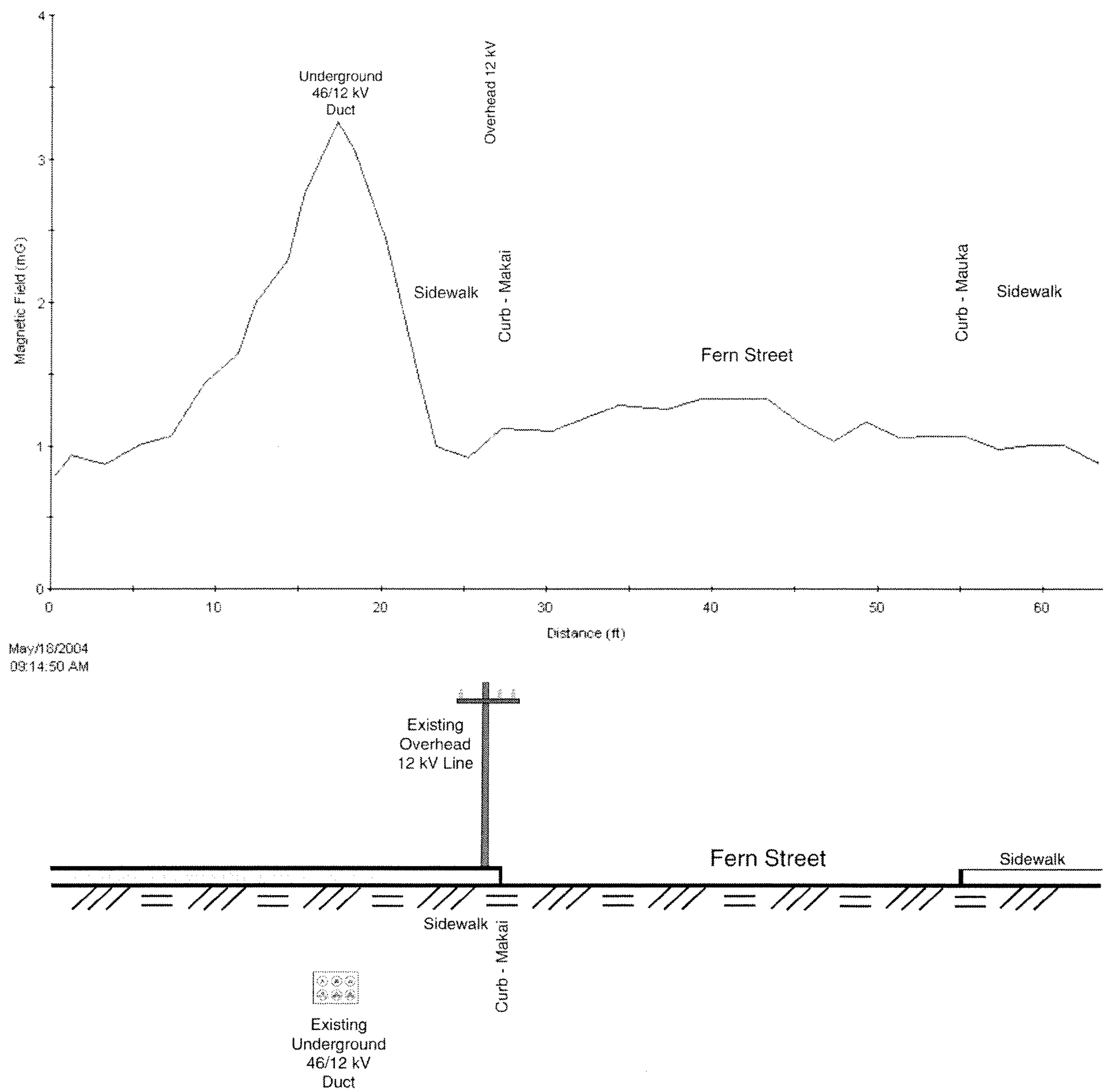
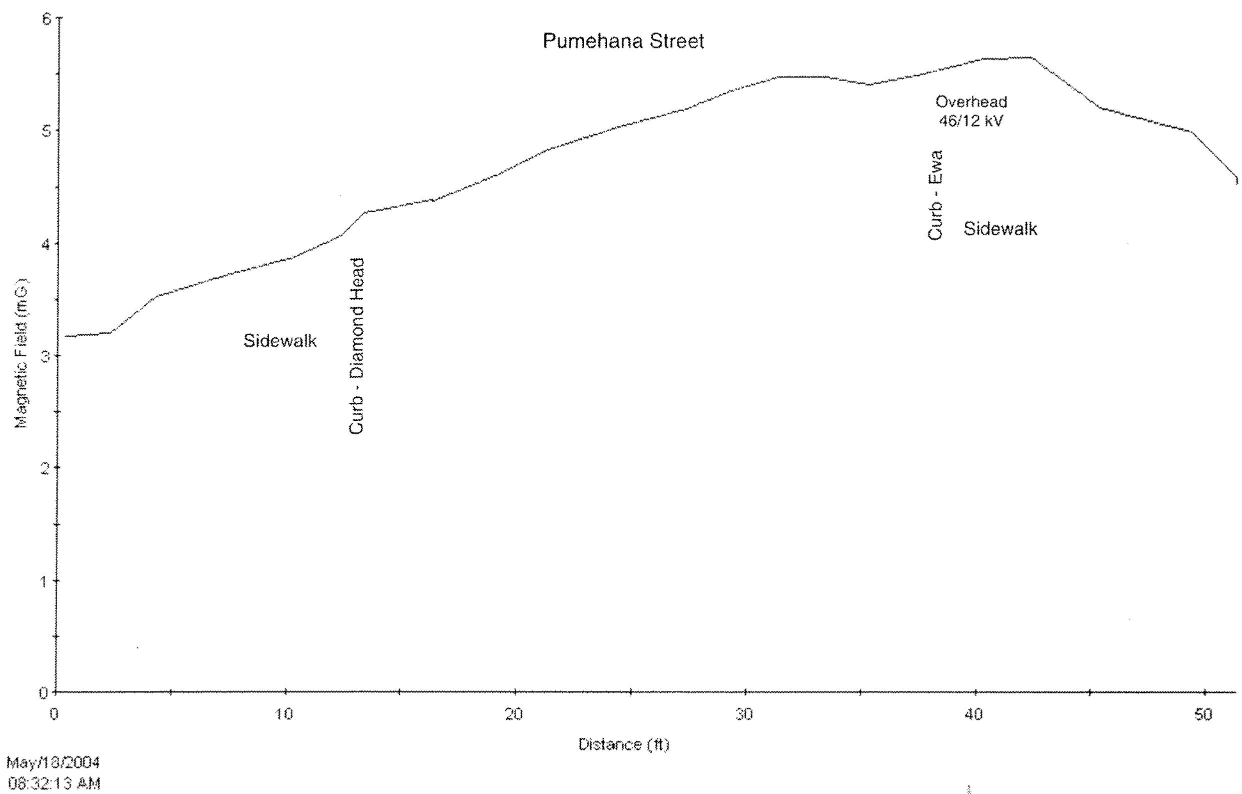


Figure B-2. Magnetic Field Measurements at Segment 'B'
(Fern Street between Punahou and Hauoli Streets)



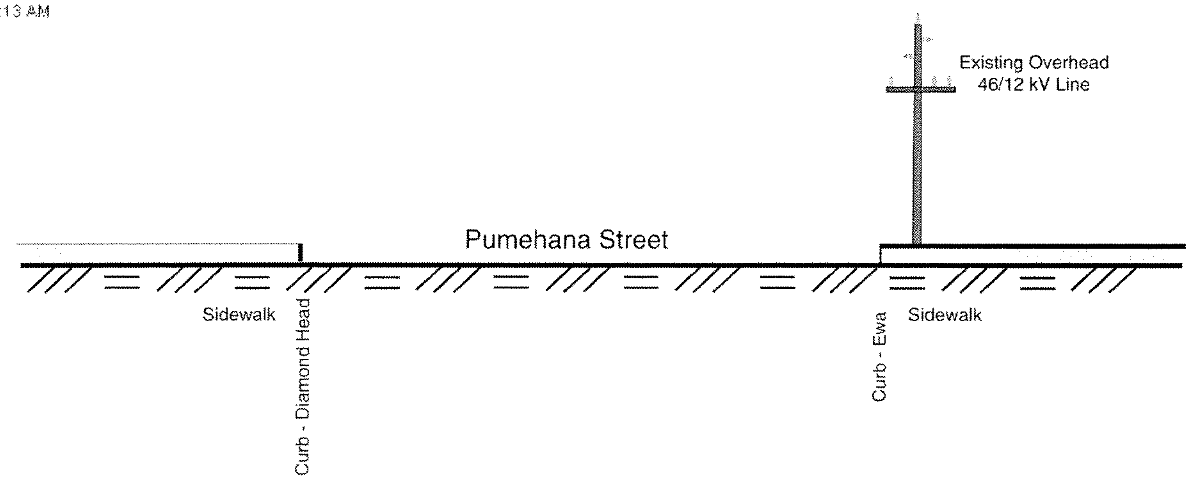


Figure B-3. Magnetic Field Measurements at Segment 'C'
(Pumehana Street between Lime and Date Streets)

Date Street

Overhead
46/12 kV

Underground
138/25 kV
Duct

Curb - Mauka

Curb - Makai

Sidewalk

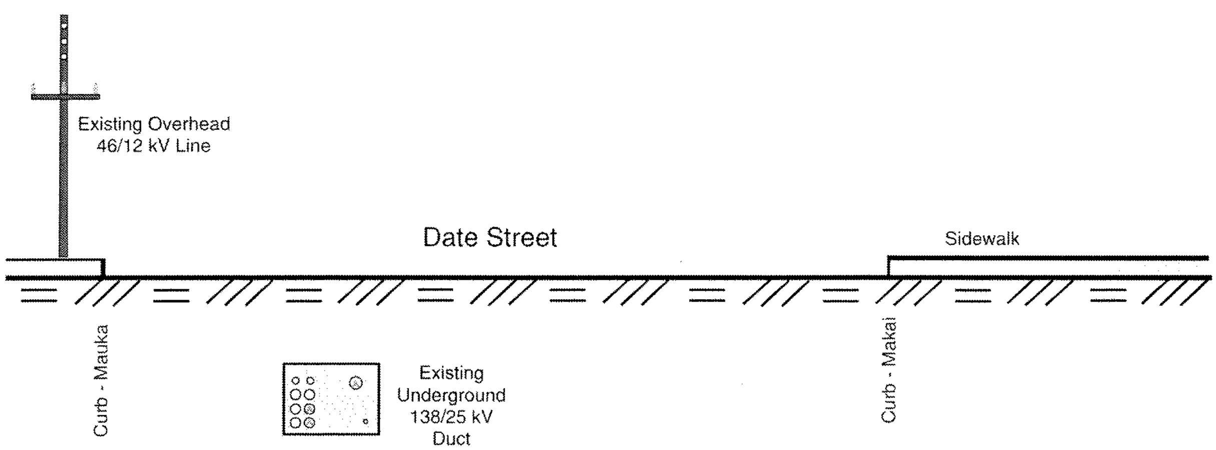


Figure B-4. Magnetic Field Measurements at Segment 'D'
(Date Street west of Kamoku Substation)

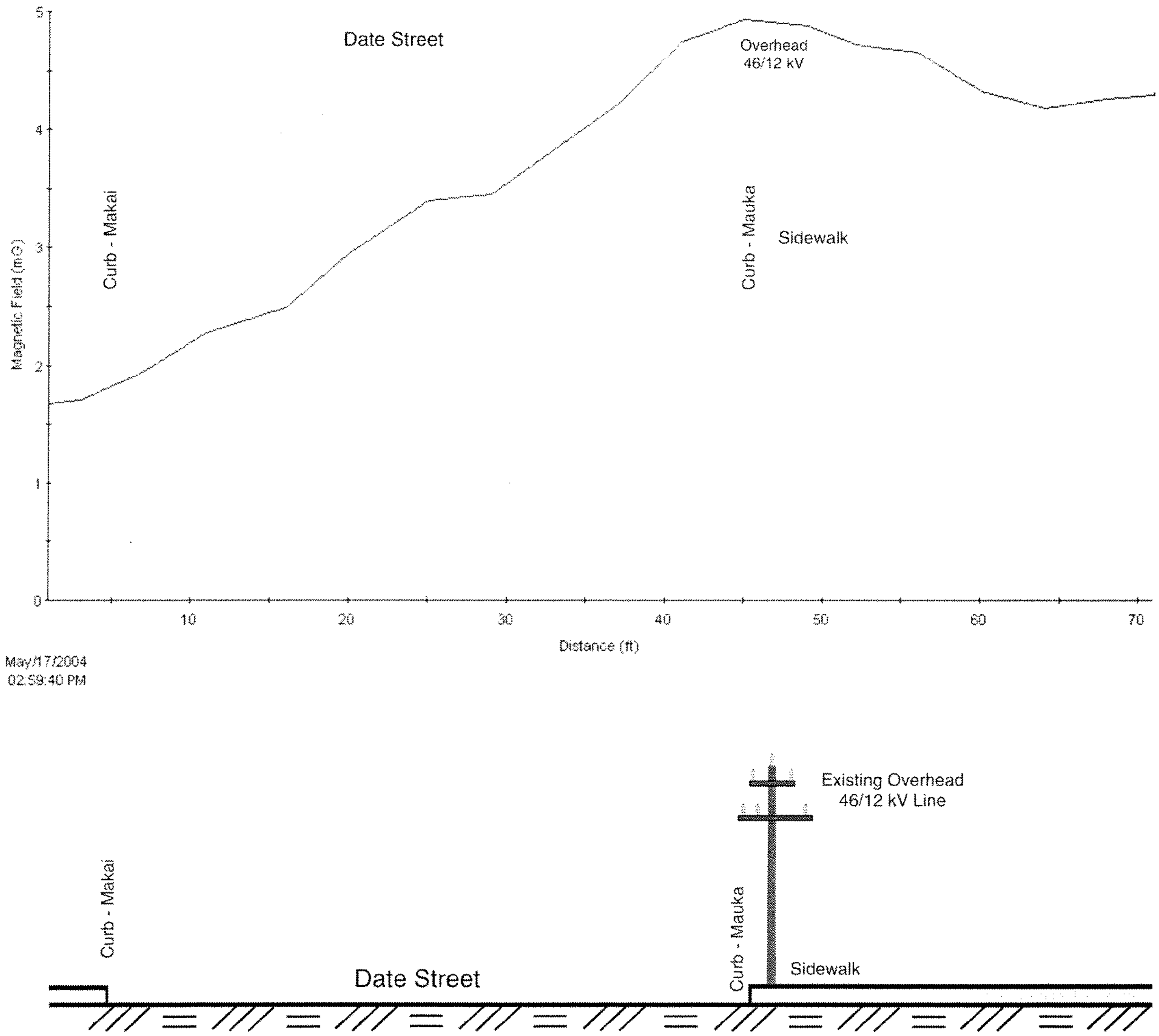


Figure B-5. Magnetic Field Measurements at Segment ‘E’
(Date Street east of Kamoku Substation)

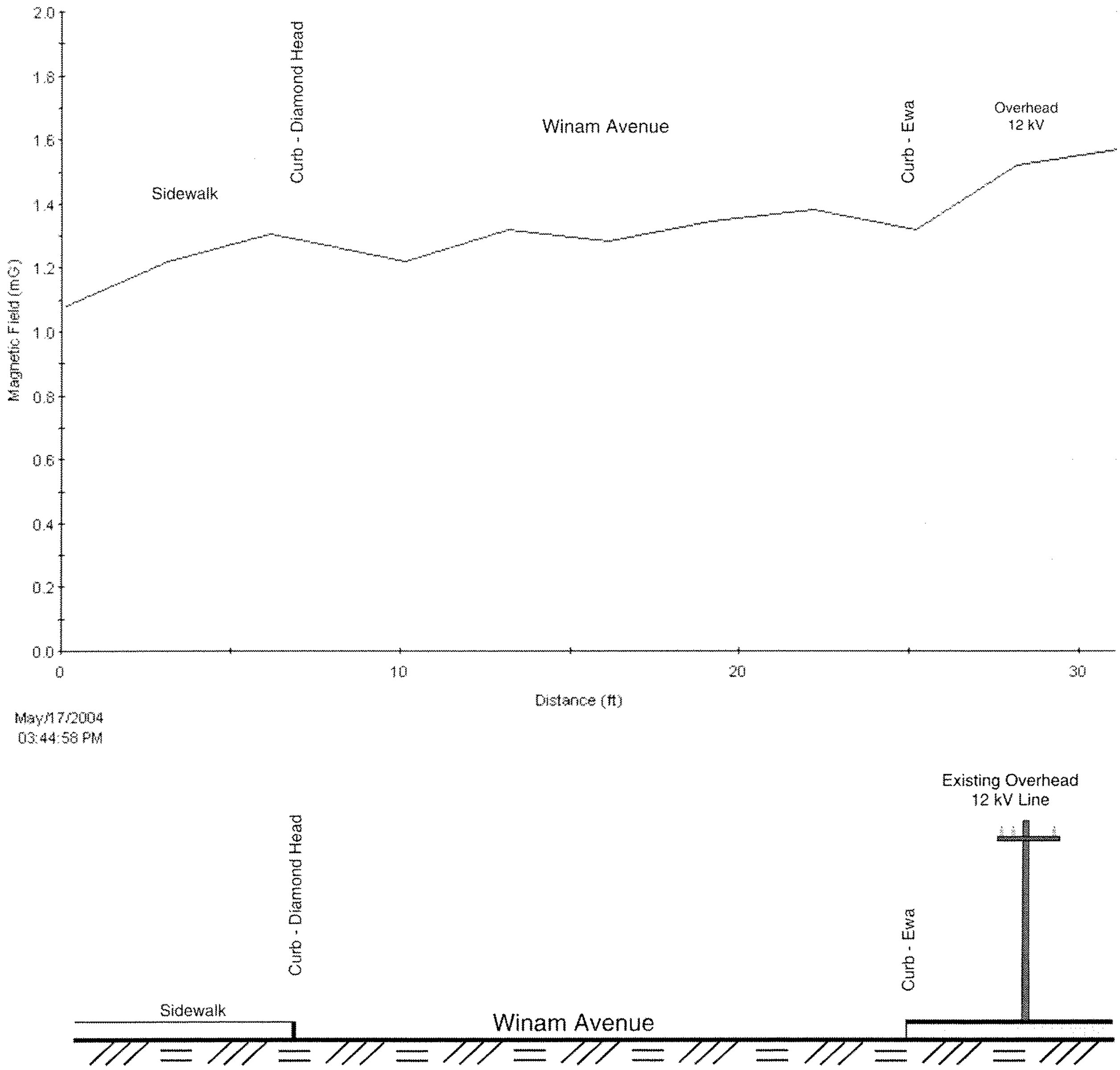


Figure B-6. Magnetic Field Measurements at Segment 'F'
(Winam Avenue between Hoolulu and Mooheau Streets)

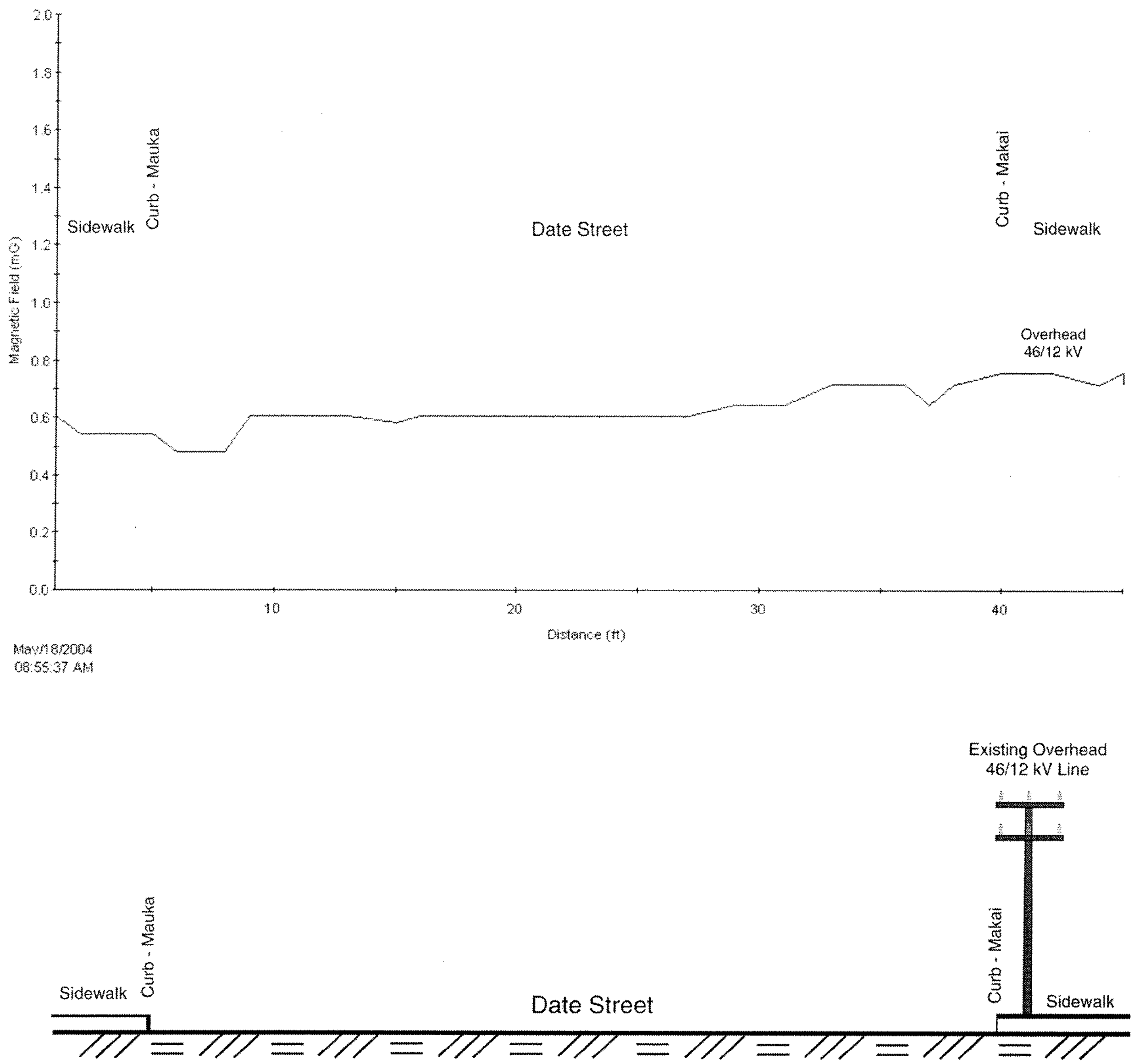
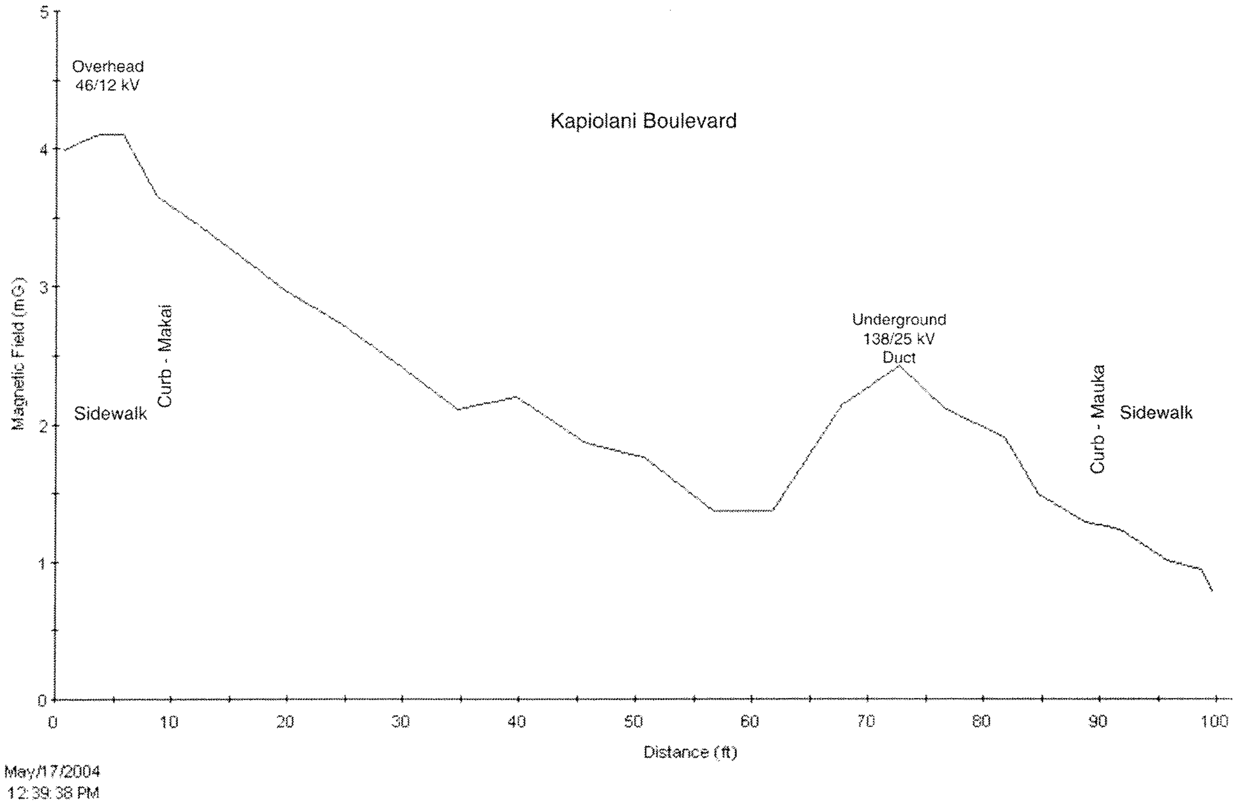


Figure B-7. Magnetic Field Measurements at Segment 'G'
(Date Street between Pumehana and McCully Streets)



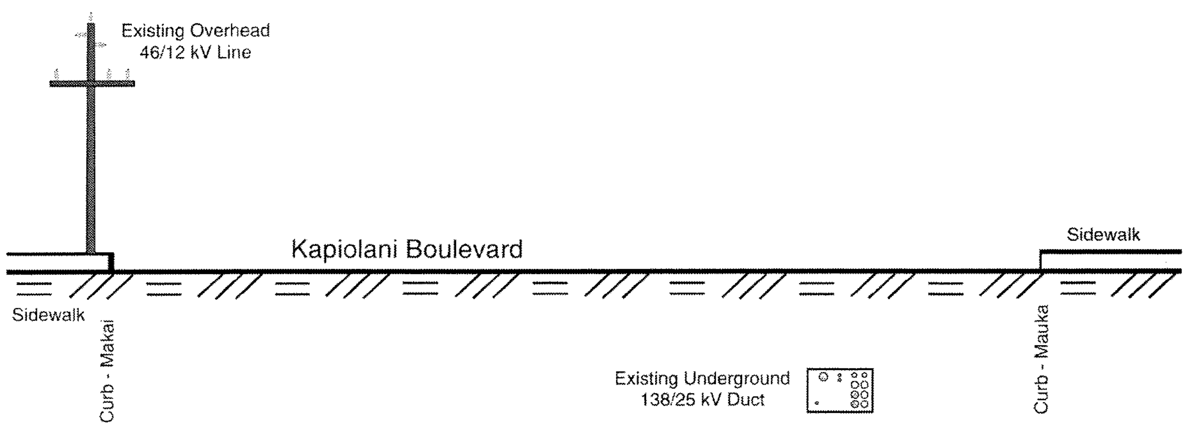
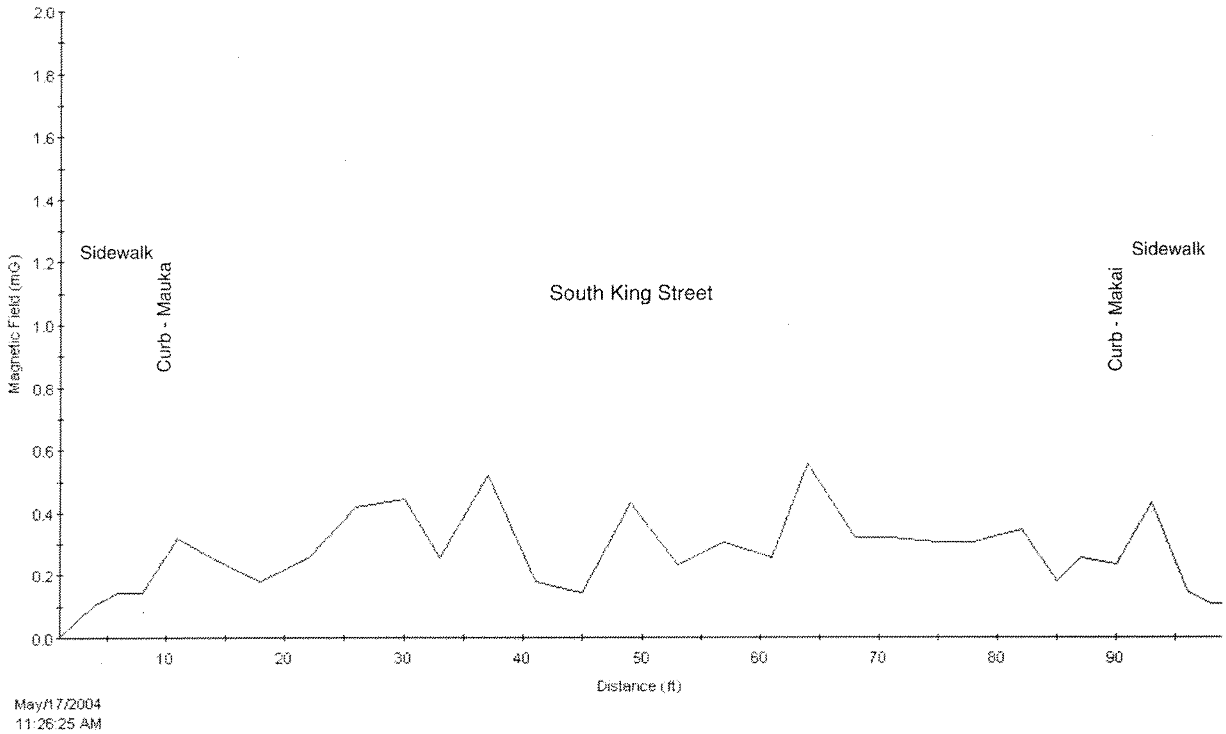


Figure B-8. Magnetic Field Measurements at Segment 'H'
(Kapiolani Boulevard between Wiliwili and McCully Streets)



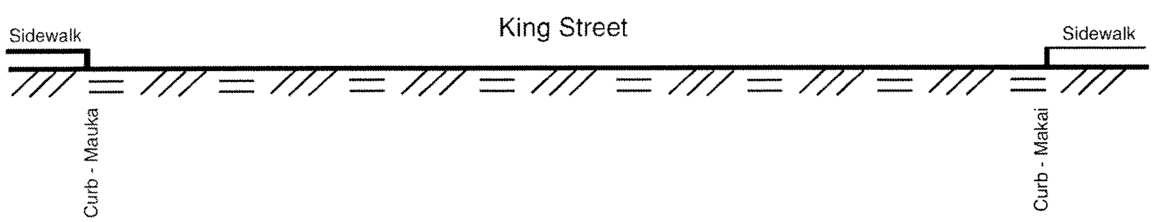
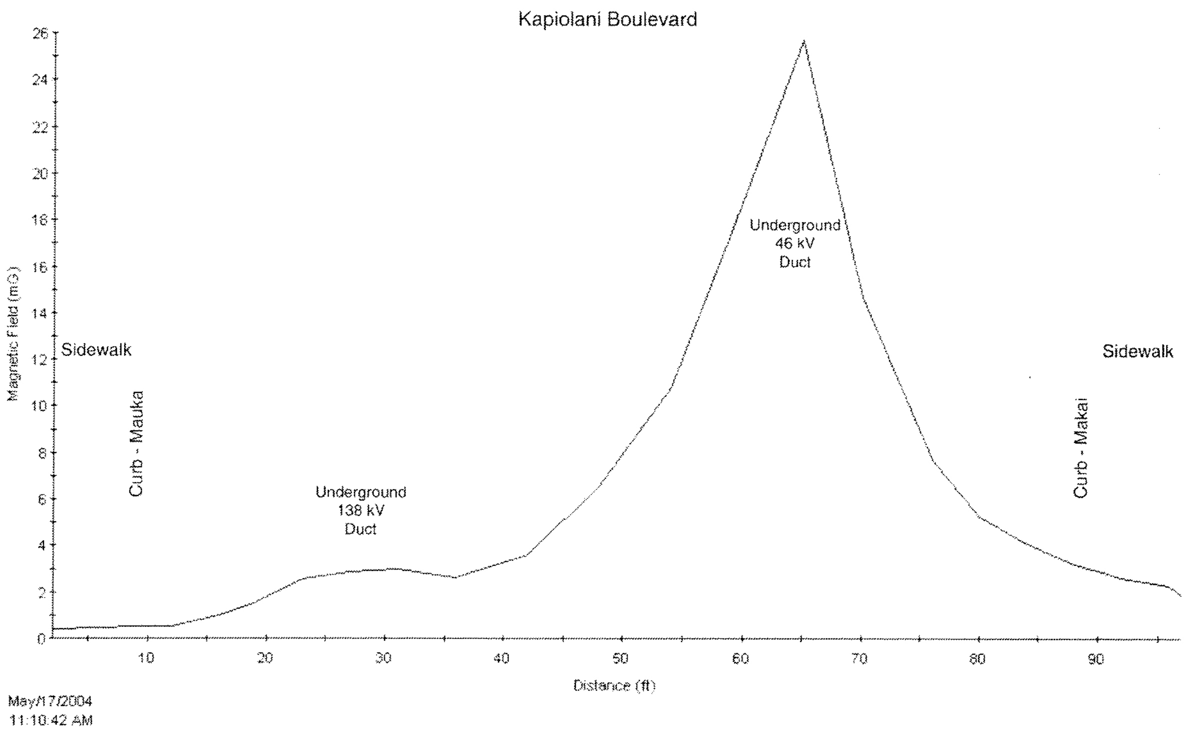


Figure B-9. Magnetic Field Measurements at Segment 'I'
(King Street between Ward Avenue and Victoria Street)



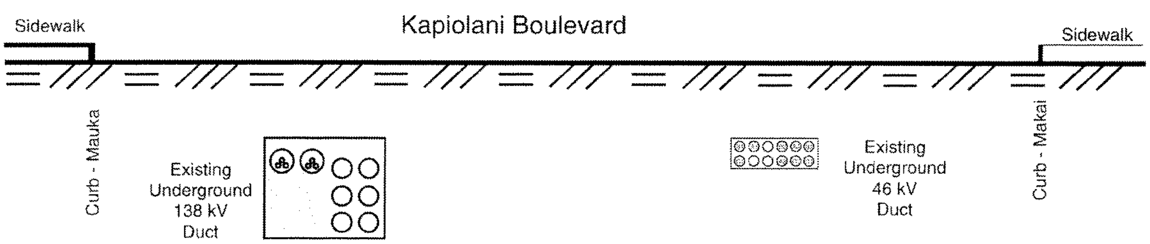


Figure B-10. Magnetic Field Measurements at Segment 'J'
(Kapiolani Boulevard between Clayton Street and Ward Avenue)

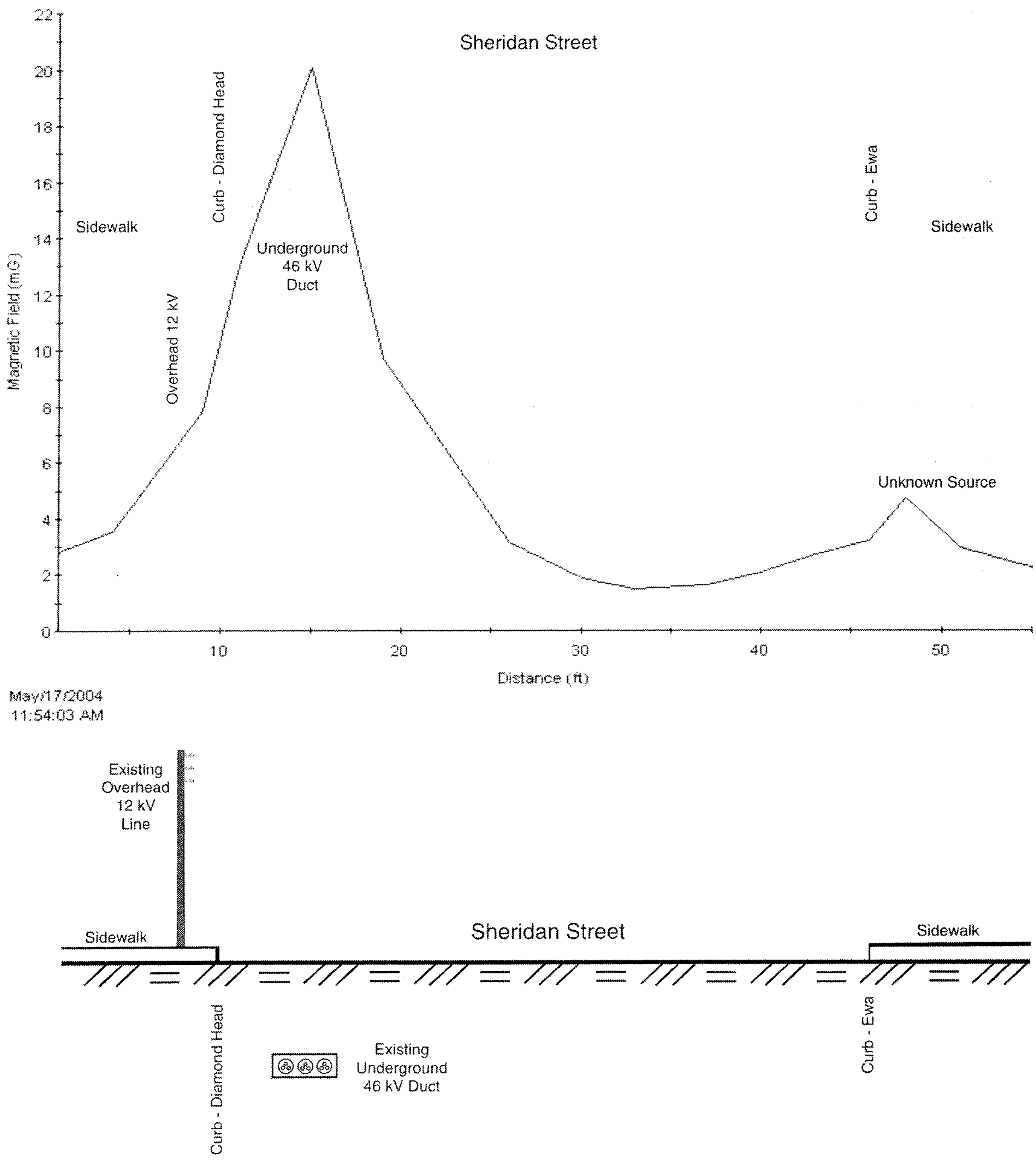


Figure B-11. Magnetic Field Measurements at Segment 'K'
(Sheridan Street between Kapiolani Boulevard and Makaloa Street)

Table B-1. Summary of Line Loading for Each Segment During Field Measurements

Segment	Date	Time	Power Line Name	Load Range (Amps)
A	May 18, 2004	9:58 AM	Archer 41	163 - 173
			Archer 43	0
			Archer 46	100 - 108
			Pawaa Kai	88 - 106
			Shopping Center	180
			Kona Street	84 - 91
B	May 18, 2004	9:14 AM	Archer 41	147 - 159
			Archer 43	0
			Archer 46	100 - 108
			McCully #5	29 - 30
			Pawaa Kai	94 - 111
			Shopping Center	175
			Kona Street	79 - 88
C	May 18, 2004	8:30 AM	Archer 41	0
			McCully #1	167 - 170
D	May 17, 2004	2:45 PM	Kewalo - Kamoku	39
			Kamoku 9	49 - 51
			Kamoku 10	59 - 61
			Pukele #4	240
			Moiliili #1	21 - 34
E	May 17, 2004	2:58 PM	Pukele #4	240
			Moiliili #1	0
F	May 17, 2004	3:44 PM	Kanaina	3 - 9
G	May 18, 2004	8:54 AM	Pukele #2	0
			McCully #1	0
H	May 17, 2004	12:39 PM	Kewalo - Kamoku	38
			Kamoku 9	45 - 48
			Kamoku 10	57 - 60
			Pukele #4	240
			Hawaiian Village #2	47 - 55
I	May 17, 2004	11:25 AM	No Circuits	N/A
J	May 17, 2004	11:10 AM	Archer - Kewalo #1	36
			Archer - Kewalo #2	30
			Archer 41	194
			Archer 43	121
			Archer 46	226
K	May 17, 2004	11:55 AM	Archer 41	158 - 168
			Archer 43	66 - 70
			Archer 46	230
			Kewalo #1	20 - 27

APPENDIX C

Magnetic Field Profile Calculations at Segment Locations

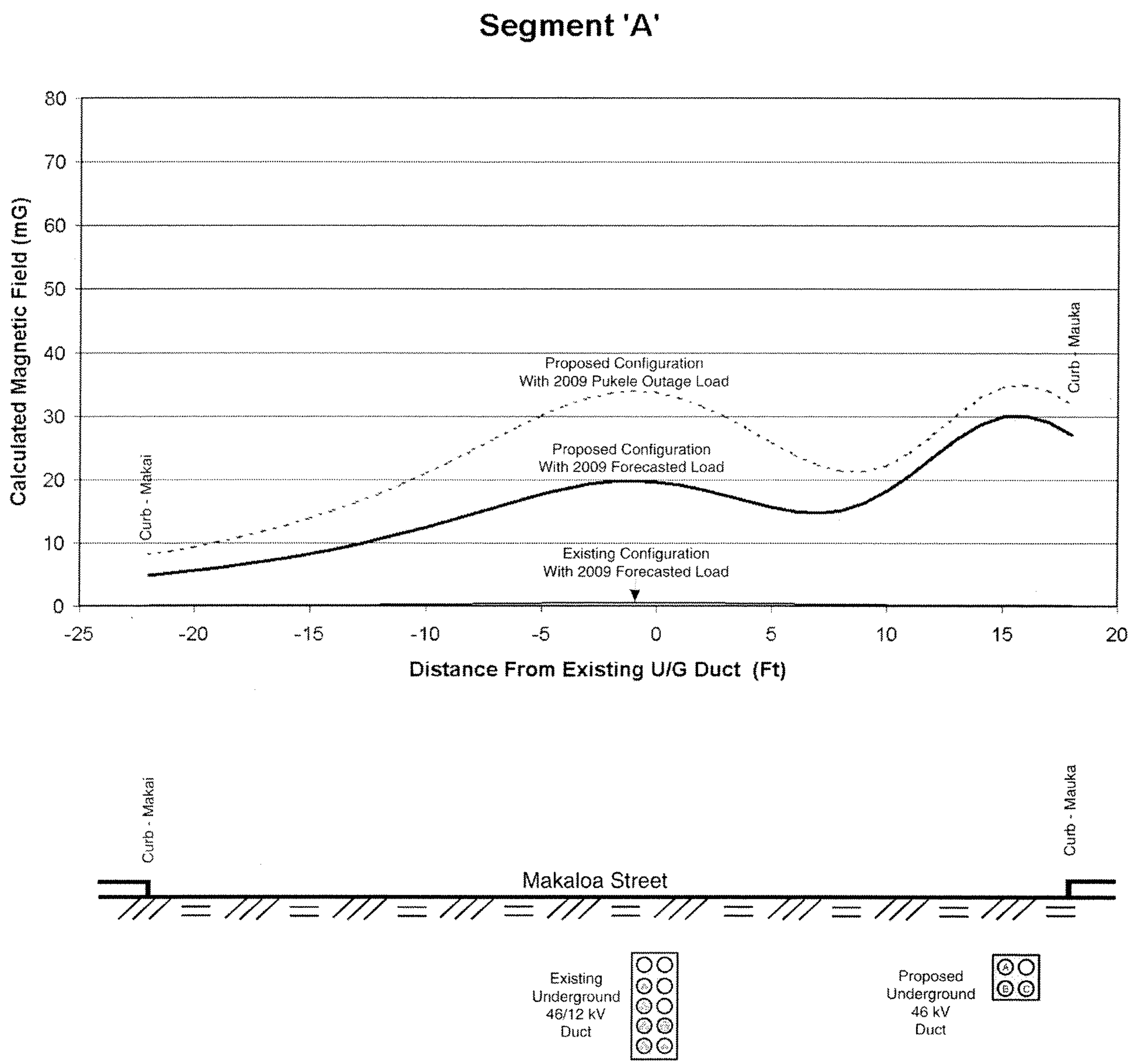


Figure C-1. Magnetic Field Calculations at Segment 'A'

(Makaloa Street between Kaheka and Poni Streets :
three existing 46 kV underground circuits would be replaced with two 46 kV circuits
(one circuit in a new duct), while three existing 12 kV underground circuits would remain)

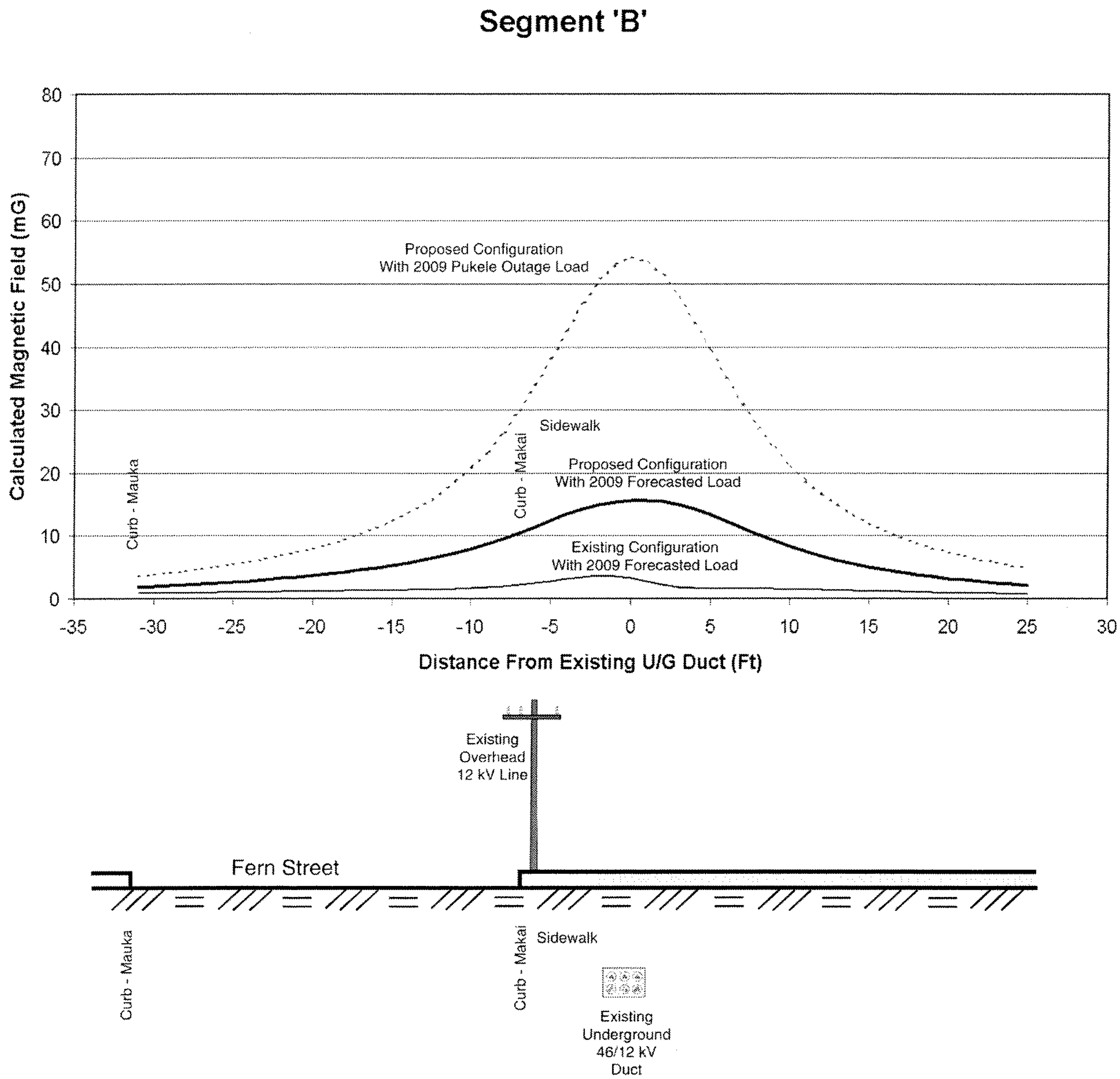


Figure C-2. Magnetic Field Calculations at Segment 'B'

(Fern Street between Punahou and Hauoli Street :
three existing 46 kV underground circuits and three 12 kV underground circuits would be replaced with two 46 kV underground circuits within the existing duct, an existing 12 kV overhead distribution line would remain)

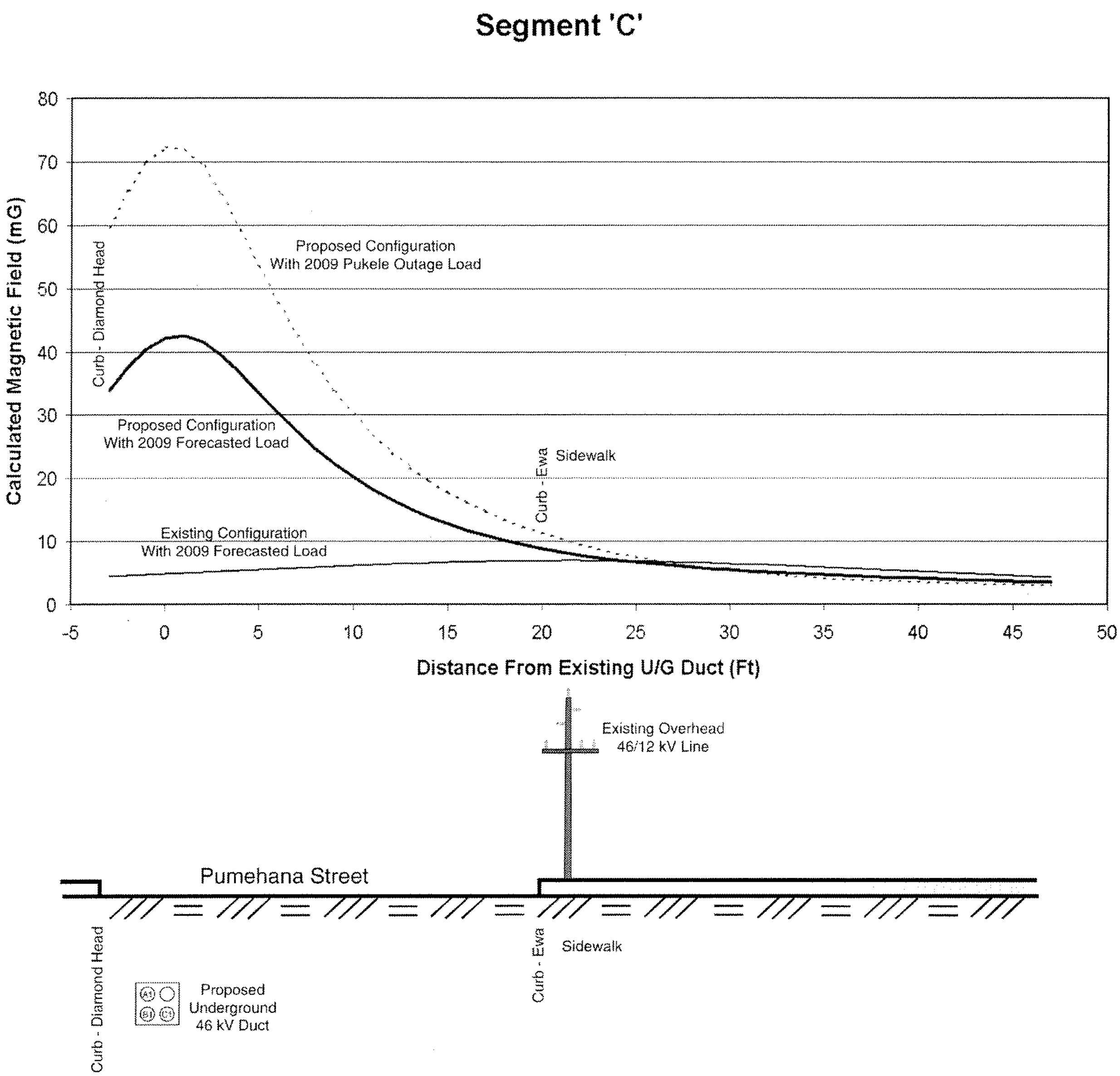
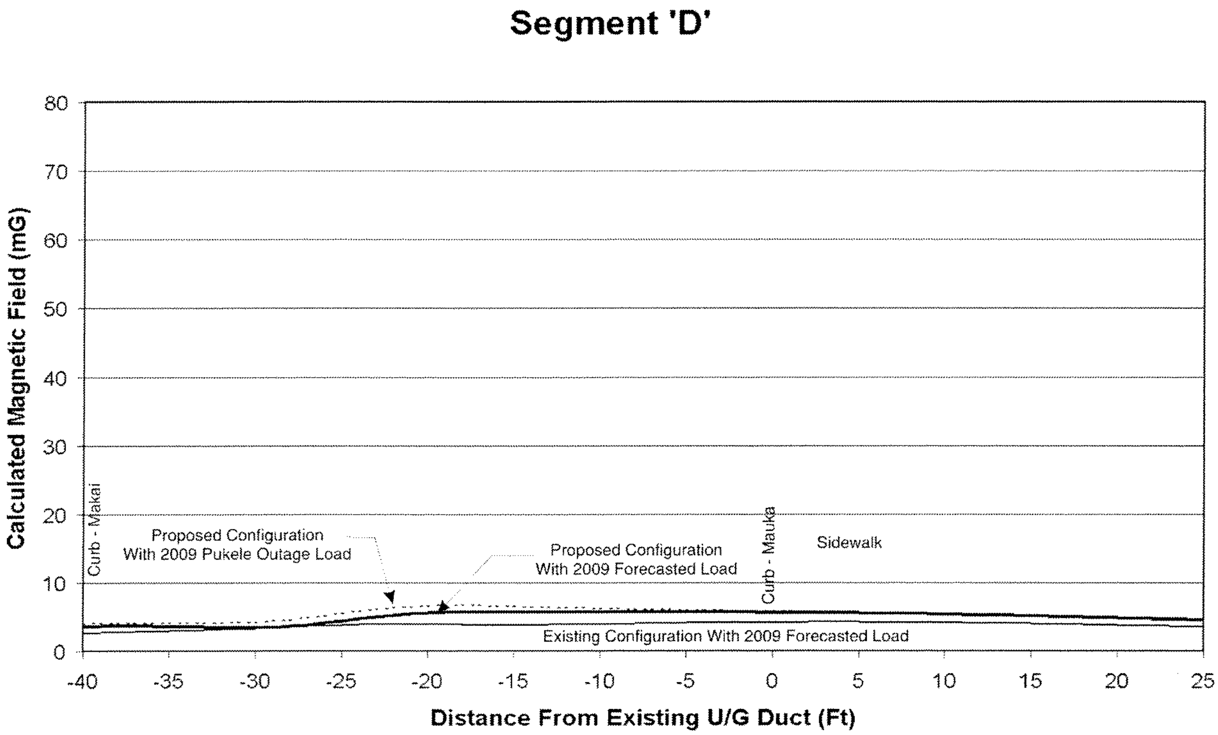


Figure C-3. Magnetic Field Calculations at Segment 'C'

(Pumehana Street between Lime and Date Streets :
one new 46 kV underground circuit would be installed in new duct,
an existing 46 kV and 12 kV overhead power line would remain)



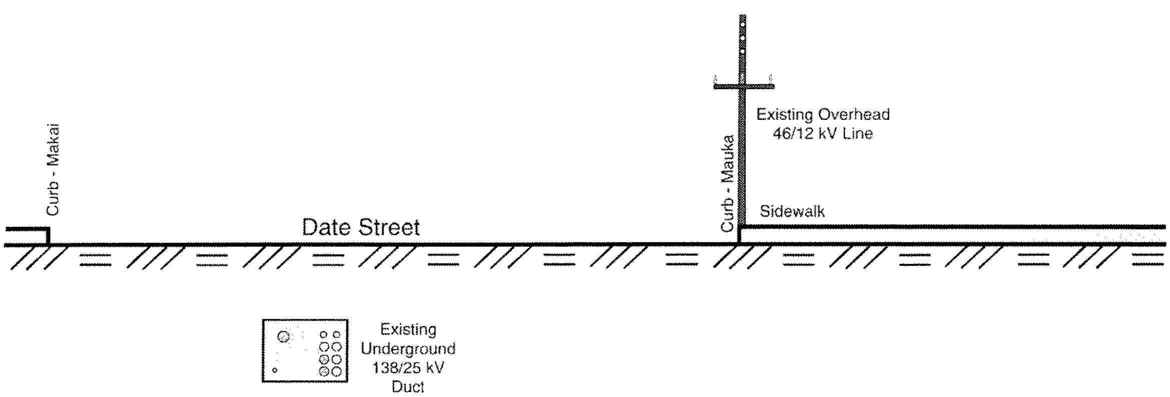


Figure C-4. Magnetic Field Calculations at Segment 'D'

(Date Street west of Kamoku Substation :
one new 46 kV underground intertie would cross Date Street
(from the substation to a new pole) and feed an existing 46 kV overhead circuit,
one existing 138 kV and two existing 25 kV underground circuits would remain,
one existing 12 kV overhead circuit would also remain)

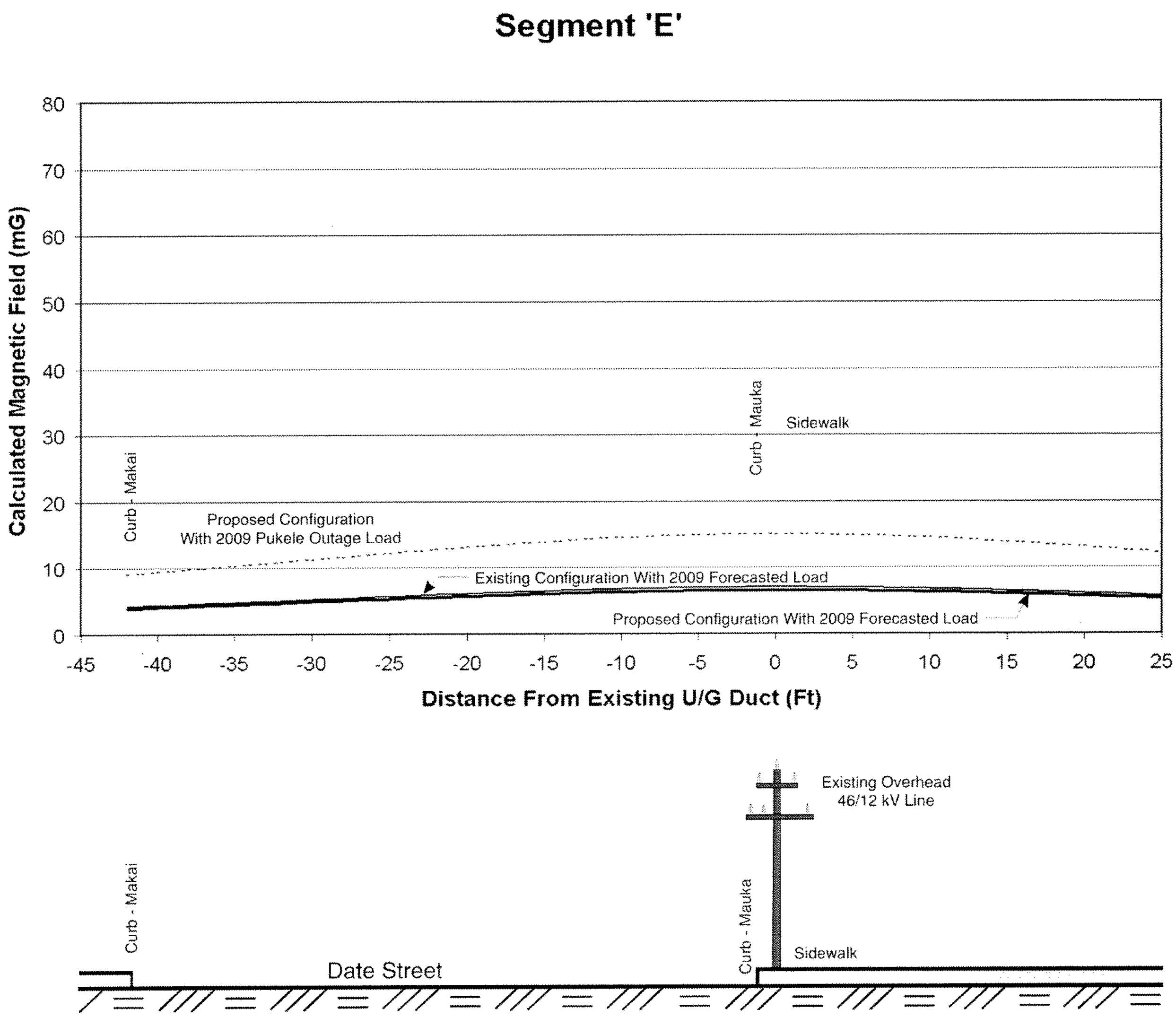


Figure C-5. Magnetic Field Calculations at Segment 'E'

(Date Street east of Kamoku Substation :
one new 46 kV underground intertie would travel down and cross Date Street
(from the substation to an existing pole) and feed an existing 46 kV overhead circuit,
a segment of the existing 46 kV circuit between segments 'D' and 'E' would be removed,
an existing 12 kV overhead circuit would remain)

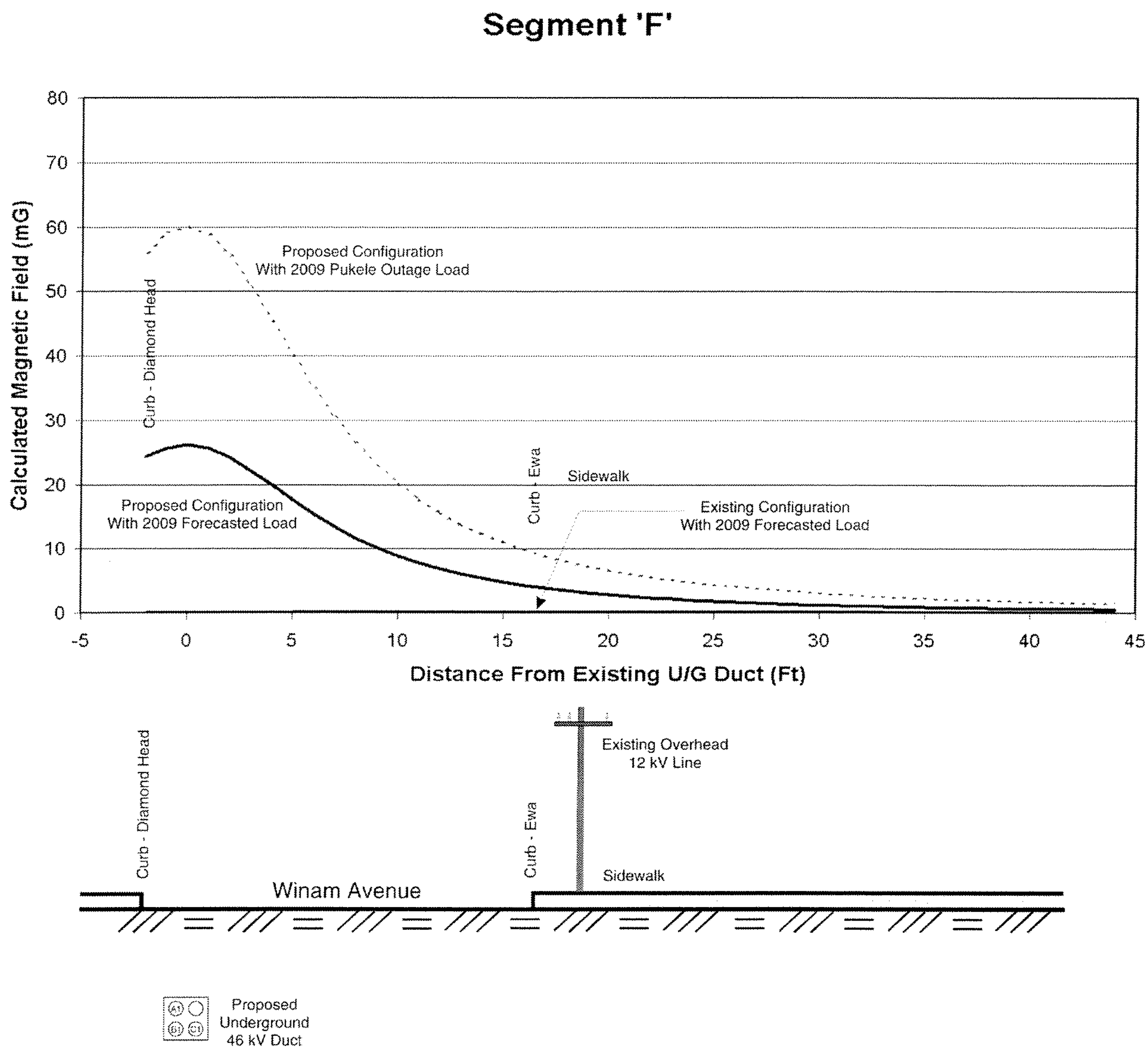


Figure C-6. Magnetic Field Calculations at Segment 'F'

(Winam Avenue between Hoolulu and Mooheau Streets :
one new 46 kV underground circuit in a new duct would connect
two existing 46 kV overhead circuits, an existing 12 kV overhead circuit would remain)

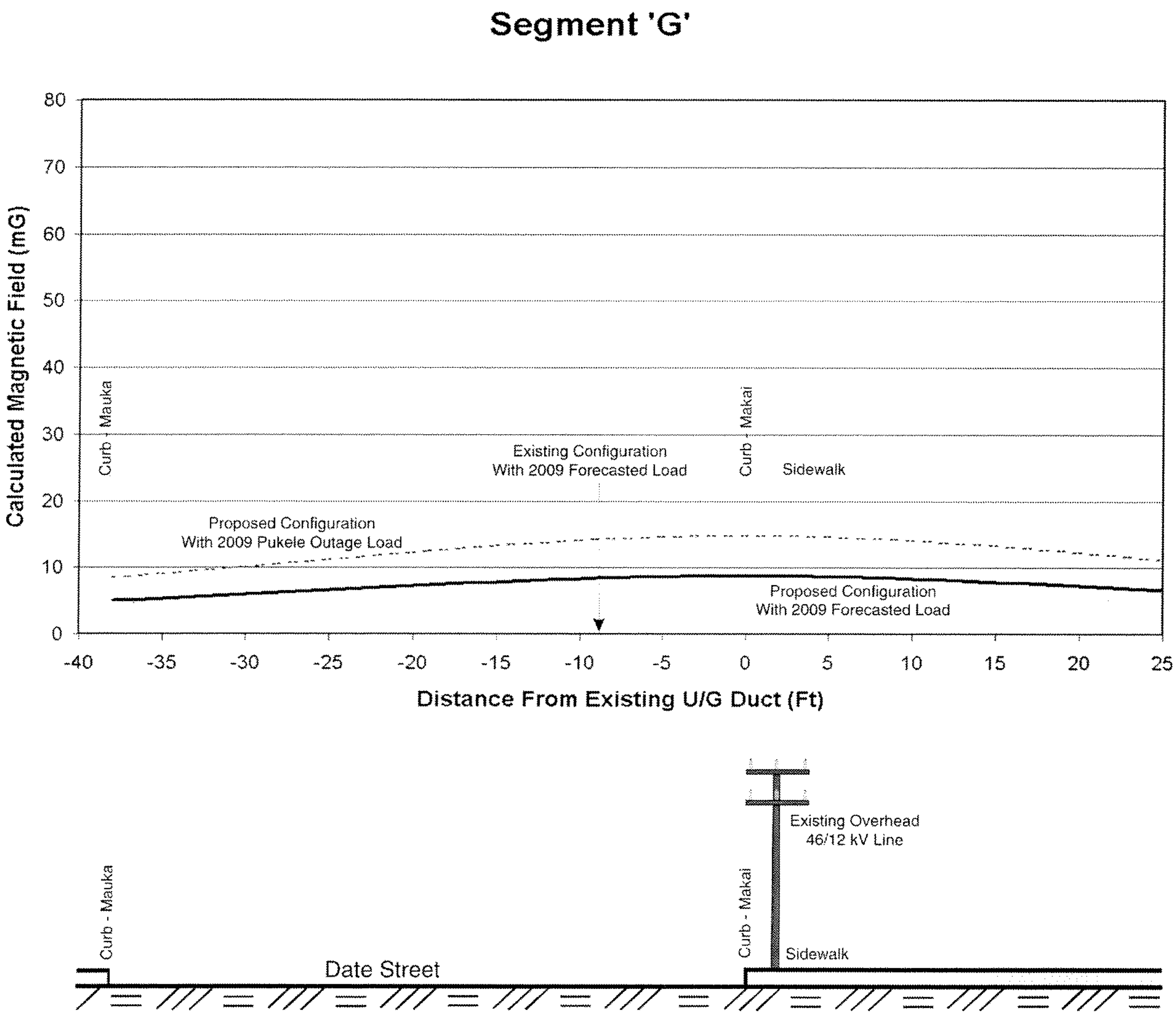


Figure C-7. Magnetic Field Calculations at Segment 'G'

(Date Street between Pumehana and McCully Streets :
one existing 46 kV overhead circuit would have increased loading,
an existing 12 kV underbuild circuit would remain)

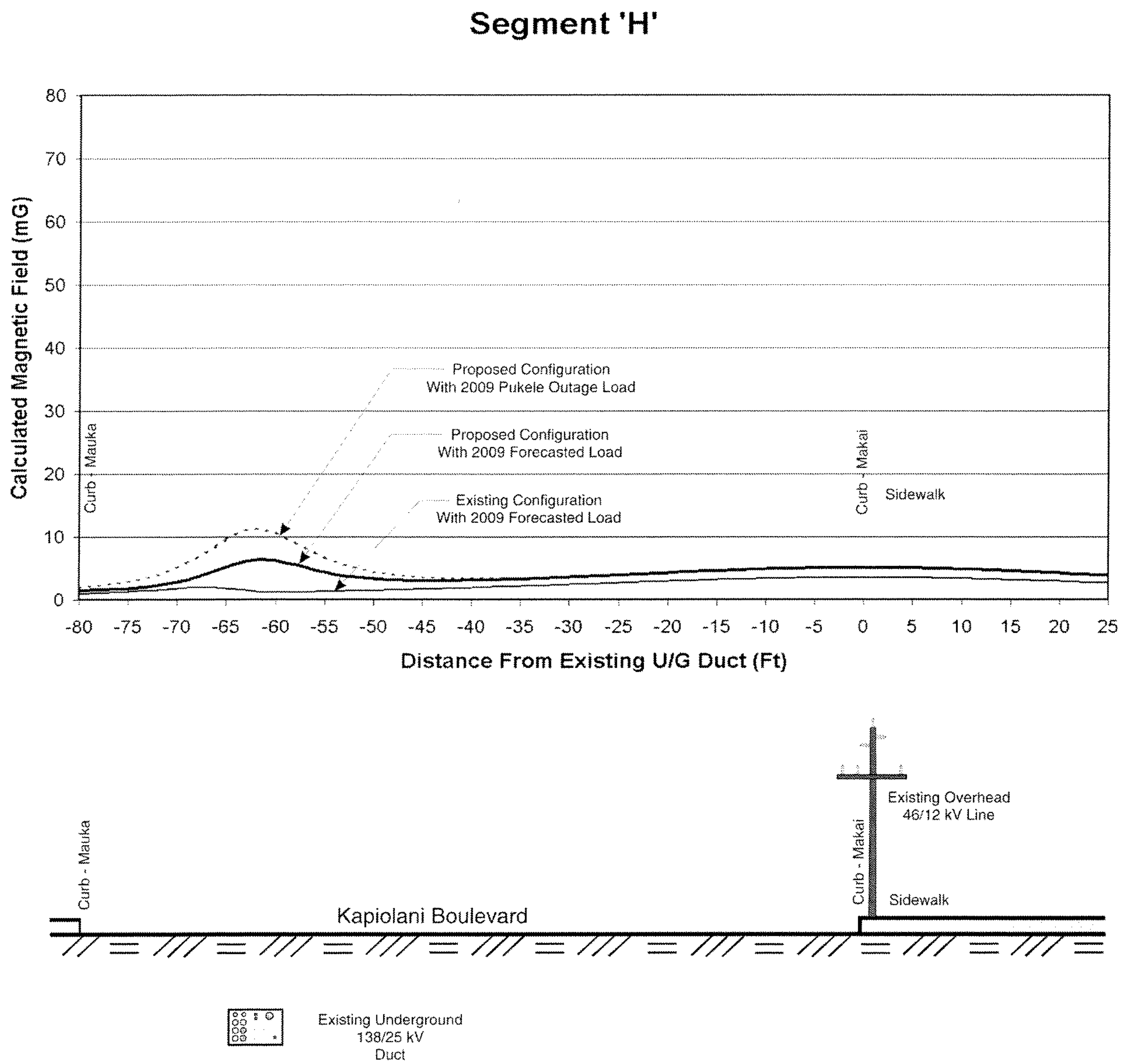
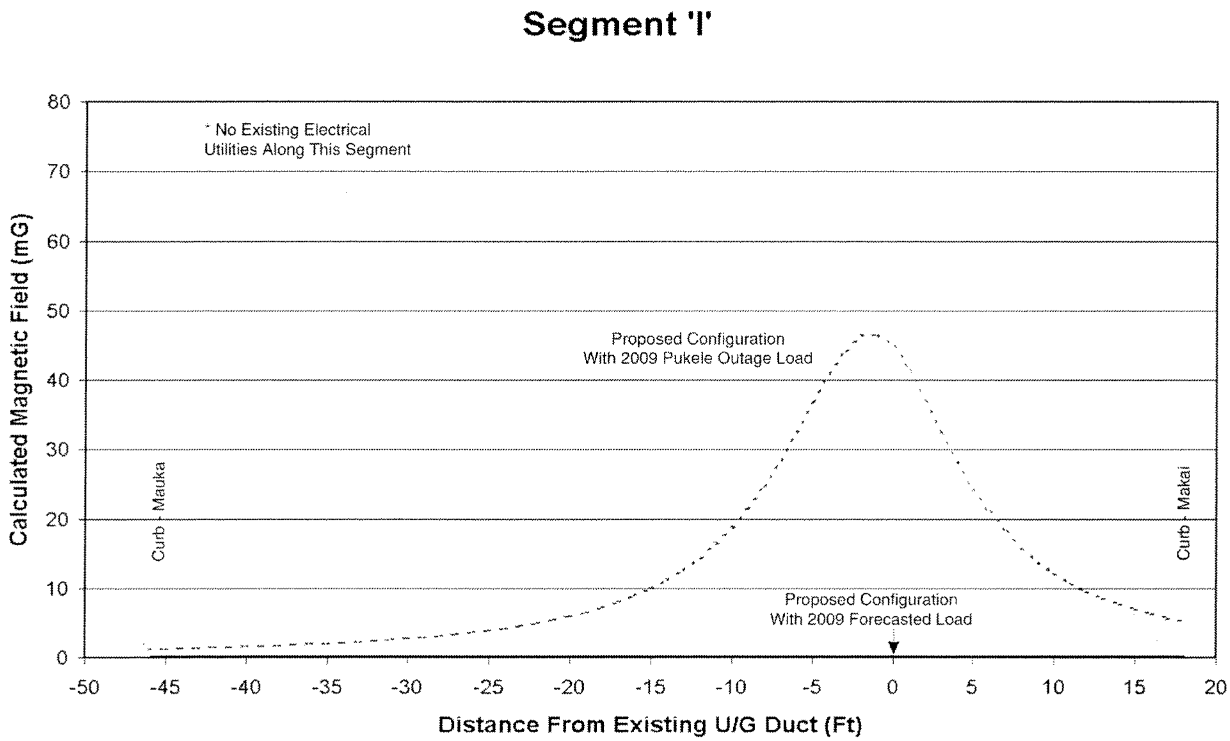


Figure C-8. Magnetic Field Calculations at Segment 'H'

(Kapiolani Boulevard between Wiliwili and McCully Streets :
one existing 46 kV overhead circuit would have increased loading,
an existing 12 kV underbuild circuit would remain,
one existing 138 kV and two existing 25 kV underground circuits remain)



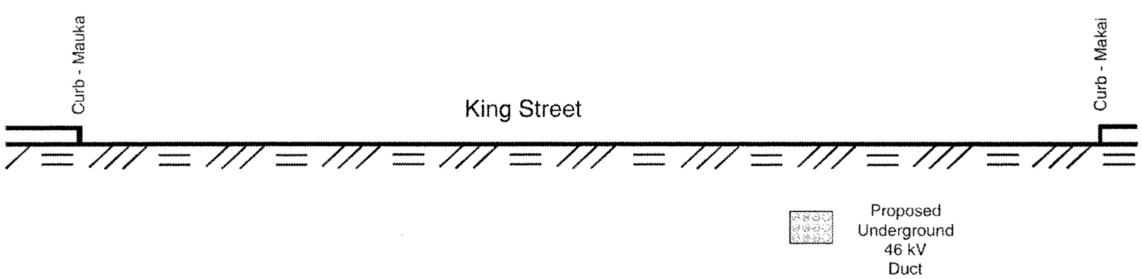
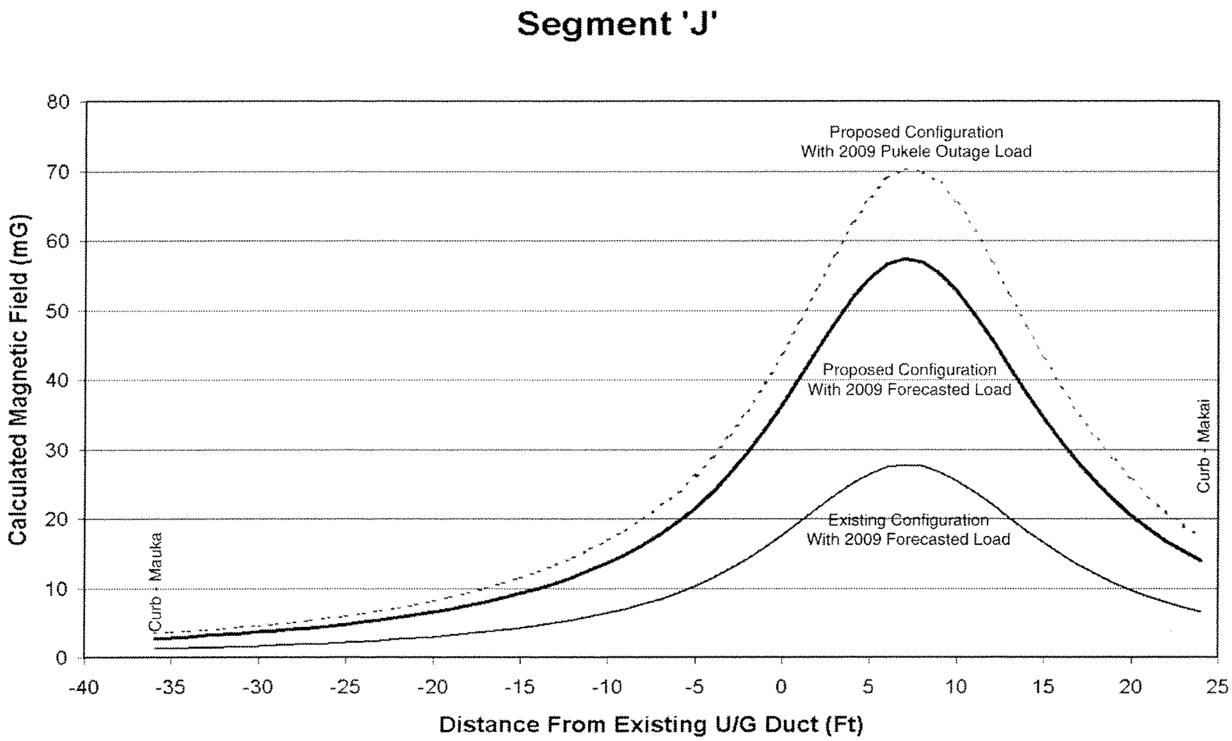


Figure C-9. Magnetic Field Calculations at Segment 'I'

(King Street between Ward Avenue and Victoria Street :
three new 46 kV underground circuits would be installed in a new duct)



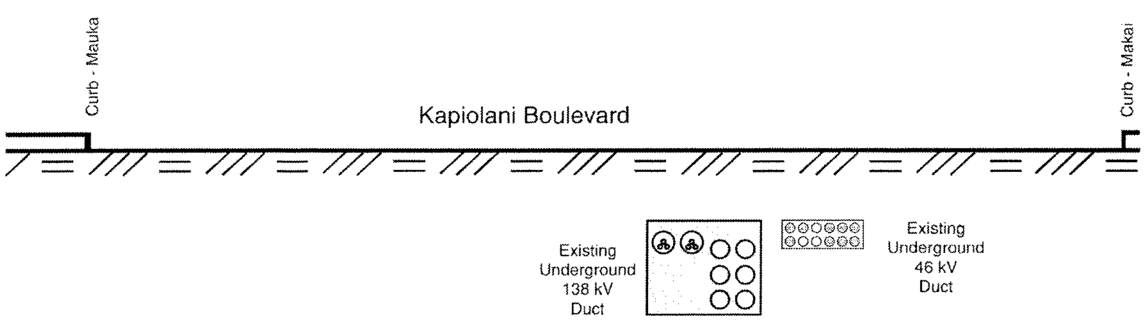


Figure C-10. Magnetic Field Calculations at Segment 'J'

(Kapiolani Boulevard between Clayton Street and Ward Avenue :
three existing 46 kV underground circuits would have increased loading,
two existing 138 kV underground circuits would remain)

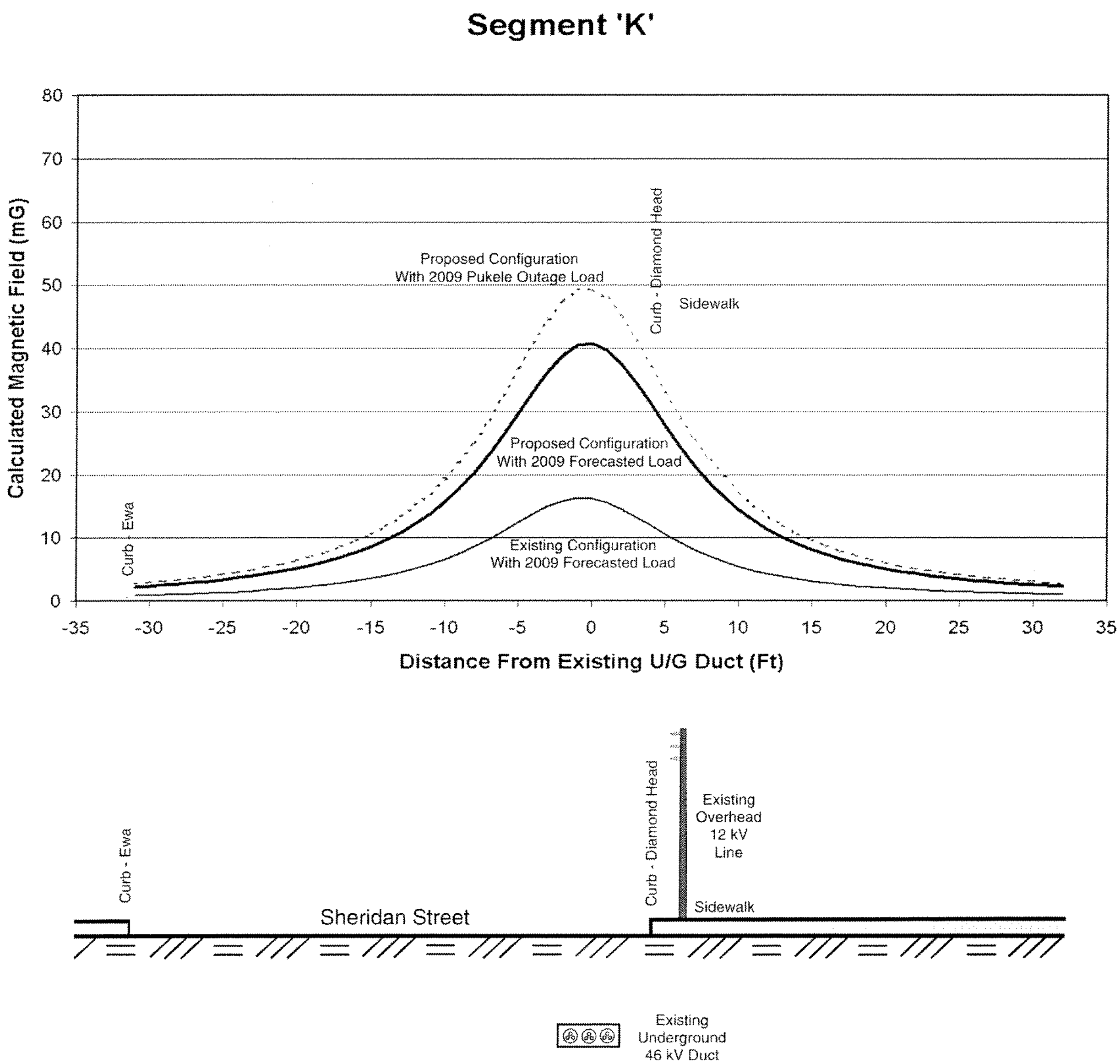


Figure C-11. Magnetic Field Calculations at Segment 'K'

(Sheridan Street between Kapiolani Boulevard and Makaloa Street :
three existing 46 kV underground circuits would have increased loading,
one existing 12 kV overhead circuit would remain)

APPENDIX D

Segment 'J' Phasing Analysis

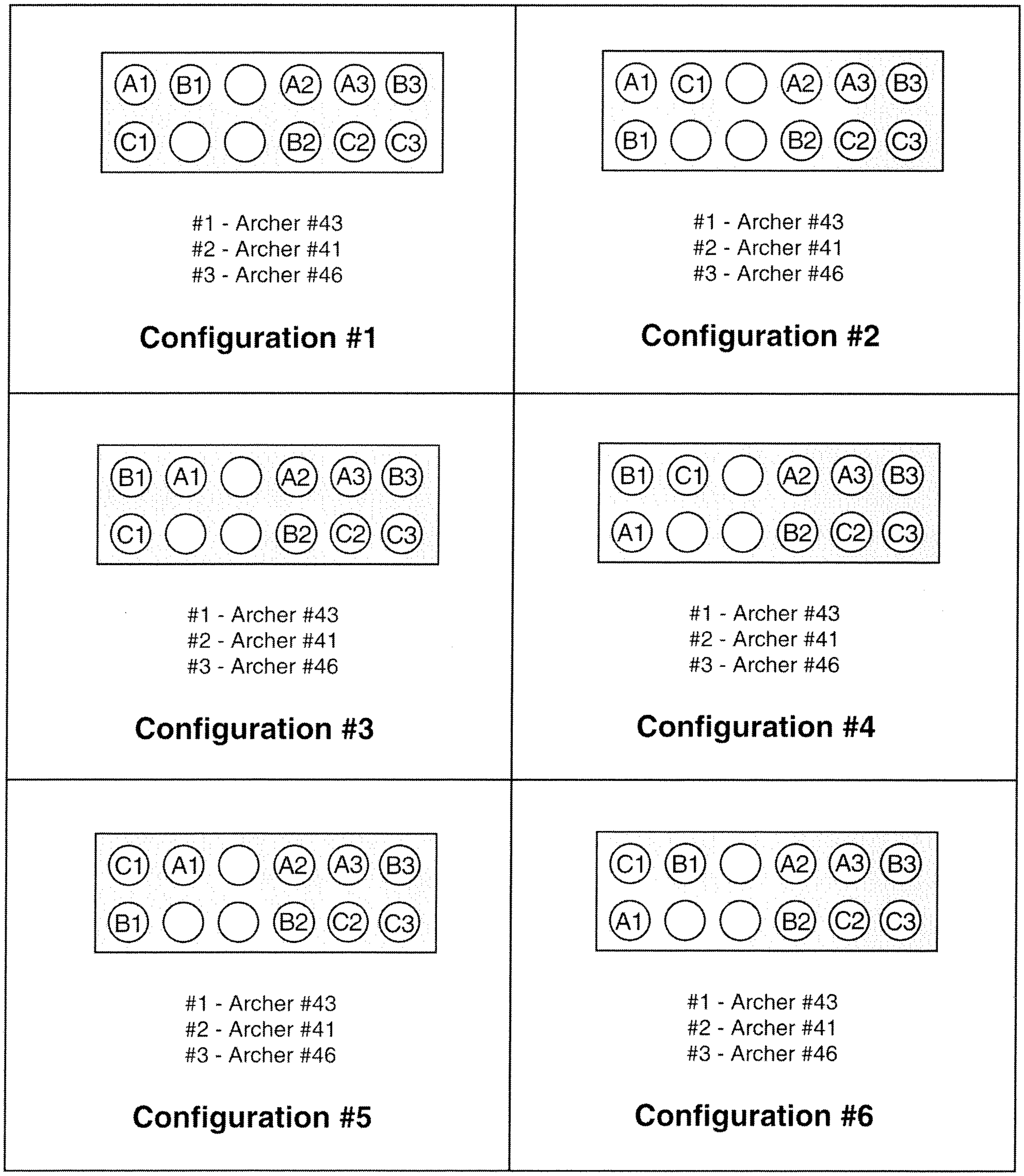


Figure D-1. Segment ‘J’ Phasing Configurations #1 - #6

Table D-1. Calculated Magnetic Field Versus Measurements at Segment 'J' With Day of Measurement Loading for Phasing Configurations #1 - #6

Location	Distance From 138 kV U/G Duct (Feet)	Field Measurements (mG)	Calculated Magnetic Field Config. #1 (mG)	Config. #2 (mG)	Config. #3 (mG)	Config. #4 (mG)	Config. #5 (mG)	Config. #6 (mG)
North Sidewalk Edge	-36		1.4	1.4	1.3	1.2	1.1	1.1
	-35	2.5	1.5	1.5	1.3	1.3	1.1	1.1
	-34		1.5	1.6	1.4	1.4	1.2	1.2
	-33		1.6	1.6	1.5	1.4	1.3	1.2
	-32		1.7	1.7	1.5	1.5	1.3	1.3
	-31	2.9	1.8	1.8	1.6	1.6	1.4	1.3
	-30		1.9	1.9	1.7	1.7	1.5	1.4
	-29		2.0	2.0	1.8	1.7	1.5	1.5
	-28		2.1	2.1	1.9	1.8	1.6	1.6
	-27	3.0	2.2	2.2	2.0	1.9	1.7	1.6
	-26		2.3	2.4	2.1	2.1	1.8	1.7
	-25		2.5	2.5	2.2	2.2	1.9	1.8
	-24		2.6	2.7	2.4	2.3	2.1	2.0
	-23		2.8	2.8	2.5	2.5	2.2	2.1
	-22	2.6	3.0	3.0	2.7	2.6	2.3	2.2
	-21		3.2	3.2	2.8	2.8	2.5	2.3
	-20		3.4	3.4	3.0	3.0	2.6	2.5
	-19		3.6	3.7	3.2	3.2	2.8	2.7
	-18		3.9	4.0	3.5	3.4	3.0	2.9
	-17		4.2	4.3	3.7	3.6	3.3	3.1
	-16	3.6	4.5	4.6	4.0	3.9	3.5	3.3
	-15		4.9	5.0	4.3	4.2	3.8	3.6
	-14		5.3	5.4	4.7	4.6	4.1	3.9
	-13		5.7	5.8	5.1	4.9	4.4	4.2
	-12		6.2	6.3	5.5	5.3	4.8	4.5
	-11		6.8	6.9	6.0	5.8	5.2	4.9
	-10	6.6	7.4	7.5	6.5	6.3	5.7	5.3
	-9		8.1	8.1	7.1	6.8	6.2	5.8
	-8		8.9	8.9	7.8	7.4	6.8	6.3
	-7		9.8	9.7	8.5	8.1	7.4	6.9
	-6		10.8	10.7	9.4	8.8	8.1	7.6
	-5		11.9	11.7	10.3	9.6	8.9	8.3
	-4	10.8	13.1	12.8	11.5	10.5	9.8	9.1
	-3		14.5	14.1	12.7	11.4	10.9	9.9
	-2		16.1	15.5	14.2	12.5	12.0	10.9
	-1		17.9	17.0	15.8	13.6	13.4	12.0
138 kV U/G Duct	0		19.8	18.7	17.7	14.8	14.9	13.2
	1	17.5	21.8	20.4	19.6	16.1	16.6	14.5
	2		23.9	22.1	21.6	17.5	18.4	15.9
	3		25.8	23.8	23.6	18.8	20.1	17.4
	4		27.6	25.3	25.4	20.0	21.8	18.8
	5		29.0	26.5	26.8	21.1	23.1	20.0
	6		29.9	27.2	27.8	21.9	24.1	21.0
46 kV U/G Duct	7	25.7	30.2	27.4	28.1	22.4	24.4	21.6
	8		29.8	27.1	27.8	22.4	24.2	21.7
	9		28.8	26.3	26.8	22.0	23.5	21.3
	10		27.4	25.1	25.4	21.3	22.3	20.5
	11		25.5	23.5	23.7	20.1	20.8	19.4
	12	14.7	23.5	21.7	21.8	18.8	19.1	18.1
	13		21.4	19.9	19.8	17.4	17.4	16.6
	14		19.4	18.1	17.9	15.9	15.7	15.1
	15		17.5	16.4	16.1	14.5	14.1	13.7
	16		15.7	14.8	14.5	13.1	12.6	12.4
	17		14.1	13.3	13.0	11.9	11.3	11.1
	18	7.7	12.7	12.0	11.7	10.8	10.2	10.0
	19		11.4	10.9	10.5	9.8	9.1	9.0
	20		10.3	9.8	9.4	8.8	8.2	8.2
	21		9.3	8.9	8.5	8.0	7.4	7.4
	22	5.2	8.5	8.1	7.7	7.3	6.7	6.7
	23		7.7	7.4	7.0	6.7	6.1	6.1
South Sidewalk Edge	24		7.0	6.8	6.4	6.1	5.6	5.6
	25							
	26	4.1						

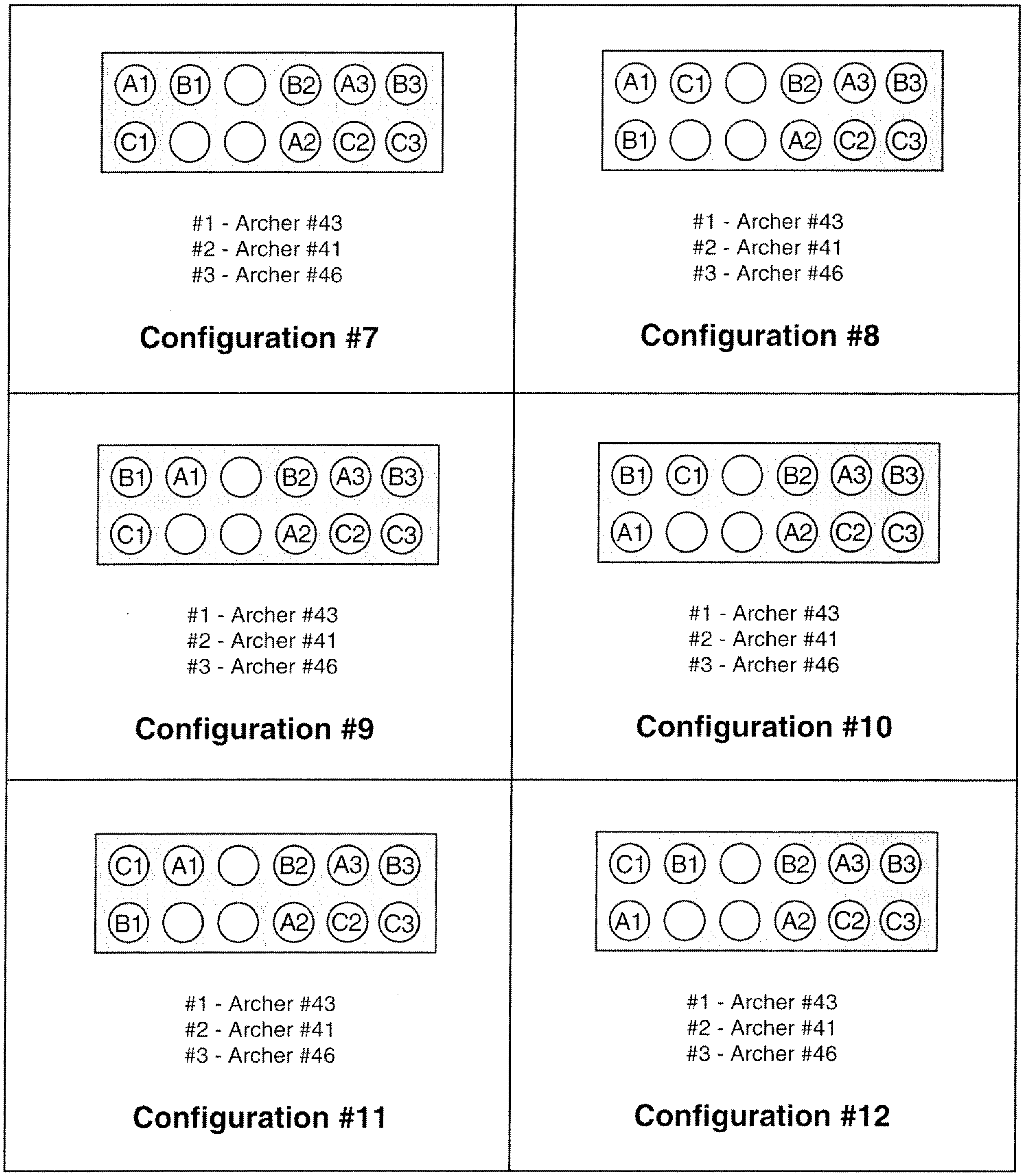


Figure D-2. Segment 'J' Phasing Configurations #7 - #12

Table D-2. Calculated Magnetic Field Versus Measurements at Segment 'J' With Day of Measurement Loading for Phasing Configurations #7 - #12

Location	Distance From 138 kV U/G Duct (Feet)	Field Measurements (mG)	Calculated Magnetic Field Config. #7 (mG)	Config. #8 (mG)	Config. #9 (mG)	Config. #10 (mG)	Config. #11 (mG)	Config. #12 (mG)
North Sidewalk Edge	-36		1.4	1.2	1.2	1.3	0.8	1.2
	-35	2.5	1.4	1.3	1.3	1.4	0.9	1.2
	-34		1.5	1.3	1.3	1.5	0.9	1.3
	-33		1.6	1.4	1.4	1.5	1.0	1.3
	-32		1.6	1.5	1.5	1.6	1.0	1.4
	-31	2.9	1.7	1.6	1.5	1.7	1.0	1.5
	-30		1.8	1.6	1.6	1.8	1.1	1.5
	-29		1.9	1.7	1.7	1.9	1.2	1.6
	-28		2.0	1.8	1.8	2.0	1.2	1.7
	-27	3.0	2.1	1.9	1.9	2.1	1.3	1.8
	-26		2.2	2.0	2.0	2.2	1.4	1.9
	-25		2.4	2.2	2.1	2.3	1.4	2.0
	-24		2.5	2.3	2.2	2.5	1.5	2.1
	-23		2.7	2.4	2.4	2.6	1.6	2.3
	-22	2.6	2.9	2.6	2.5	2.8	1.7	2.4
	-21		3.0	2.7	2.7	3.0	1.8	2.6
	-20		3.2	2.9	2.8	3.2	1.9	2.7
	-19		3.5	3.1	3.0	3.4	2.1	2.9
	-18		3.7	3.4	3.3	3.6	2.2	3.1
	-17		4.0	3.6	3.5	3.9	2.3	3.4
	-16	3.6	4.3	3.9	3.8	4.2	2.5	3.6
	-15		4.7	4.2	4.0	4.5	2.7	3.9
	-14		5.0	4.5	4.4	4.8	2.9	4.2
	-13		5.5	4.9	4.7	5.2	3.1	4.6
	-12		5.9	5.3	5.1	5.7	3.4	5.0
	-11		6.5	5.8	5.5	6.2	3.6	5.4
	-10	6.6	7.1	6.3	6.0	6.7	3.9	5.9
	-9		7.8	6.9	6.6	7.3	4.2	6.5
	-8		8.5	7.5	7.2	8.0	4.6	7.1
	-7		9.4	8.2	7.9	8.8	5.0	7.8
	-6		10.4	9.0	8.7	9.6	5.4	8.6
	-5		11.5	9.8	9.6	10.5	5.9	9.5
	-4	10.8	12.8	10.8	10.7	11.6	6.5	10.5
	-3		14.3	11.8	11.9	12.7	7.2	11.6
	-2		15.9	13.0	13.2	13.9	8.0	12.9
	-1		17.7	14.2	14.7	15.2	8.9	14.2
138 kV U/G Duct	0		19.6	15.6	16.4	16.6	9.9	15.7
	1	17.5	21.6	17.0	18.1	18.0	11.1	17.3
	2		23.7	18.5	19.9	19.3	12.5	18.8
	3		25.7	19.9	21.6	20.6	13.9	20.4
	4		27.4	21.1	23.2	21.8	15.2	21.8
	5		28.7	22.2	24.5	22.8	16.5	23.0
	6		29.6	22.9	25.3	23.4	17.5	23.8
46 kV U/G Duct	7	25.7	29.8	23.2	25.7	23.7	18.2	24.2
	8		29.4	23.2	25.5	23.7	18.4	24.0
	9		28.5	22.6	24.8	23.2	18.1	23.5
	10		27.0	21.7	23.6	22.3	17.5	22.5
	11		25.2	20.5	22.1	21.2	16.5	21.2
	12	14.7	23.3	19.1	20.5	19.8	15.4	19.6
	13		21.2	17.6	18.7	18.3	14.2	18.0
	14		19.2	16.1	17.0	16.8	12.9	16.4
	15		17.4	14.6	15.4	15.4	11.7	14.9
	16		15.6	13.3	13.9	14.0	10.5	13.5
	17		14.0	12.0	12.5	12.7	9.5	12.2
	18	7.7	12.6	10.8	11.2	11.5	8.5	11.0
	19		11.4	9.8	10.1	10.4	7.7	9.9
	20		10.3	8.9	9.2	9.5	6.9	8.9
	21		9.3	8.1	8.3	8.6	6.3	8.1
	22	5.2	8.4	7.3	7.5	7.8	5.7	7.4
	23		7.7	6.7	6.8	7.2	5.2	6.7
South Sidewalk Edge	24		7.0	6.1	6.2	6.6	4.7	6.1
	25							
	26	4.1						

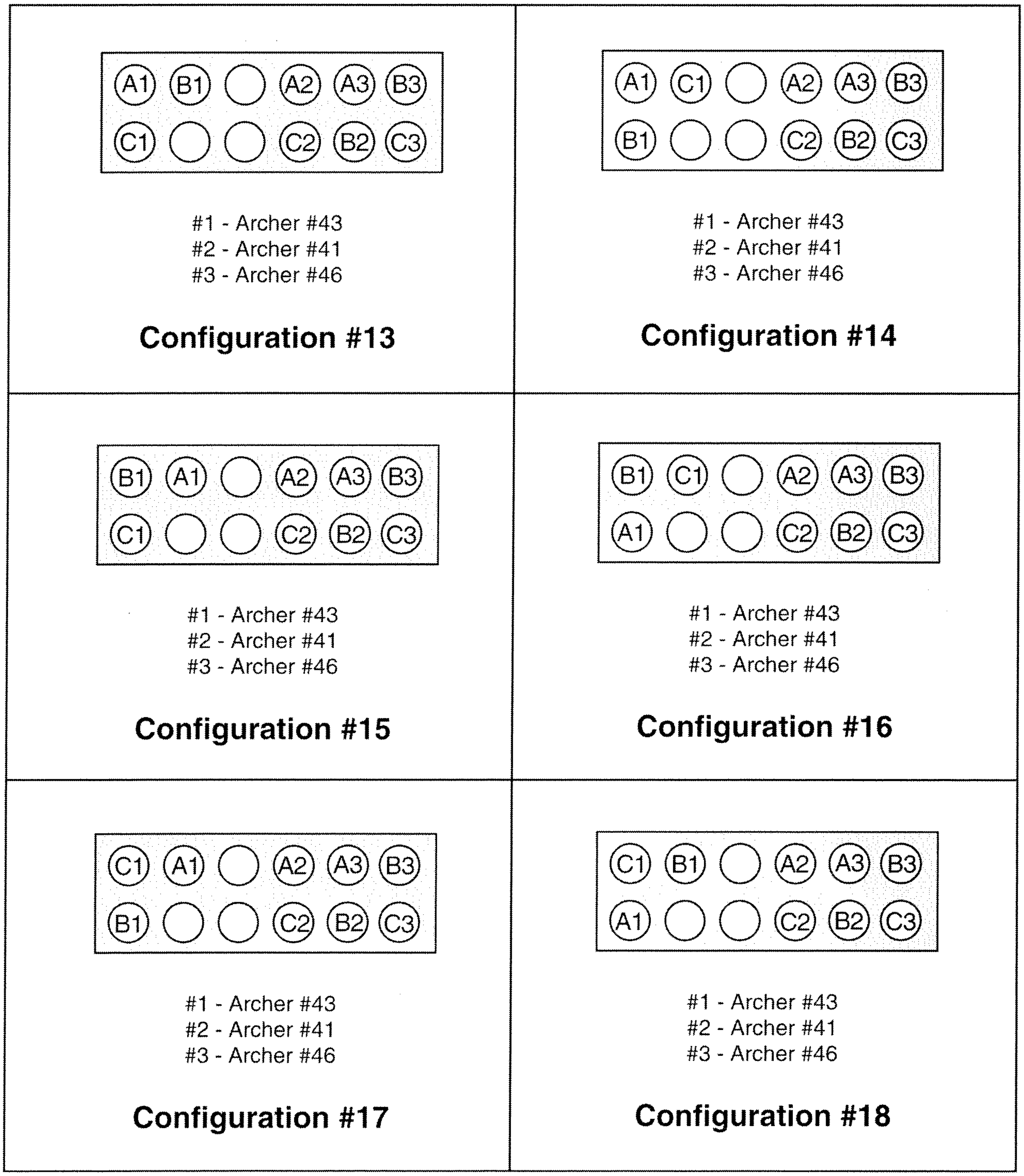


Figure D-3. Segment 'J' Phasing Configurations #13 - #18

Table D-3. Calculated Magnetic Field Versus Measurements at Segment 'J' With Day of Measurement Loading for Phasing Configurations #13 - #18

Location	Distance From 138 kV U/G Duct (Feet)	Field Measurements (mG)	Calculated Magnetic Field Config. #13 (mG)	Config. #14 (mG)	Config. #15 (mG)	Config. #16 (mG)	Config. #17 (mG)	Config. #18 (mG)
North Sidewalk Edge	-36		1.5	1.3	1.2	1.0	1.1	1.2
	-35	2.5	1.6	1.3	1.3	1.1	1.1	1.2
	-34		1.6	1.4	1.3	1.1	1.2	1.3
	-33		1.7	1.4	1.4	1.2	1.2	1.3
	-32		1.8	1.5	1.5	1.3	1.3	1.4
	-31	2.9	1.9	1.6	1.6	1.3	1.3	1.5
	-30		2.0	1.7	1.6	1.4	1.4	1.6
	-29		2.1	1.8	1.7	1.5	1.5	1.6
	-28		2.2	1.9	1.8	1.5	1.6	1.7
	-27	3.0	2.4	2.0	1.9	1.6	1.7	1.8
	-26		2.5	2.1	2.0	1.7	1.8	1.9
	-25		2.6	2.2	2.1	1.8	1.9	2.1
	-24		2.8	2.4	2.3	1.9	2.0	2.2
	-23		3.0	2.5	2.4	2.0	2.1	2.3
	-22	2.6	3.2	2.7	2.6	2.2	2.2	2.5
	-21		3.4	2.8	2.7	2.3	2.4	2.6
	-20		3.6	3.0	2.9	2.5	2.6	2.8
	-19		3.9	3.3	3.1	2.6	2.7	3.0
	-18		4.2	3.5	3.4	2.8	2.9	3.2
	-17		4.5	3.8	3.6	3.0	3.2	3.5
	-16	3.6	4.8	4.1	3.9	3.3	3.4	3.7
	-15		5.2	4.4	4.2	3.5	3.7	4.0
	-14		5.6	4.8	4.5	3.8	4.0	4.4
	-13		6.1	5.2	4.9	4.1	4.4	4.7
	-12		6.7	5.6	5.3	4.5	4.7	5.1
	-11		7.3	6.2	5.8	4.8	5.2	5.6
	-10	6.6	7.9	6.7	6.3	5.3	5.7	6.1
	-9		8.7	7.4	6.9	5.7	6.2	6.7
	-8		9.6	8.1	7.6	6.3	6.8	7.4
	-7		10.6	8.9	8.4	6.8	7.6	8.2
	-6		11.7	9.8	9.2	7.5	8.4	9.0
	-5		12.9	10.8	10.2	8.1	9.3	9.9
	-4	10.8	14.3	11.9	11.4	8.9	10.3	11.0
	-3		15.9	13.1	12.6	9.7	11.6	12.2
	-2		17.6	14.5	14.1	10.6	12.9	13.5
	-1		19.5	16.0	15.7	11.6	14.5	14.9
138 kV U/G Duct	0		21.5	17.7	17.5	12.7	16.3	16.4
	1	17.5	23.7	19.5	19.4	13.9	18.2	18.1
	2		25.8	21.3	21.4	15.1	20.2	19.8
	3		27.9	23.0	23.4	16.4	22.1	21.4
	4		29.7	24.6	25.1	17.6	24.0	23.0
	5		31.1	25.9	26.6	18.8	25.4	24.3
	6		32.0	26.7	27.5	19.8	26.4	25.2
46 kV U/G Duct	7	25.7	32.2	27.0	27.9	20.4	26.7	25.6
	8		31.8	26.7	27.6	20.6	26.4	25.5
	9		30.7	25.9	26.7	20.3	25.4	24.8
	10		29.1	24.5	25.3	19.6	24.0	23.7
	11		27.1	22.9	23.6	18.6	22.2	22.2
	12	14.7	24.9	21.1	21.7	17.3	20.3	20.5
	13		22.7	19.2	19.7	16.0	18.3	18.7
	14		20.6	17.3	17.8	14.6	16.5	17.0
	15		18.5	15.6	16.0	13.2	14.7	15.3
	16		16.6	14.0	14.3	11.9	13.1	13.8
	17		14.9	12.6	12.8	10.8	11.7	12.4
	18	7.7	13.4	11.3	11.5	9.7	10.5	11.1
	19		12.1	10.2	10.3	8.8	9.4	10.0
	20		10.9	9.2	9.3	7.9	8.4	9.1
	21		9.9	8.3	8.4	7.2	7.5	8.2
	22	5.2	9.0	7.5	7.6	6.5	6.8	7.4
	23		8.1	6.8	6.9	5.9	6.2	6.7
South Sidewalk Edge	24		7.4	6.2	6.3	5.4	5.6	6.2
	25							
	26	4.1						

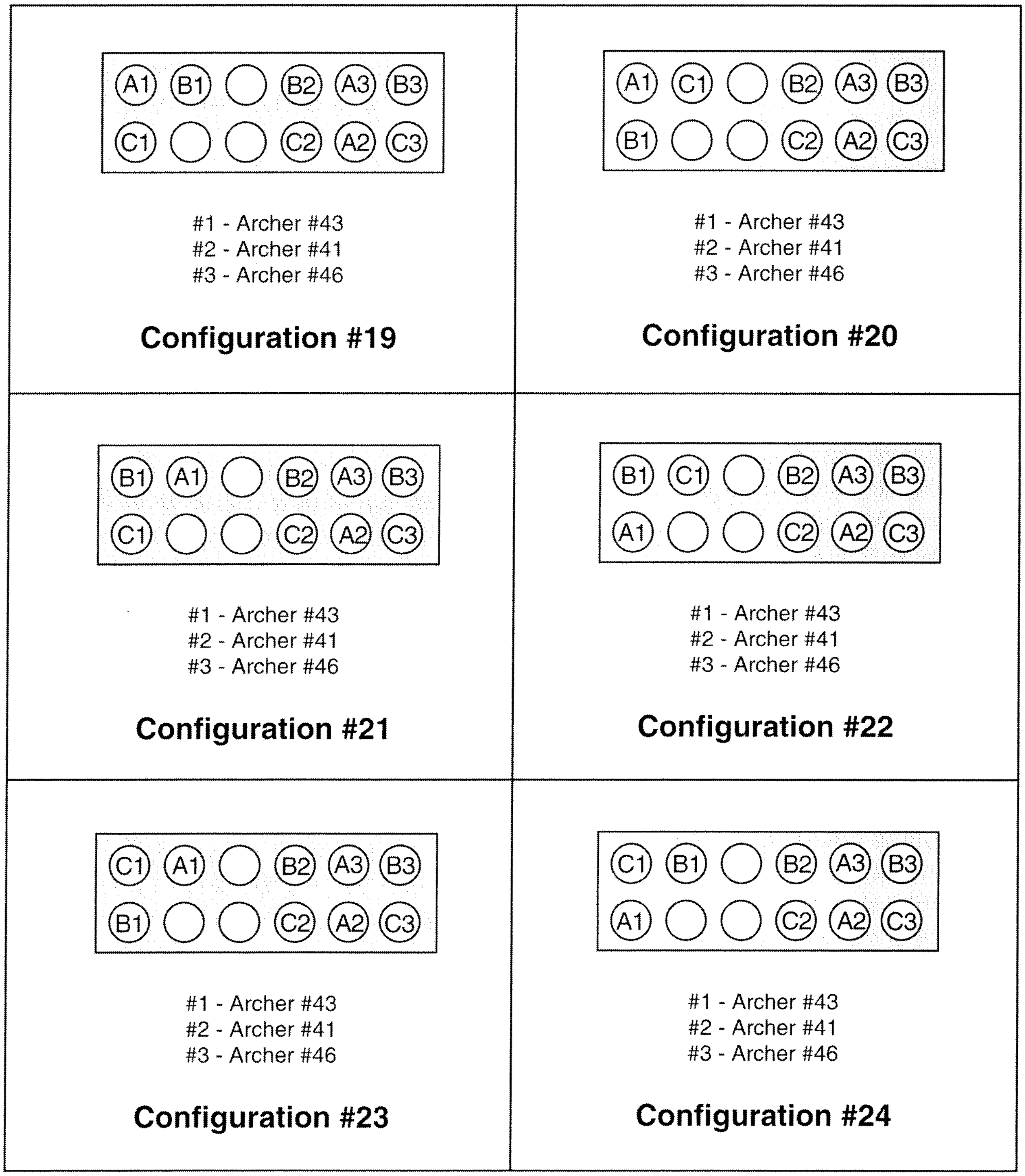


Figure D-4. Segment ‘J’ Phasing Configurations #19 - #24

Table D-4. Calculated Magnetic Field Versus Measurements at Segment 'J' With Day of Measurement Loading for Phasing Configurations #19 - #24

			Calculated Magnetic Field					
Location	Distance From 138 kV U/G Duct (Feet)	Field Measurements (mG)	Config. #19 (mG)	Config. #20 (mG)	Config. #21 (mG)	Config. #22 (mG)	Config. #23 (mG)	Config. #24 (mG)
North Sidewalk Edge	-36		1.1	0.7	1.1	0.9	0.6	0.8
	-35	2.5	1.1	0.7	1.1	0.9	0.6	0.9
	-34		1.2	0.8	1.2	1.0	0.7	0.9
	-33		1.2	0.8	1.2	1.0	0.7	0.9
	-32		1.3	0.8	1.3	1.0	0.7	1.0
	-31	2.9	1.4	0.9	1.4	1.1	0.8	1.0
	-30		1.4	0.9	1.4	1.1	0.8	1.1
	-29		1.5	1.0	1.5	1.2	0.9	1.2
	-28		1.6	1.0	1.6	1.3	0.9	1.2
	-27	3.0	1.7	1.1	1.7	1.3	0.9	1.3
	-26		1.8	1.1	1.8	1.4	1.0	1.3
	-25		1.9	1.2	1.9	1.5	1.1	1.4
	-24		2.0	1.3	2.0	1.6	1.1	1.5
	-23		2.1	1.3	2.1	1.7	1.2	1.6
	-22	2.6	2.3	1.4	2.2	1.8	1.2	1.7
	-21		2.4	1.5	2.4	1.9	1.3	1.8
	-20		2.6	1.6	2.5	2.0	1.4	1.9
	-19		2.7	1.7	2.7	2.1	1.5	2.0
	-18		2.9	1.8	2.9	2.3	1.6	2.2
	-17		3.2	2.0	3.1	2.4	1.7	2.3
	-16	3.6	3.4	2.1	3.3	2.6	1.8	2.5
	-15		3.7	2.3	3.5	2.8	1.9	2.7
	-14		4.0	2.4	3.8	3.0	2.0	2.9
	-13		4.3	2.6	4.1	3.3	2.2	3.2
	-12		4.7	2.8	4.4	3.5	2.3	3.5
	-11		5.1	3.0	4.8	3.8	2.5	3.8
	-10	6.6	5.5	3.2	5.2	4.1	2.7	4.2
	-9		6.1	3.5	5.7	4.5	2.9	4.6
	-8		6.7	3.8	6.2	4.9	3.2	5.1
	-7		7.4	4.1	6.9	5.4	3.5	5.7
	-6		8.2	4.4	7.6	5.9	3.8	6.3
	-5		9.1	4.8	8.4	6.5	4.3	7.1
	-4	10.8	10.2	5.2	9.4	7.2	4.8	8.0
	-3		11.4	5.7	10.5	7.9	5.5	9.0
	-2		12.8	6.2	11.7	8.7	6.2	10.1
	-1		14.2	6.8	13.1	9.6	7.1	11.3
138 kV U/G Duct	0		15.9	7.5	14.6	10.5	8.1	12.7
	1	17.5	17.5	8.2	16.1	11.5	9.3	14.1
	2		19.2	9.0	17.6	12.4	10.5	15.5
	3		20.8	9.7	19.0	13.3	11.6	16.9
	4		22.2	10.5	20.3	14.0	12.8	18.1
	5		23.2	11.3	21.3	14.7	13.7	19.1
	6		23.9	11.9	21.9	15.2	14.4	19.7
46 kV U/G Duct	7	25.7	24.0	12.3	22.0	15.4	14.8	19.9
	8		23.6	12.5	21.7	15.5	14.7	19.7
	9		22.8	12.5	21.0	15.2	14.4	19.0
	10		21.6	12.2	19.9	14.7	13.7	18.0
	11		20.1	11.6	18.6	14.0	12.8	16.8
	12	14.7	18.5	10.9	17.2	13.1	11.8	15.5
	13		16.9	10.1	15.7	12.2	10.8	14.1
	14		15.3	9.3	14.3	11.2	9.7	12.8
	15		13.7	8.5	12.9	10.2	8.7	11.5
	16		12.4	7.7	11.6	9.3	7.8	10.3
	17		11.1	7.0	10.5	8.4	7.0	9.3
	18	7.7	10.0	6.3	9.4	7.6	6.3	8.3
	19		9.0	5.7	8.5	6.9	5.7	7.5
	20		8.1	5.2	7.7	6.3	5.1	6.7
	21		7.3	4.7	7.0	5.7	4.6	6.1
	22	5.2	6.6	4.3	6.3	5.2	4.2	5.5
	23		6.0	3.9	5.8	4.8	3.8	5.0
South Sidewalk Edge	24		5.5	3.5	5.3	4.4	3.4	4.6
	25							
	26	4.1						

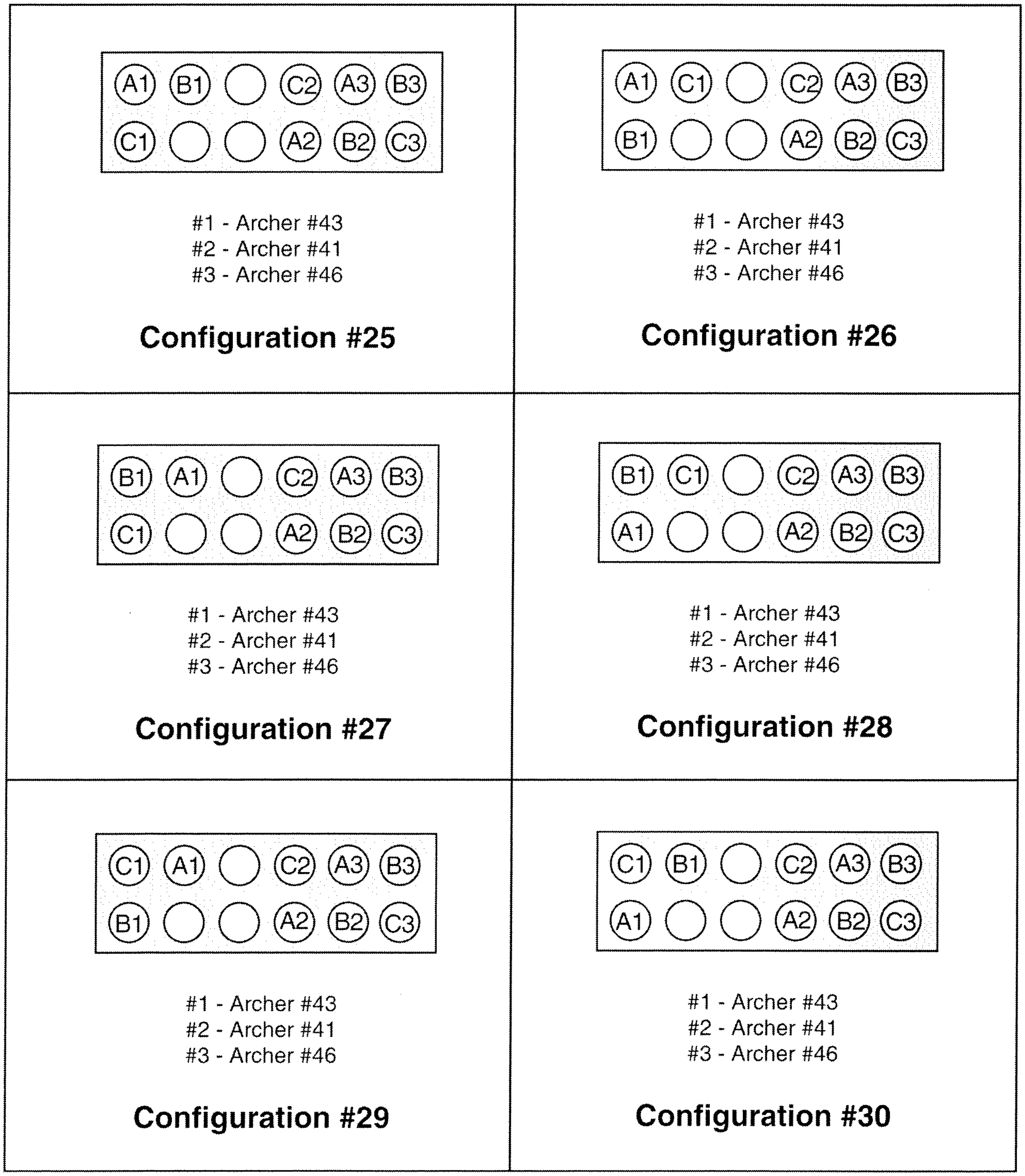


Figure D-5. Segment ‘J’ Phasing Configurations #25 - #30

Table D-5. Calculated Magnetic Field Versus Measurements at Segment 'J' With Day of Measurement Loading for Phasing Configurations #25 - #30

			Calculated Magnetic Field					
Location	Distance From 138 kV U/G Duct (Feet)	Field Measurements (mG)	Config. #25 (mG)	Config. #26 (mG)	Config. #27 (mG)	Config. #28 (mG)	Config. #29 (mG)	Config. #30 (mG)
North Sidewalk Edge	-36		1.1	0.9	0.6	0.9	0.6	1.0
	-35	2.5	1.1	1.0	0.7	0.9	0.7	1.1
	-34		1.2	1.0	0.7	0.9	0.7	1.1
	-33		1.2	1.1	0.7	1.0	0.7	1.2
	-32		1.3	1.1	0.8	1.0	0.8	1.2
	-31	2.9	1.4	1.2	0.8	1.1	0.8	1.3
	-30		1.4	1.2	0.8	1.2	0.8	1.4
	-29		1.5	1.3	0.9	1.2	0.9	1.4
	-28		1.6	1.4	0.9	1.3	0.9	1.5
	-27	3.0	1.7	1.5	1.0	1.4	1.0	1.6
	-26		1.8	1.6	1.1	1.4	1.1	1.7
	-25		1.9	1.7	1.1	1.5	1.1	1.8
	-24		2.0	1.8	1.2	1.6	1.2	1.9
	-23		2.1	1.9	1.3	1.7	1.3	2.0
	-22	2.6	2.3	2.0	1.3	1.8	1.4	2.2
	-21		2.4	2.1	1.4	1.9	1.5	2.3
	-20		2.6	2.3	1.5	2.1	1.6	2.5
	-19		2.8	2.5	1.6	2.2	1.7	2.6
	-18		3.0	2.7	1.7	2.4	1.8	2.8
	-17		3.2	2.9	1.9	2.6	2.0	3.1
	-16	3.6	3.5	3.1	2.0	2.8	2.2	3.3
	-15		3.8	3.4	2.2	3.0	2.3	3.6
	-14		4.1	3.7	2.4	3.3	2.6	3.9
	-13		4.5	4.0	2.6	3.6	2.8	4.2
	-12		4.9	4.4	2.8	3.9	3.1	4.6
	-11		5.4	4.9	3.1	4.3	3.4	5.1
	-10	6.6	5.9	5.3	3.4	4.7	3.8	5.6
	-9		6.5	5.9	3.7	5.2	4.2	6.2
	-8		7.2	6.5	4.0	5.7	4.6	6.8
	-7		7.9	7.2	4.5	6.3	5.1	7.6
	-6		8.8	7.9	4.9	6.9	5.7	8.4
	-5		9.7	8.8	5.4	7.6	6.4	9.3
	-4	10.8	10.8	9.7	6.0	8.3	7.1	10.3
	-3		12.0	10.7	6.7	9.1	7.9	11.4
	-2		13.3	11.9	7.4	9.9	8.9	12.5
	-1		14.6	13.1	8.3	10.8	9.9	13.7
138 kV U/G Duct	0		16.1	14.4	9.2	11.6	11.1	15.0
	1	17.5	17.7	15.8	10.2	12.5	12.3	16.3
	2		19.2	17.2	11.3	13.4	13.6	17.6
	3		20.6	18.5	12.4	14.3	14.9	18.8
	4		21.9	19.7	13.5	15.0	16.0	19.9
	5		22.9	20.5	14.4	15.6	17.0	20.6
	6		23.5	21.0	15.2	16.1	17.6	21.1
46 kV U/G Duct	7	25.7	23.6	21.0	15.6	16.3	17.8	21.2
	8		23.3	20.6	15.6	16.2	17.5	21.0
	9		22.5	19.8	15.3	15.9	16.8	20.3
	10		21.3	18.7	14.7	15.3	15.8	19.3
	11		19.9	17.3	13.8	14.4	14.6	18.1
	12	14.7	18.3	15.9	12.7	13.5	13.3	16.7
	13		16.7	14.4	11.6	12.4	12.0	15.3
	14		15.1	13.0	10.5	11.4	10.7	13.9
	15		13.6	11.7	9.5	10.3	9.5	12.6
	16		12.3	10.5	8.5	9.4	8.5	11.3
	17		11.0	9.4	7.6	8.5	7.5	10.2
	18	7.7	9.9	8.4	6.8	7.7	6.7	9.2
	19		8.9	7.6	6.1	6.9	6.0	8.3
	20		8.0	6.8	5.5	6.3	5.3	7.5
	21		7.3	6.1	4.9	5.7	4.8	6.8
	22	5.2	6.6	5.6	4.5	5.2	4.3	6.2
	23		6.0	5.0	4.0	4.7	3.9	5.6
South Sidewalk Edge	24		5.5	4.6	3.7	4.3	3.5	5.1
	25							
	26	4.1						

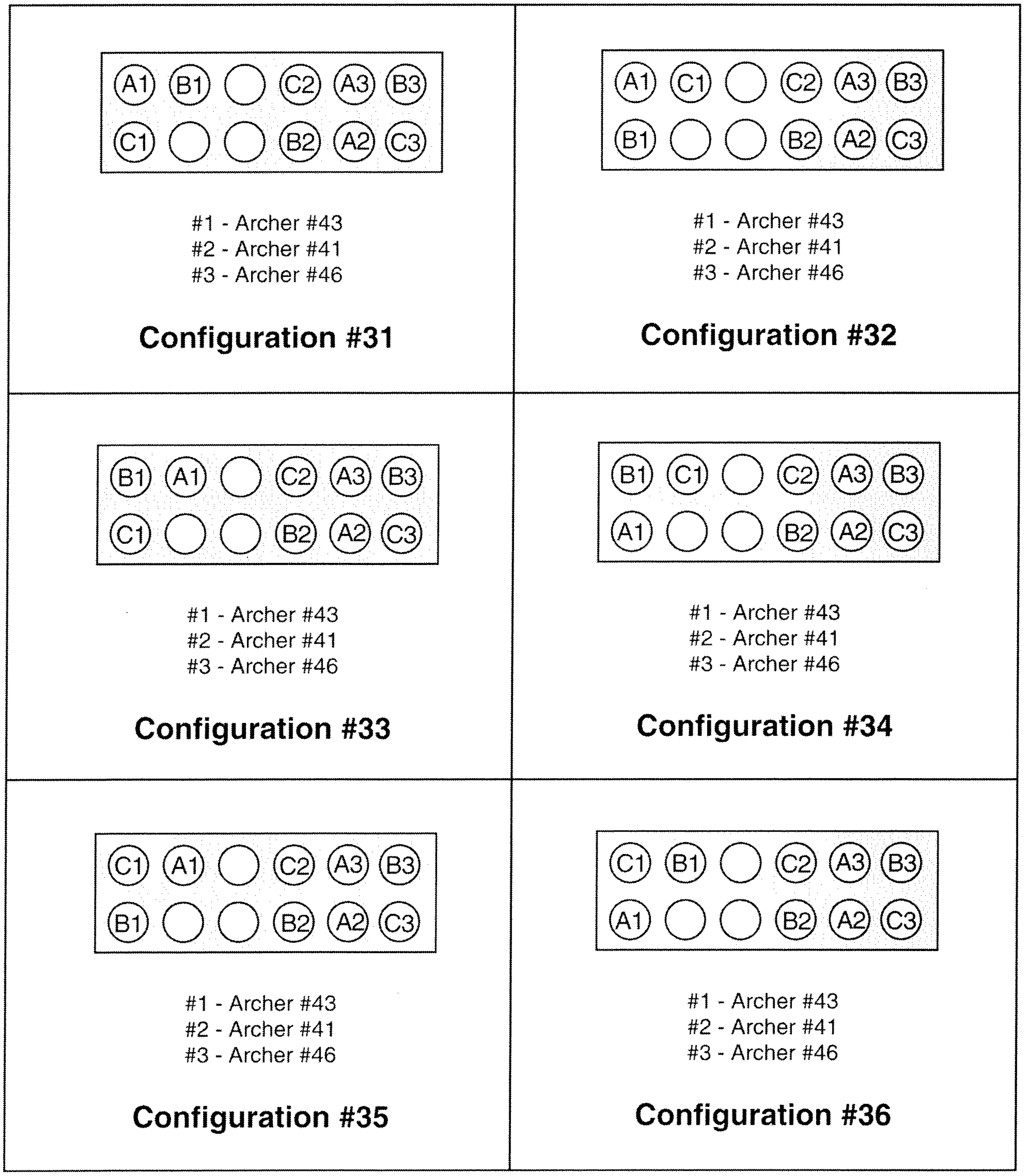


Figure D-6. Segment ‘J’ Phasing Configurations #31 - #36

Table D-6. Calculated Magnetic Field Versus Measurements at Segment 'J' With Day of Measurement Loading for Phasing Configurations #31 - #36

Location	Distance From 138 kV U/G Duct (Feet)	Field Measurements (mG)	Calculated Magnetic Field Config. #31 (mG)	Config. #32 (mG)	Config. #33 (mG)	Config. #34 (mG)	Config. #35 (mG)	Config. #36 (mG)
North Sidewalk Edge	-36		0.5	0.5	0.4	0.4	0.4	0.3
	-35	2.5	0.5	0.6	0.5	0.4	0.4	0.3
	-34		0.5	0.6	0.5	0.5	0.5	0.4
	-33		0.6	0.6	0.5	0.5	0.5	0.4
	-32		0.6	0.6	0.5	0.5	0.5	0.4
	-31	2.9	0.6	0.7	0.6	0.5	0.5	0.4
	-30		0.6	0.7	0.6	0.6	0.6	0.4
	-29		0.7	0.8	0.6	0.6	0.6	0.5
	-28		0.7	0.8	0.7	0.6	0.6	0.5
	-27	3.0	0.8	0.9	0.7	0.7	0.7	0.5
	-26		0.8	0.9	0.7	0.7	0.7	0.5
	-25		0.9	1.0	0.8	0.8	0.8	0.6
	-24		0.9	1.0	0.8	0.8	0.8	0.6
	-23		1.0	1.1	0.9	0.9	0.9	0.7
	-22	2.6	1.0	1.2	0.9	0.9	0.9	0.7
	-21		1.1	1.3	1.0	1.0	1.0	0.8
	-20		1.2	1.4	1.1	1.1	1.1	0.8
	-19		1.3	1.5	1.1	1.1	1.2	0.9
	-18		1.4	1.6	1.2	1.2	1.3	1.0
	-17		1.5	1.7	1.3	1.3	1.4	1.0
	-16	3.6	1.6	1.9	1.4	1.4	1.5	1.1
	-15		1.7	2.1	1.5	1.5	1.6	1.3
	-14		1.9	2.2	1.6	1.7	1.8	1.4
	-13		2.0	2.4	1.7	1.8	1.9	1.5
	-12		2.2	2.7	1.8	2.0	2.1	1.7
	-11		2.4	2.9	1.9	2.2	2.3	1.9
	-10	6.6	2.7	3.2	2.1	2.4	2.5	2.2
	-9		2.9	3.5	2.2	2.6	2.7	2.4
	-8		3.2	3.8	2.4	2.9	3.0	2.7
	-7		3.6	4.2	2.6	3.2	3.3	3.1
	-6		4.0	4.6	2.9	3.5	3.7	3.5
	-5		4.4	5.0	3.2	3.8	4.1	3.9
	-4	10.8	4.9	5.4	3.6	4.2	4.5	4.4
	-3		5.4	5.9	4.0	4.5	5.1	5.0
	-2		6.1	6.4	4.6	4.9	5.6	5.5
	-1		6.7	7.0	5.2	5.3	6.3	6.1
138 kV U/G Duct	0		7.4	7.5	5.8	5.6	7.0	6.7
	1	17.5	8.1	8.1	6.5	5.9	7.7	7.2
	2		8.8	8.6	7.2	6.1	8.4	7.8
	3		9.5	9.0	7.8	6.1	9.0	8.2
	4		10.1	9.2	8.3	6.1	9.4	8.5
	5		10.5	9.3	8.7	5.8	9.7	8.7
	6		10.7	9.1	8.9	5.5	9.7	8.7
46 kV U/G Duct	7	25.7	10.8	8.8	8.9	5.1	9.4	8.6
	8		10.6	8.3	8.7	4.7	8.9	8.3
	9		10.3	7.7	8.3	4.4	8.2	7.9
	10		9.7	7.1	7.8	4.2	7.3	7.4
	11		9.1	6.4	7.2	4.0	6.5	6.8
	12	14.7	8.3	5.8	6.6	3.8	5.7	6.2
	13		7.6	5.2	6.0	3.6	4.9	5.6
	14		6.8	4.7	5.4	3.5	4.2	5.1
	15		6.1	4.2	4.8	3.3	3.7	4.5
	16		5.5	3.8	4.3	3.0	3.2	4.0
	17		4.9	3.4	3.9	2.8	2.8	3.6
	18	7.7	4.4	3.1	3.5	2.6	2.5	3.2
	19		3.9	2.8	3.1	2.4	2.2	2.9
	20		3.5	2.5	2.8	2.2	1.9	2.6
	21		3.2	2.3	2.6	2.1	1.7	2.3
	22	5.2	2.9	2.1	2.3	1.9	1.6	2.1
	23		2.6	1.9	2.1	1.8	1.4	1.9
South Sidewalk Edge	24		2.4	1.8	1.9	1.6	1.3	1.7
	25							
	26	4.1						

APPENDIX E

Magnetic Field Measurements of HECO Electrical Facilities

Table E-1. Magnetic Field Measurements of Substation Transformers at Kapiolani Substation

46 kV to 12 kV XFMR at Kapiolani Substation #1

Distance (ft)	Magnetic Field (mG)	Normalized
0	145	1.00
1		
2		
3		
4		
5	28	0.19
6		
7		
8		
9		
10	18.5	0.13
11		
12		
13		
14		
15	17.2	0.12
16		
17		
18		
19		
20	14	0.10
21		
22		
23		
24		
25	11.1	0.08
26		
27		
28		
29		
30	8.4	0.06
31		
32		
33		
34		
35	6.9	0.05
36		
37		
38		
39		
40	6.5	0.04

46 kV to 12 kV XFMR at Kapiolani Substation #2

Distance (ft)	Magnetic Field (mG)	Normalized
0	104	1.00
1		
2		
3		
4		
5	11.7	0.11
6		
7		
8		
9		
10	5.1	0.05
11		
12		
13		
14		
15	1.6	0.02
16		
17		
18		
19		
20	1.2	0.01
21		
22		
23		
24		
25	1	0.01
26		
27		
28		
29		
30	0.9	0.01
31		
32		
33		
34		
35	0.8	0.01

46 kV to 12 kV XFMR at Kapiolani Substation #3

Distance (ft)	Magnetic Field (mG)	Normalized
0	89	1.00
1		
2		
3		
4		
5	29.7	0.33
6		
7		
8		
9		
10	22.9	0.26
11		
12		
13		
14		
15	19.4	0.22

Table E-2. Magnetic Field Measurements of Substation Transformers at McCully Substation

46 kV XFMR at McCully Substation #1

Distance (ft)	Magnetic Field (mG)	Normalized
0	28.1	1.00
1	23.1	0.82
2	18.7	0.67
3	15.7	0.56
4	13.9	0.49
5	12.1	0.43
6	9.9	0.35
7	8.9	0.32
8	8.7	0.31
9	8.0	0.28
10	7.5	0.27
11	7.8	0.28
12	7.2	0.26
13	6.7	0.24
14	6.6	0.24
15	6.1	0.22
16	6.1	0.22
17	5.9	0.21
18	5.9	0.21

46 kV XFMR at McCully Substation #2

Distance (ft)	Magnetic Field (mG)	Normalized
0	119.9	1.00
1	114.1	0.95
2	98.5	0.82
3	72.3	0.60
4	55.7	0.46
5	46.9	0.39
6	40.1	0.33
7	35.3	0.29
8	34.9	0.29
9	31.3	0.26
10	27.3	0.23
11	24.7	0.21
12	24.7	0.21
13	24.9	0.21
14	24.1	0.20
15	14.9	0.12

46 kV XFMR at McCully Substation #3

Distance (ft)	Magnetic Field (mG)	Normalized
0	39.9	1.00
1	39.7	0.99
2	38.5	0.96
3	34.9	0.87
4	32.1	0.80
5	31.1	0.78
6	28.1	0.70
7	23.3	0.58
8	20.1	0.50
9	17.5	0.44
10	15.3	0.38
11	13.3	0.33
12	11.1	0.28
13	9.1	0.23
14	7.5	0.19
15	6.3	0.16
16	5.3	0.13
17	4.3	0.11
18	3.8	0.09
19	3.2	0.08
20	2.9	0.07
21	2.6	0.06
22	2.4	0.06

Between 46 kV XFMR's at McCully Substation

Distance (ft)	Magnetic Field (mG)	Normalized
0	32.5	1.00
1	31.1	0.96
2	28.3	0.87
3	25.9	0.80
4	23.1	0.71
5	20.5	0.63
6	17.7	0.54
7	15.7	0.48
8	14.3	0.44
9	13.5	0.42

Table E-3. Magnetic Field Measurements of Substation Transformers at Moiliili and Kewalo Substations

46 kV to 12 kV XFMR at Moiliili Substation

Distance (ft)	Magnetic Field (mG)	Normalized
0	133	1.00
1		
2		
3		
4		
5	4.7	0.04
6		
7		
8		
9		
10	2.1	0.02
11		
12		
13		
14		
15	1.6	0.01
16		
17		
18		
19		
20	1.4	0.01
21		
22		
23		
24		
25	1.1	0.01
26		
27		
28		
29		
30	1	0.01
31		
32		
33		
34		
35	1	0.01
36		
37		
38		
39		
40	0.9	0.01
41		
42		
43		
44		
45	0.8	0.01

46 kV XFMR at Kewalo Substation

Distance (ft)	Magnetic Field (mG)	Normalized
0	15.9	1.00
1	14.7	0.93
2	14.5	0.91
3	12.9	0.81
4	11.3	0.71
5	10.1	0.64
6	9.3	0.59
7	8.7	0.55
8	8.3	0.52
9	7.5	0.47
10	6.9	0.43

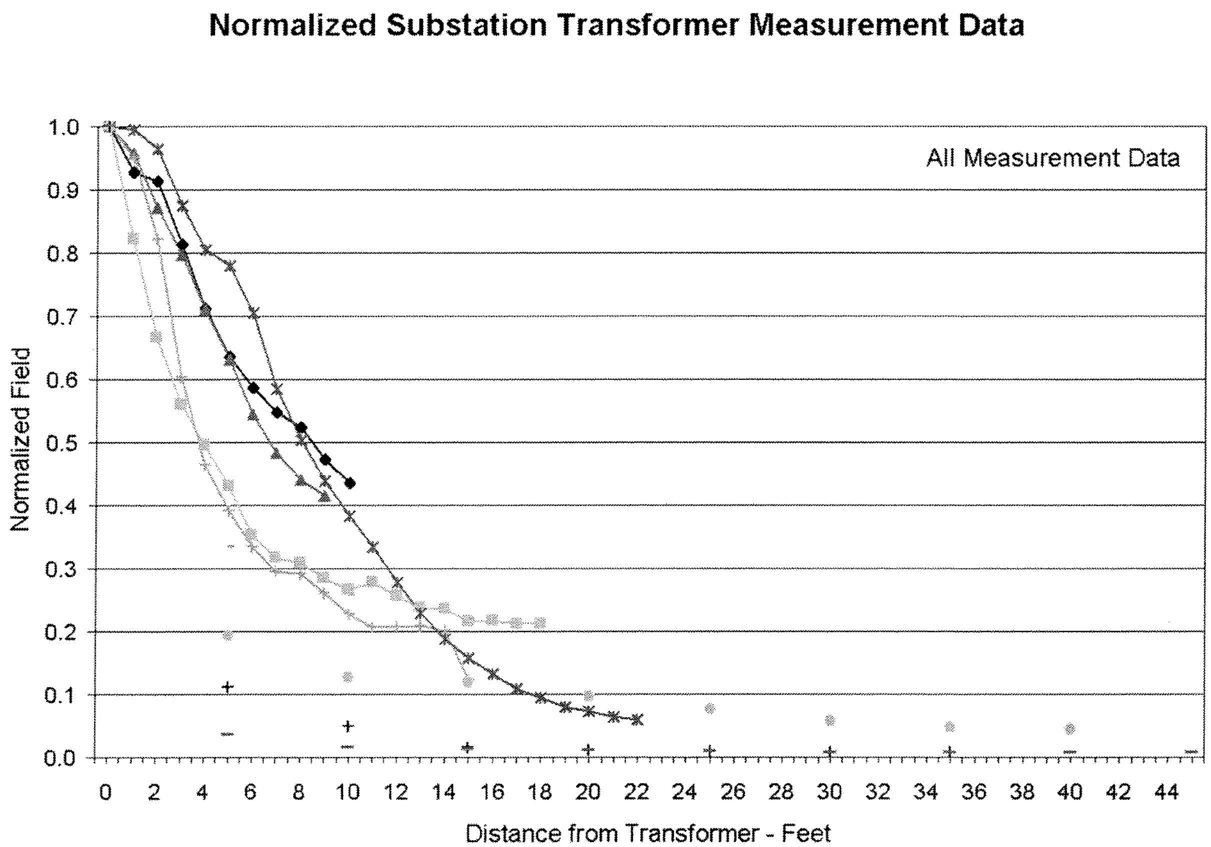


Figure E-1. Normalized Magnetic Field Measurements for HECO Substation Transformers

Table E-4. Average of Normalized Magnetic Field Measurements For HECO Substation Transformers

Average of Normalized Data for HECO Substation Transformers

Distance (ft)	Normalized
0	1.00
1	0.93
2	0.85
3	0.73
4	0.64
5	0.39
6	0.50
7	0.45
8	0.41
9	0.37
10	0.22
11	0.27
12	0.25
13	0.22
14	0.21
15	0.12
16	0.17
17	0.16
18	0.15
19	0.08
20	0.05
21	0.06
22	0.06
23	
24	
25	0.03
26	
27	
28	
29	
30	0.02
31	
32	
33	
34	
35	0.02
36	
37	
38	
39	
40	0.03
41	
42	
43	
44	
45	0.01

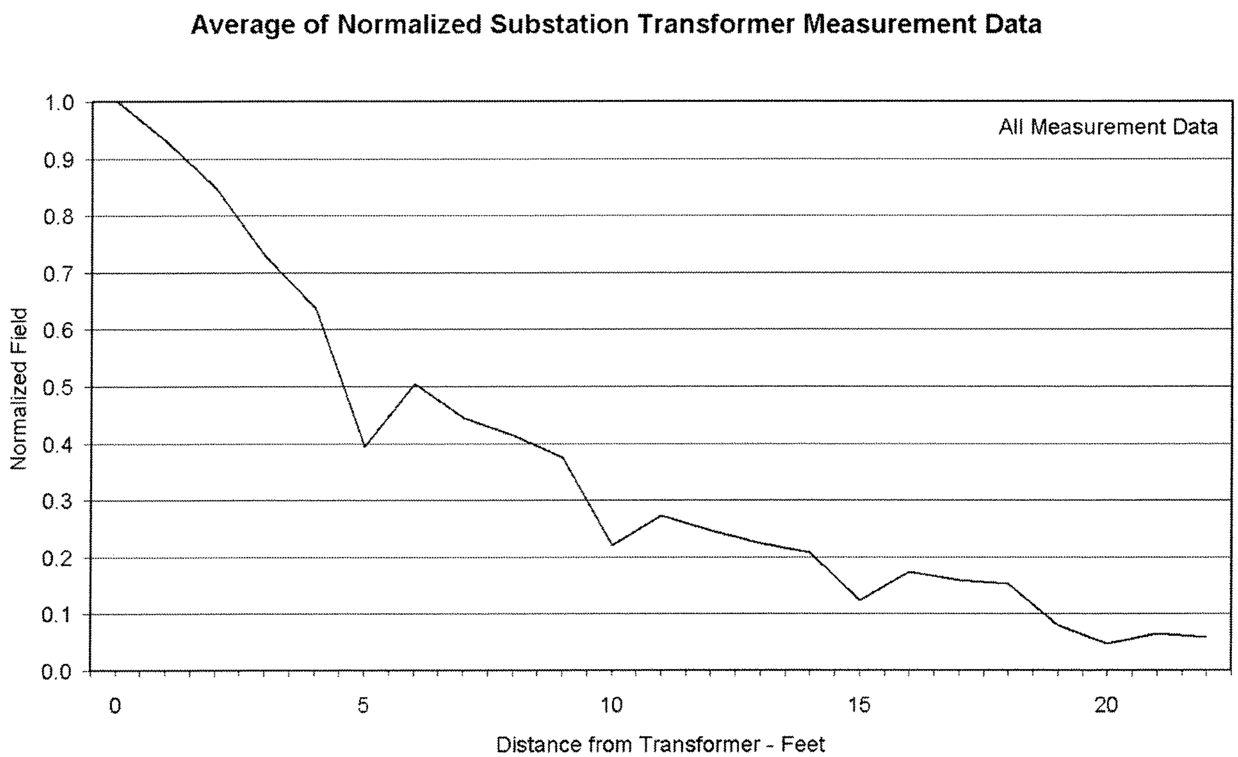


Figure E-2. Average Normalized Magnetic Field Measurements for HECO Substation Transformers

Table E-5. Magnetic Field Measurements of Manholes at Kapiolani Boulevard and Ward Avenue

46 kV Manhole at Kapiolani and Ward #1

Distance (ft)	Magnetic Field (mG)	Normalized
0	17.9	1.00
2	15.3	0.85
4	13.1	0.73
7	12.1	0.68
10	10.1	0.56
12	7.1	0.40
14	5.0	0.28
16	4.2	0.24
19	3.6	0.20
21	3.1	0.17
23	2.8	0.16
25	2.6	0.15
28	2.4	0.14
30	2.1	0.12

46 kV Manhole at Kapiolani and Ward #3

Distance (ft)	Magnetic Field (mG)	Normalized
0	25.3	1.00
2	24.5	0.97
3	21.9	0.87
5	17.3	0.68
7	13.1	0.52
9	10.3	0.41
11	7.1	0.28
13	5.0	0.20
15	4.2	0.17
16	3.8	0.15
18	3.9	0.15
20	3.6	0.14
22	3.4	0.13
23	3.1	0.12
25	2.7	0.11
27	2.4	0.10
29	2.2	0.09
31	2.1	0.08
33	1.9	0.08

46 kV Manhole at Kapiolani and Ward #2

Distance (ft)	Magnetic Field (mG)	Normalized
0	21.9	1.00
2	20.9	0.95
5	15.5	0.71
7	11.5	0.53
9	9.1	0.42
11	6.9	0.32
13	4.7	0.22
16	3.8	0.17
18	3.4	0.16
20	3.1	0.14
22	2.9	0.13
24	2.6	0.12
26	2.5	0.11
27	2.3	0.11
29	2.2	0.10
31	2.1	0.09
33	2.0	0.09
34	1.9	0.09
35	1.8	0.08

46 kV Manhole at Kapiolani and Ward #4

Distance (ft)	Magnetic Field (mG)	Normalized
0	27.3	1.00
1	25.9	0.95
3	21.7	0.79
5	17.1	0.63
7	12.5	0.46
9	9.3	0.34
11	6.5	0.24
13	5.4	0.20
15	5.0	0.18
16	4.6	0.17
19	4.2	0.15
21	3.7	0.14
23	3.2	0.12
25	2.8	0.10
27	2.5	0.09
29	2.3	0.08
30	2.2	0.08
31	2.1	0.08

Table E-6. Magnetic Field Measurements of Manholes at Kapiolani Boulevard and Ward Avenue

46 kV Manhole at Kapiolani and Ward #5

Distance (ft)	Magnetic Field (mG)	Normalized
0	23.9	1.00
1	21.5	0.90
3	20.1	0.84
5	18.5	0.77
7	15.5	0.65
9	11.3	0.47
11	7.7	0.32
14	5.5	0.23
16	4.5	0.19
17	3.9	0.16
19	3.4	0.14
20	3.2	0.13
22	2.9	0.12
24	2.9	0.12
25	2.8	0.12
27	2.7	0.11
29	2.7	0.11
31	2.4	0.10
33	2.4	0.10
35	2.3	0.10
36	2.2	0.09

46 kV Manhole on Kapiolani near Ward

Distance (ft)	Magnetic Field (mG)	Normalized
0	9.1	1.00
1	8.2	0.90
3	7.7	0.85
6	6.8	0.75
8	5.8	0.64
10	5.3	0.59
13	5.0	0.55
16	4.4	0.49
19	4.3	0.47
22	4.1	0.45
25	3.8	0.42
29	2.7	0.29
31	1.7	0.19
34	1.2	0.13
37	1.0	0.11
40	0.9	0.10
42	0.8	0.09
44	0.7	0.08

46 kV Manhole at Kapiolani and Ward #6

Distance (ft)	Magnetic Field (mG)	Normalized
0	54.3	1.00
4	29.3	0.54
8	14.5	0.27
12	7.7	0.14
16	5.7	0.11
19	4.6	0.08
21	3.8	0.07
23	3.3	0.06
26	2.7	0.05
29	2.2	0.04
31	2.0	0.04
34	1.8	0.03
37	1.6	0.03
40	1.5	0.03
43	1.3	0.02
46	1.2	0.02
48	1.1	0.02
49	1.0	0.02

138 kV Manhole on Kapiolani near Ward

Distance (ft)	Magnetic Field (mG)	Normalized
0	3.1	1.00
2	2.5	0.82
4	2.0	0.64
7	1.5	0.48
9	1.1	0.36
11	0.9	0.30

Table E-7. Magnetic Field Measurements of Manholes at Kapiolani Boulevard and Ward Avenue

46 kV Manhole on Sheridan

Distance (ft)	Magnetic Field (mG)	Normalized
0	18.5	1.00
2	17.5	0.95
3	14.9	0.81
5	11.9	0.64
7	9.3	0.50
10	6.9	0.37
12	5.4	0.29
14	4.5	0.24
16	3.9	0.21
18	3.5	0.19
20	3.3	0.18
22	3.0	0.16
24	2.8	0.15
26	2.5	0.14
27	2.6	0.14
29	2.5	0.13
31	2.4	0.13
32	2.5	0.13
34	2.4	0.13
36	2.1	0.12
37	2.0	0.11
40	1.8	0.10
41	1.6	0.08
43	1.4	0.08
45	1.4	0.07
47	1.3	0.07
49	1.1	0.06
51	1.0	0.06

46 kV Manhole on Makaloa Street

Distance (ft)	Magnetic Field (mG)	Normalized
0	4.2	1.00
2	3.9	0.93
4	3.4	0.82
6	2.8	0.68
8	2.2	0.53
11	1.7	0.41
13	1.4	0.34
15	1.2	0.28
17	1.0	0.25
19	0.9	0.21
21	0.8	0.18
23	0.7	0.17
25	0.7	0.16

46 kV Manhole on Pumehana #1

Distance (ft)	Magnetic Field (mG)	Normalized
0	33.3	1.00
2	32.1	0.96
3	28.1	0.84
5	20.9	0.63
6	14.7	0.44
8	11.1	0.33
10	8.3	0.25
12	6.2	0.18
14	4.2	0.13
16	3.3	0.10
18	2.3	0.07
20	1.8	0.05
22	1.5	0.05
24	1.2	0.04
26	1.0	0.03
28	0.9	0.03
30	0.8	0.02

46 kV Manhole on Pumehana #2

Distance (ft)	Magnetic Field (mG)	Normalized
0	28.1	1.00
1	26.9	0.96
2	22.3	0.79
3	18.1	0.64
4	15.9	0.57
5	13.9	0.49
6	11.5	0.41
8	8.1	0.29
10	5.9	0.21
12	3.8	0.14
14	2.6	0.09
16	2.0	0.07
18	1.4	0.05
20	1.1	0.04
22	1.0	0.04
24	0.8	0.03
26	0.7	0.03

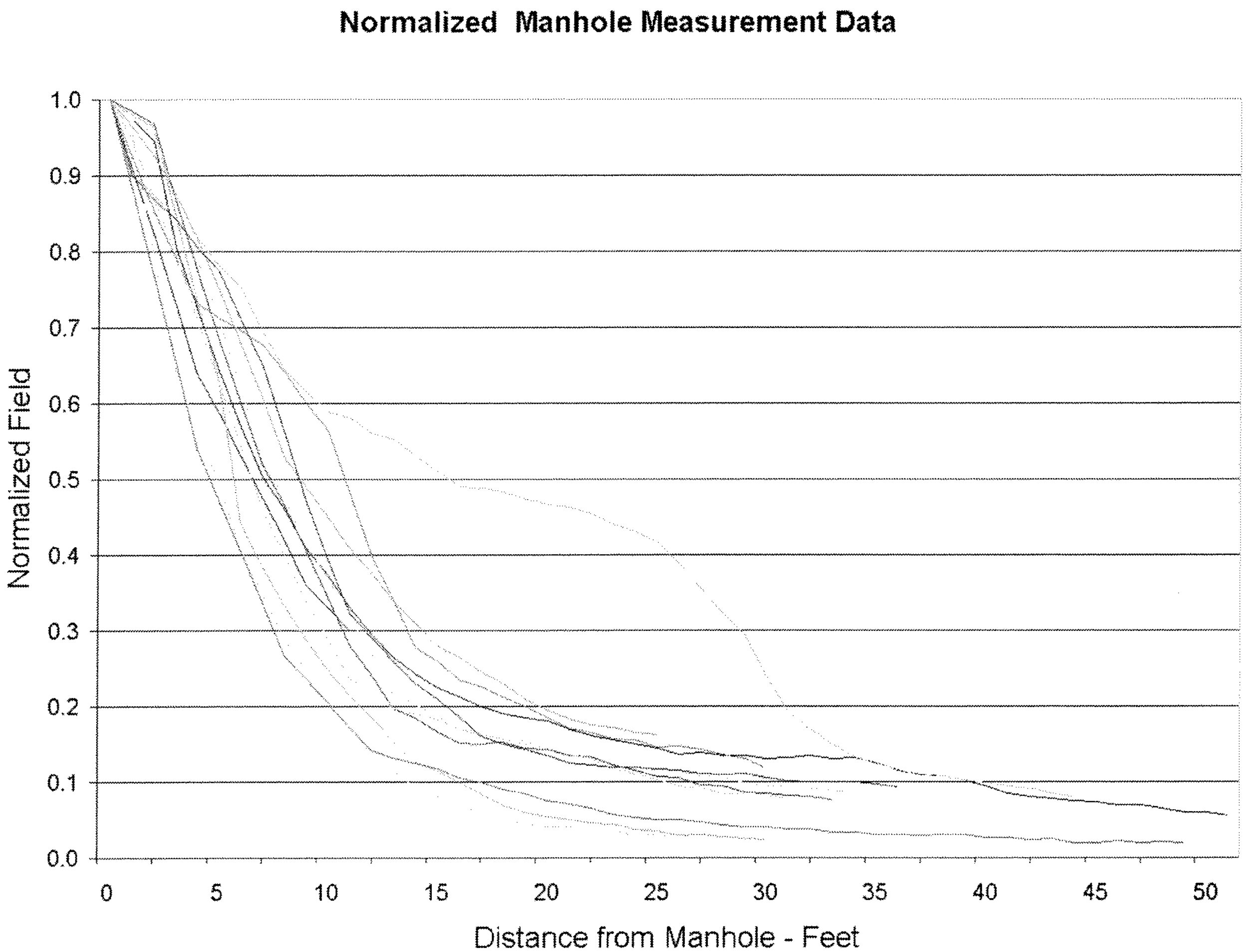


Figure E-3. Normalized Magnetic Field Measurements for HECO Manholes

Table E-8. Average of Normalized Magnetic Field Measurements
For HECO Manholes

Average of Normalized Data for HECO Manholes

Distance (ft)	Normalized
0	1.00
1	0.93
2	0.90
3	0.81
4	0.66
5	0.65
6	0.57
7	0.54
8	0.41
9	0.40
10	0.40
11	0.31
12	0.23
13	0.30
14	0.19
15	0.21
16	0.19
17	0.20
18	0.12
19	0.21
20	0.12
21	0.14
22	0.16
23	0.13
24	0.09
25	0.18
26	0.07
27	0.11
28	0.08
29	0.12
30	0.07

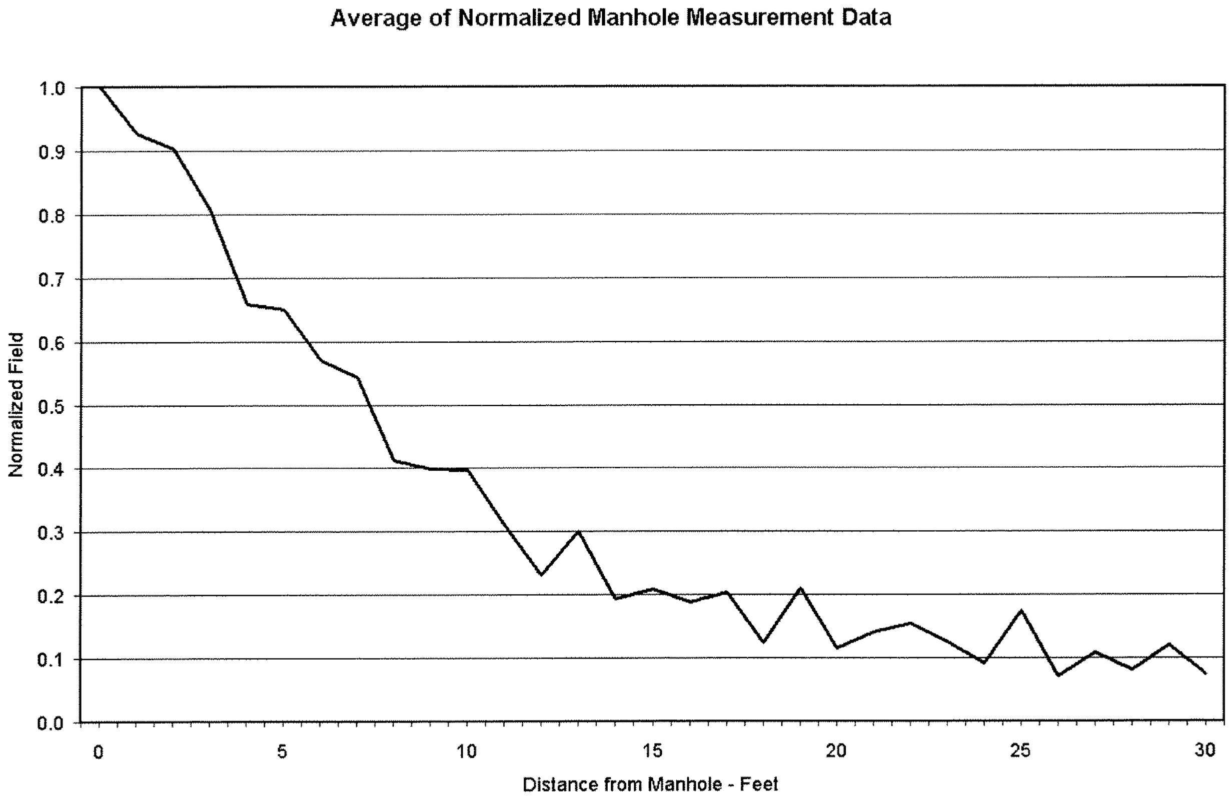


Figure E-4. Average Normalized Magnetic Field Measurements for HECO Manholes

Table E-9. Magnetic Field Measurements of Risers at Various Honolulu Locations

Riser Pole #8 (Near Alexander) - #1

Distance (ft)	Magnetic Field (mG)	Normalized
0	13.0	1.00
1	2.6	0.20
2	2.0	0.15
3	2.1	0.16
4	1.8	0.14

Riser Pole - Pukele 2 Circuit (T-Tap)

Distance (ft)	Magnetic Field (mG)	Normalized
0	249.6	1.00
1	23.2	0.09
2	4.9	0.02
3	1.8	0.01
4	1.3	0.01

Riser Pole #8 (Near Alexander) - #2

Distance (ft)	Magnetic Field (mG)	Normalized
0	14.0	1.00
1	2.4	0.17
2	2.2	0.16
3	2.0	0.14
4	1.6	0.11

46 kV Riser Pole at McCully and Kapiolani

Distance (ft)	Magnetic Field (mG)	Normalized
0	24.8	1.00
1	4.0	0.16
2	2.5	0.10
3	2.2	0.09

Note : Background = 1.8 mG

46 kV Riser Pole - 1 (Pukele 2 Circuit)

Distance (ft)	Magnetic Field (mG)	Normalized
0	64.3	1.00
1	12.1	0.19
2	9.2	0.14
3	8.8	0.14

Riser Pole - Pukele 2 Circuit to SW 5397

Distance (ft)	Magnetic Field (mG)	Normalized
0	36.4	1.00
1	12.5	0.34
2	9.8	0.27

46 kV Riser Pole - Pokele 4 Circuit

Distance (ft)	Magnetic Field (mG)	Normalized
0	1417	1.00
1	745.6	0.53
2	182.4	0.13
3	75.4	0.05
4	41.2	0.03
5	25.6	0.02
6	16.8	0.01
7	11.6	0.01
8	9.0	0.01
9	7.4	0.01
10	6.1	0.00
11	5.2	0.00
12	4.6	0.00

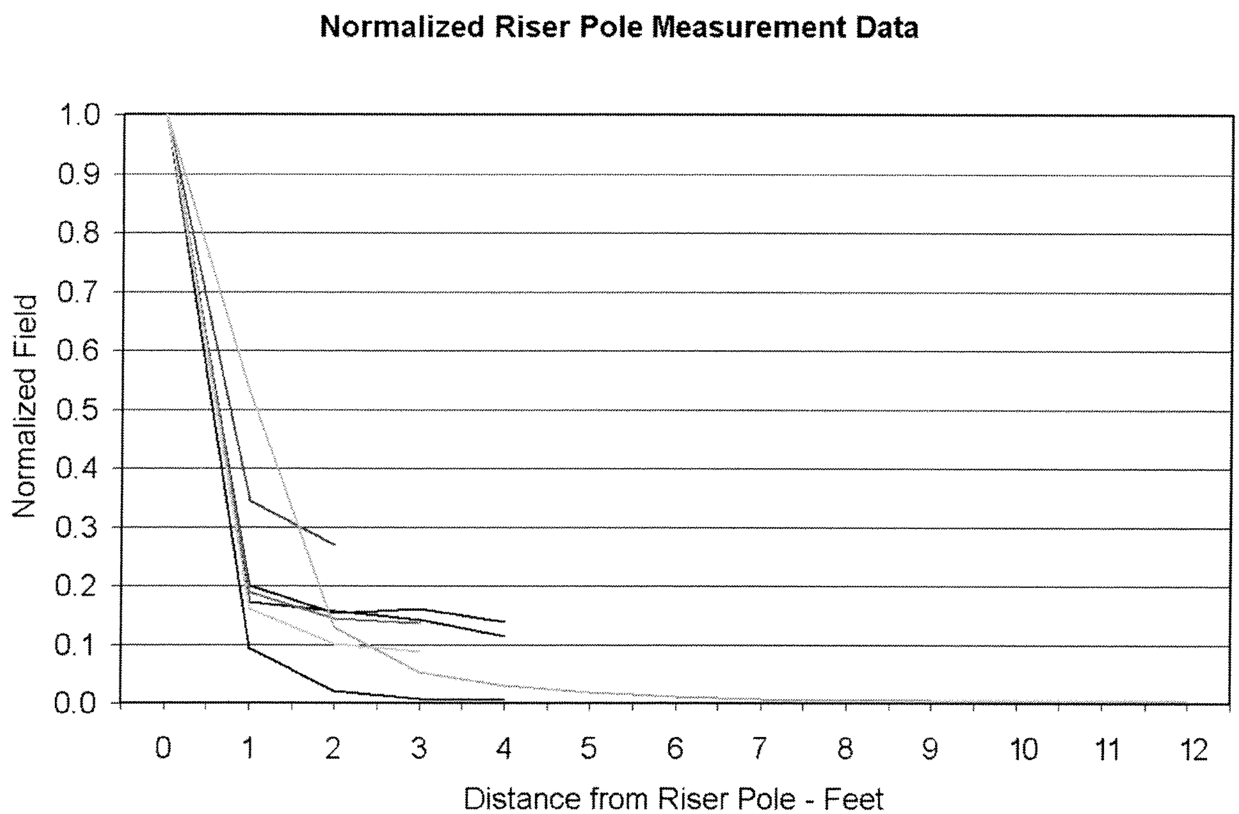


Figure E-5. Normalized Magnetic Field Measurements for HECO Risers

Table E-10. Average of Normalized Magnetic Field Measurements
For HECO Risers

Average of Normalized Data for HECO Risers

Distance (ft)	Normalized
0	1.00
1	0.24
2	0.14
3	0.10
4	0.07
5	0.02
6	0.01
7	0.01
8	0.01
9	0.01
10	0.00
11	0.00
12	0.00

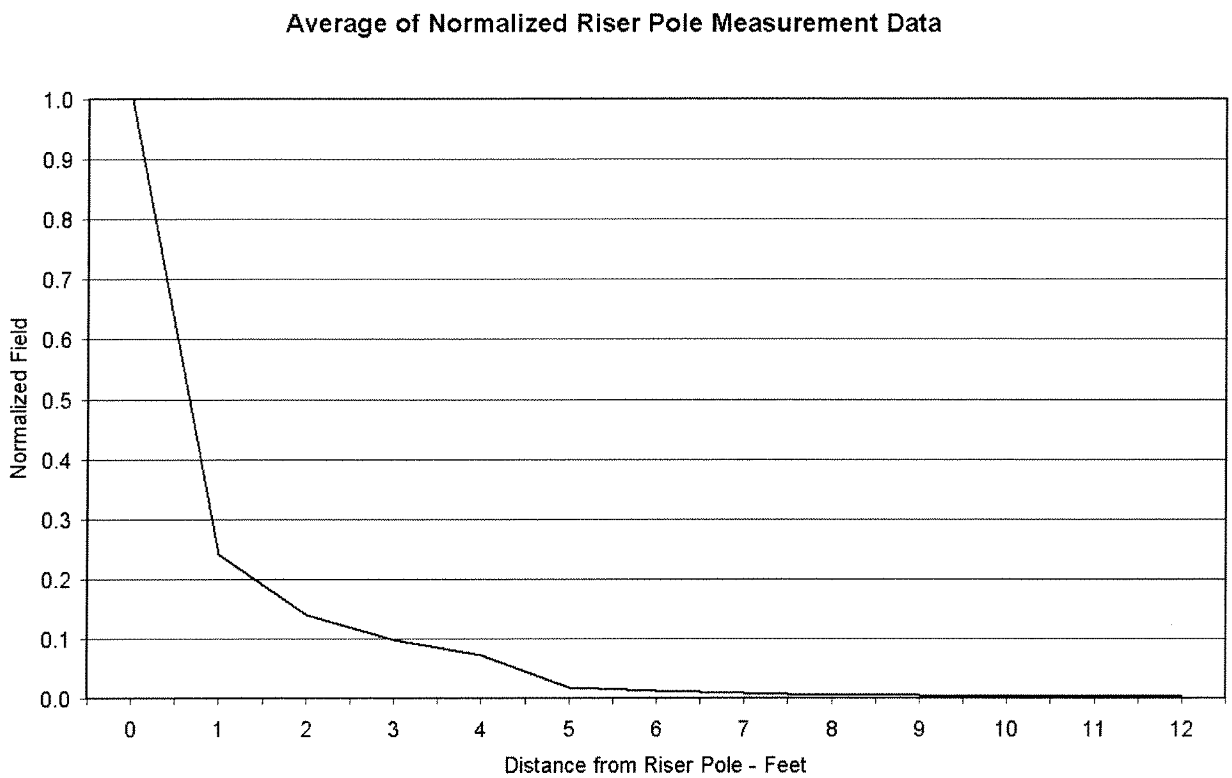


Figure E-6. Average Normalized Magnetic Field Measurements for HECO Risers

APPENDIX F

Magnetic Field Measurements at Public Locations

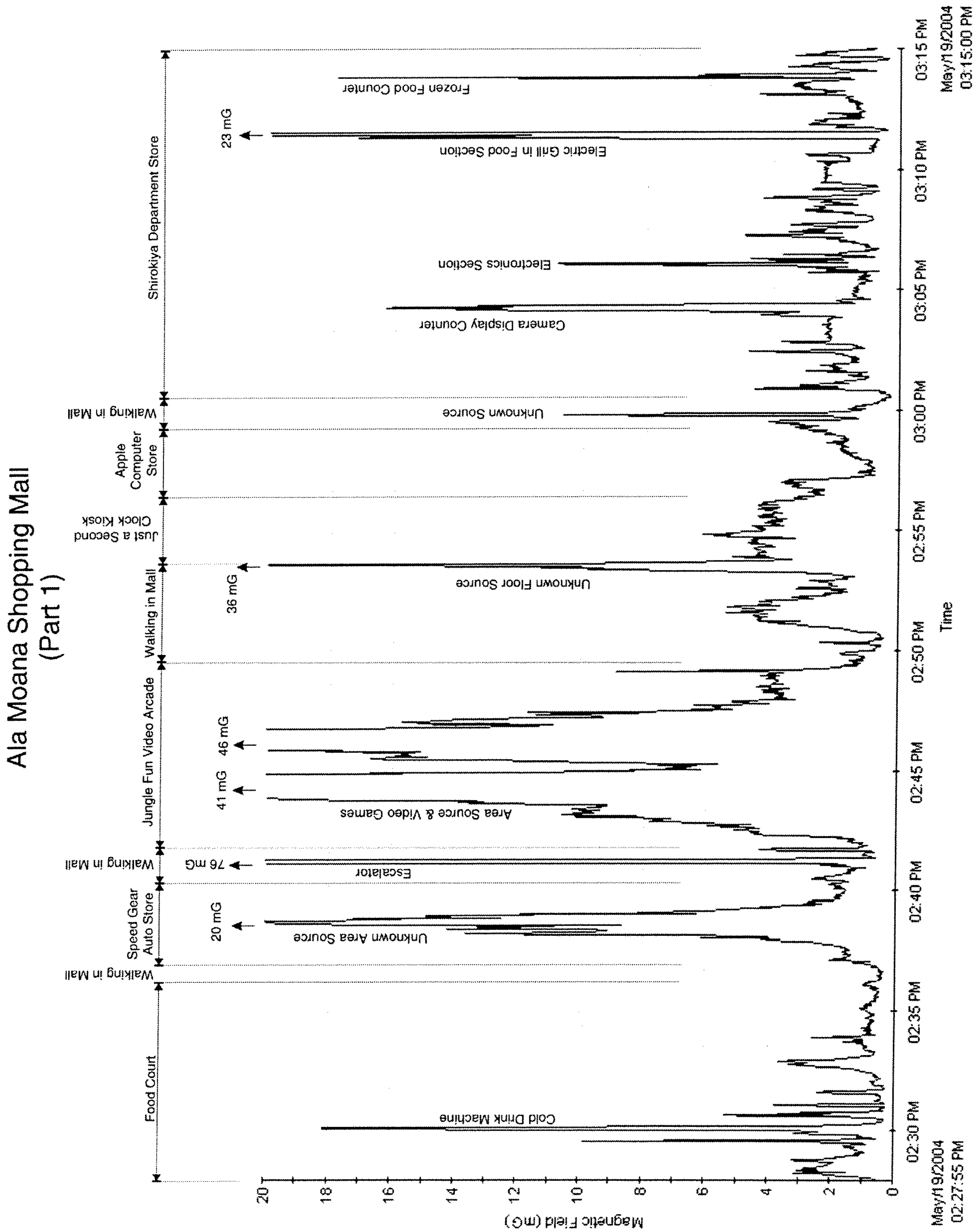


Figure F-1. Magnetic Field Measurements at Ala Moana Shopping Mall
(Part 1)

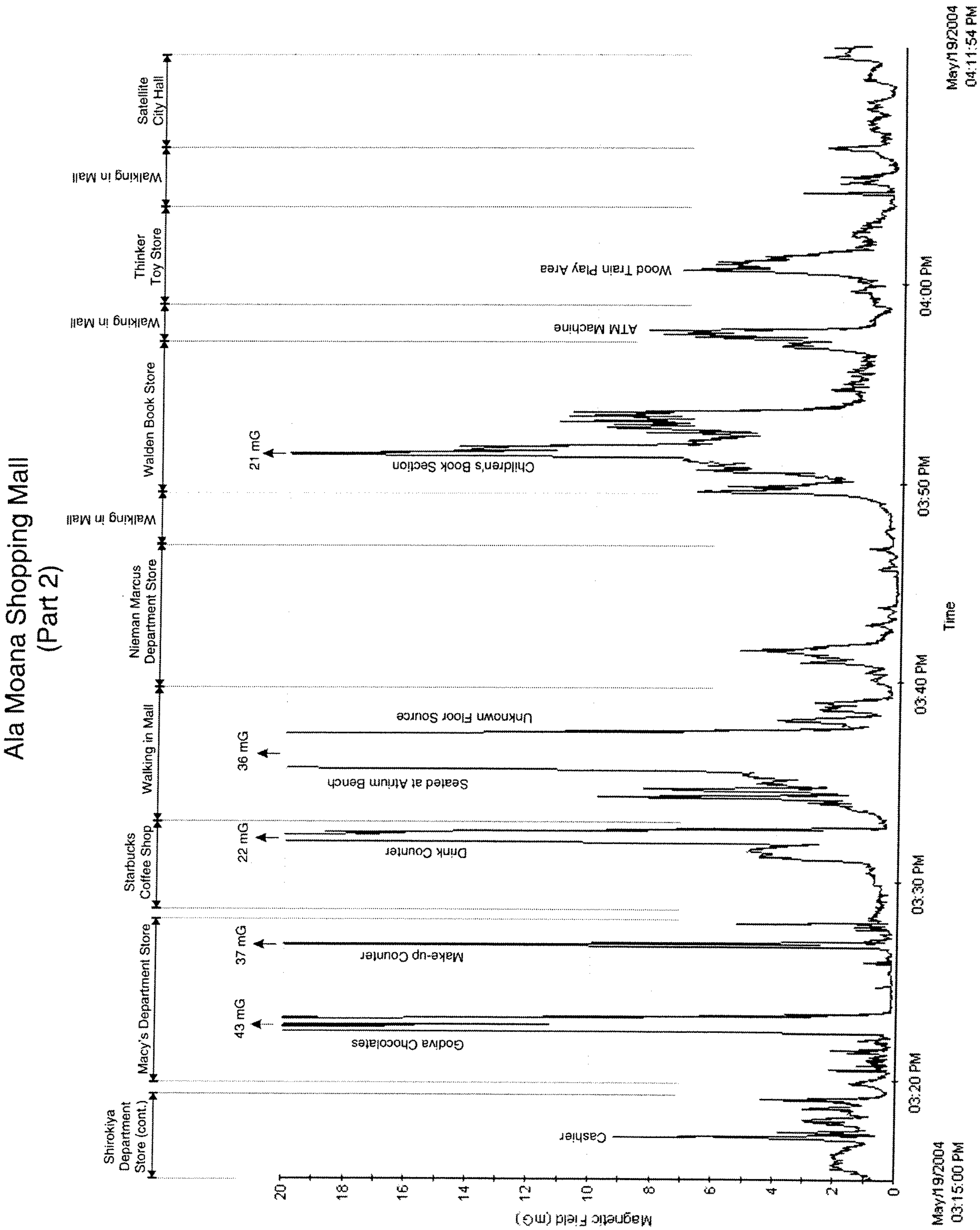


Figure F-2. Magnetic Field Measurements at Ala Moana Shopping Mall
(Part 2)

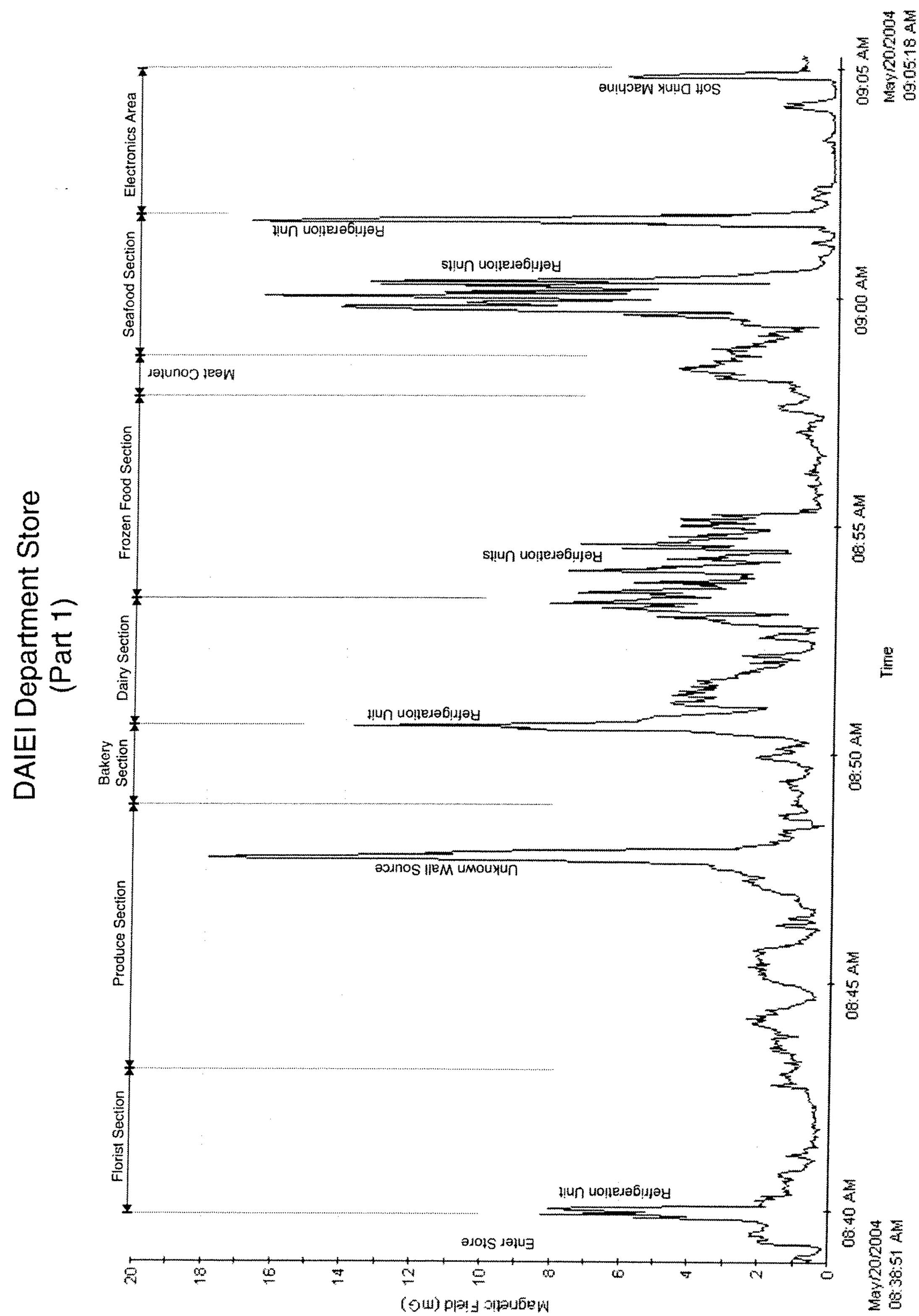


Figure F-3. Magnetic Field Measurements at Daiei Department Store (Part 1)

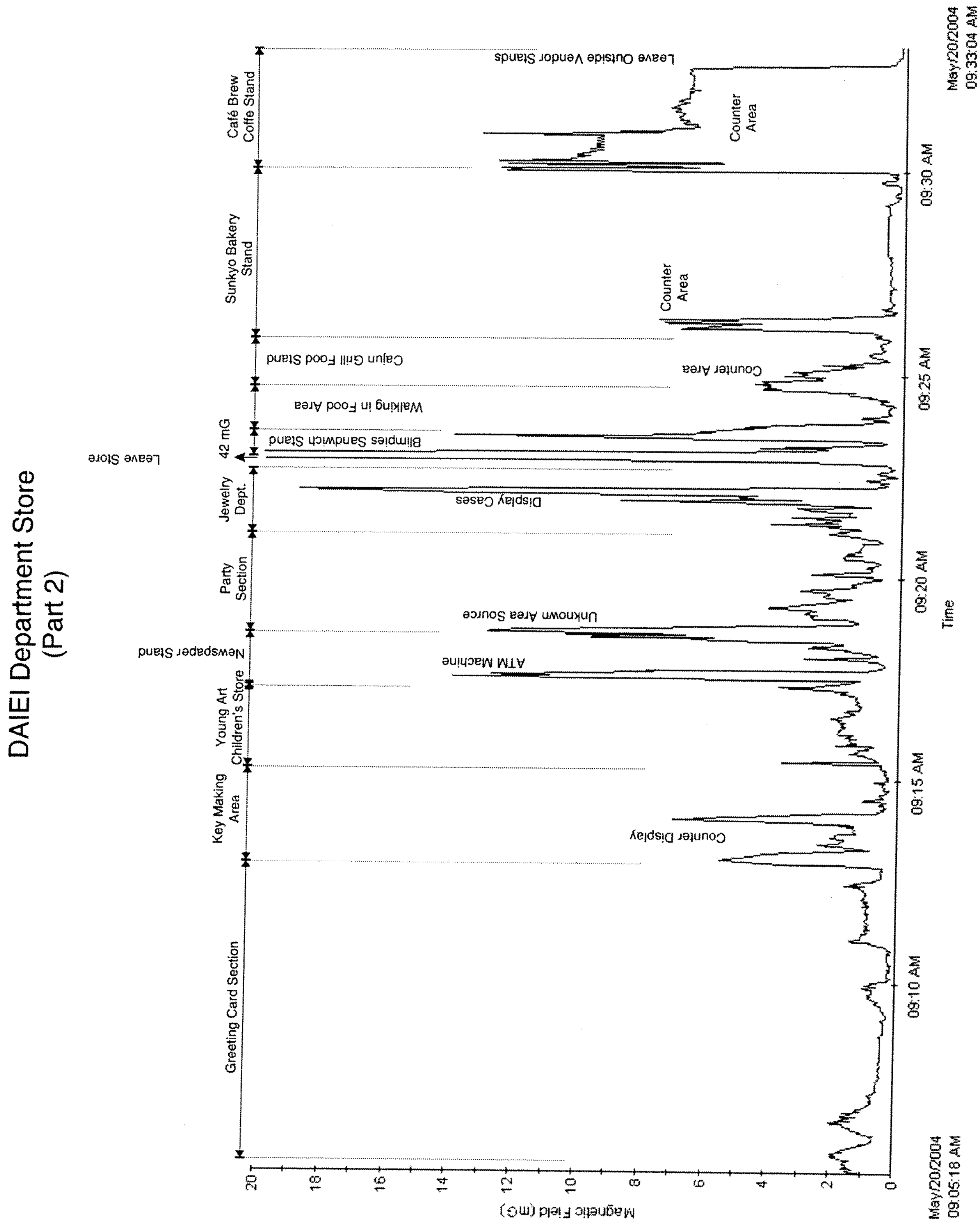


Figure F-4. Magnetic Field Measurements at Daiei Department Store
(Part 2)

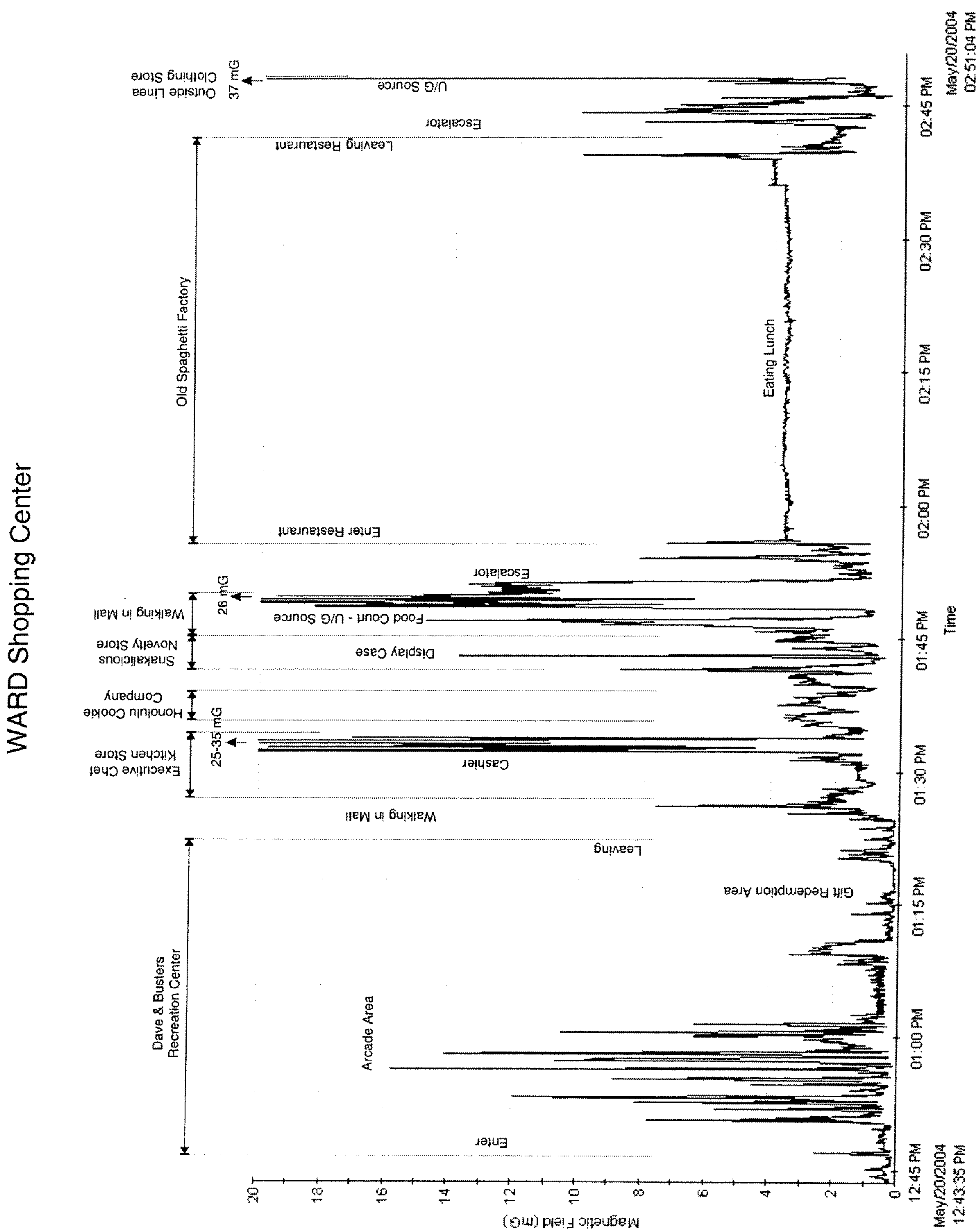


Figure F-5. Magnetic Field Measurements at Ward Shopping Center

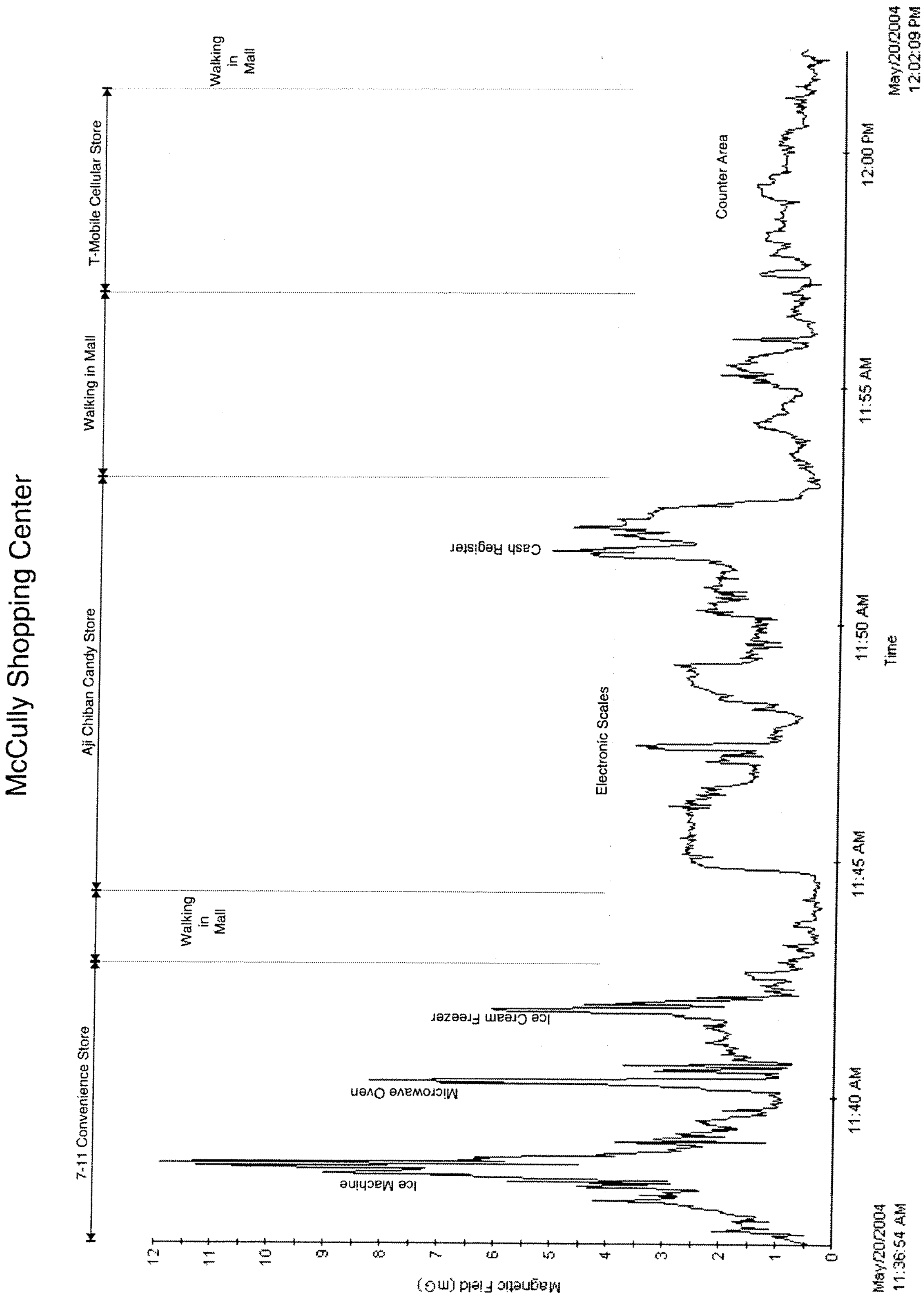


Figure F-6. Magnetic Field Measurements at McCully Shopping Center

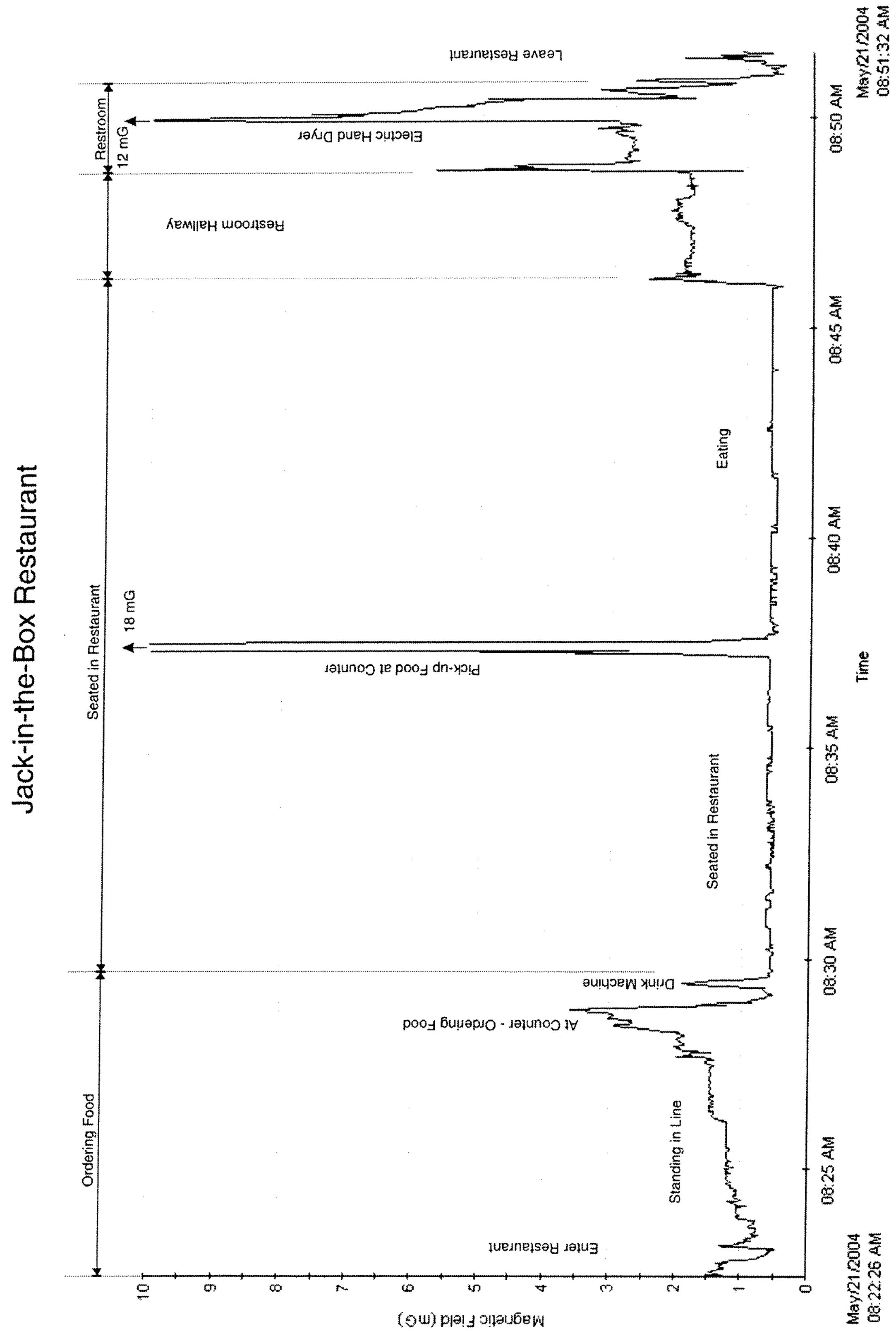


Figure F-7. Magnetic Field Measurements at Jack-In-The-Box Restaurant

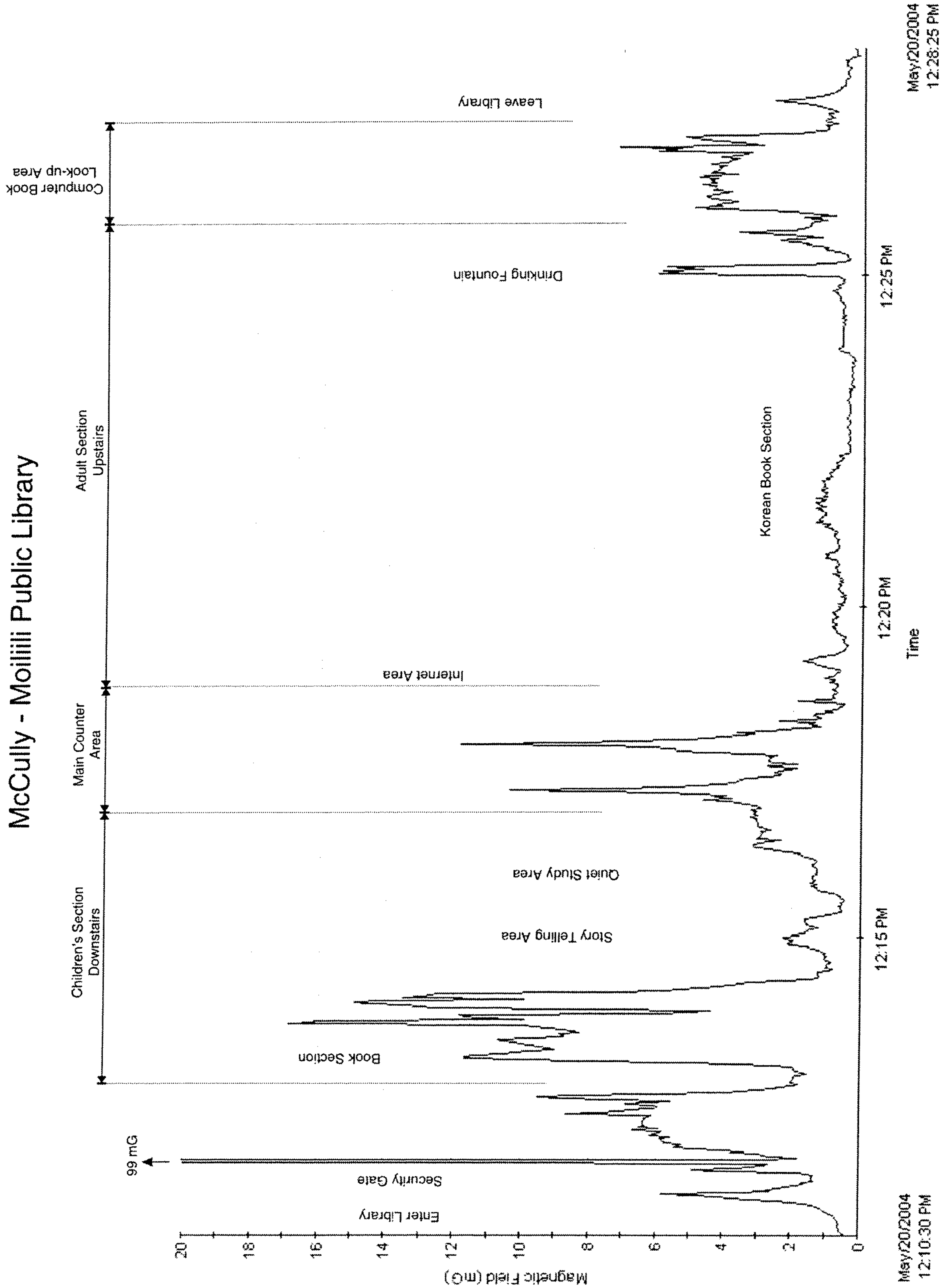


Figure F-8. Magnetic Field Measurements at McCully – Moiliili Public Library

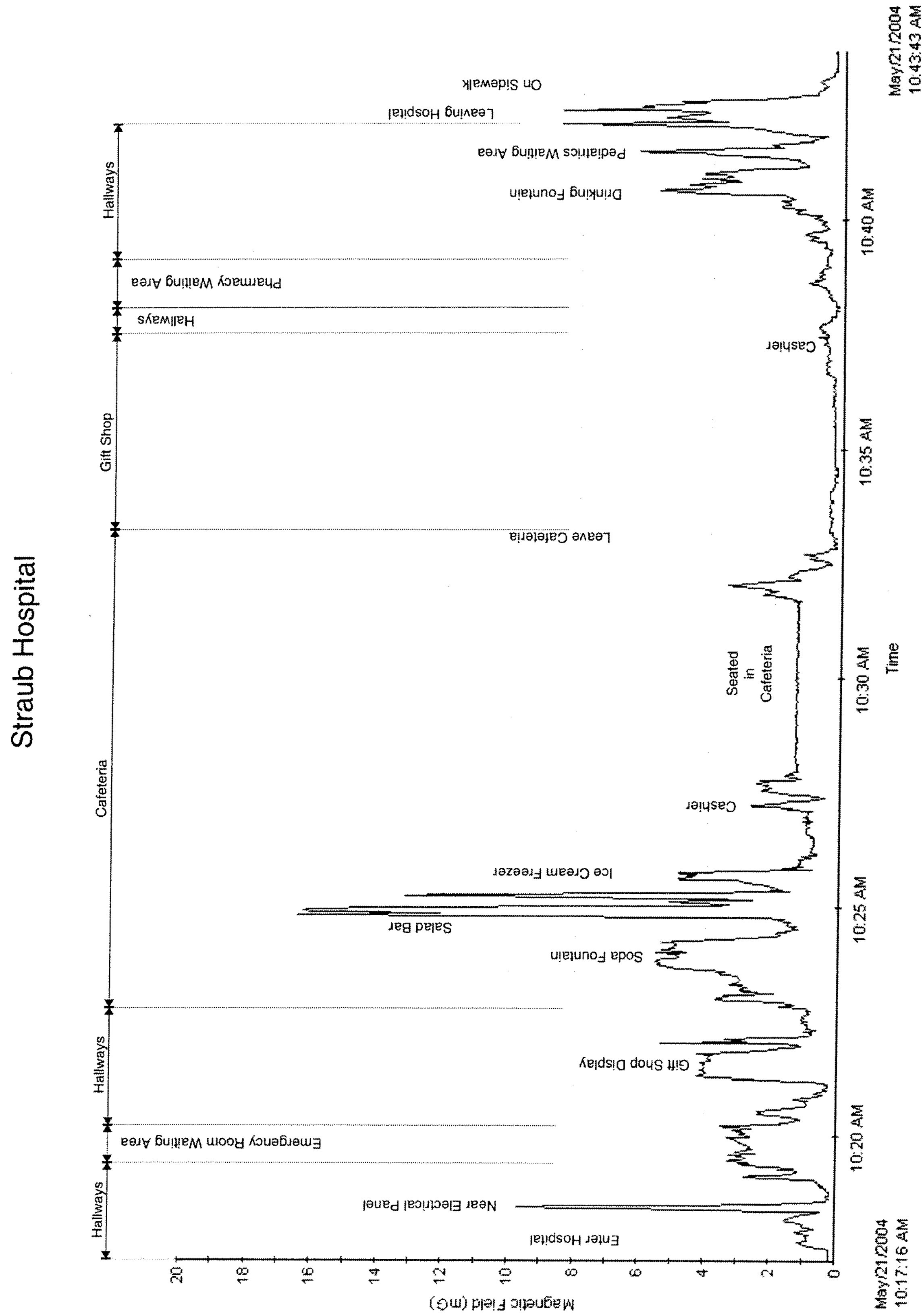


Figure F-9. Magnetic Field Measurements at Straub Hospital

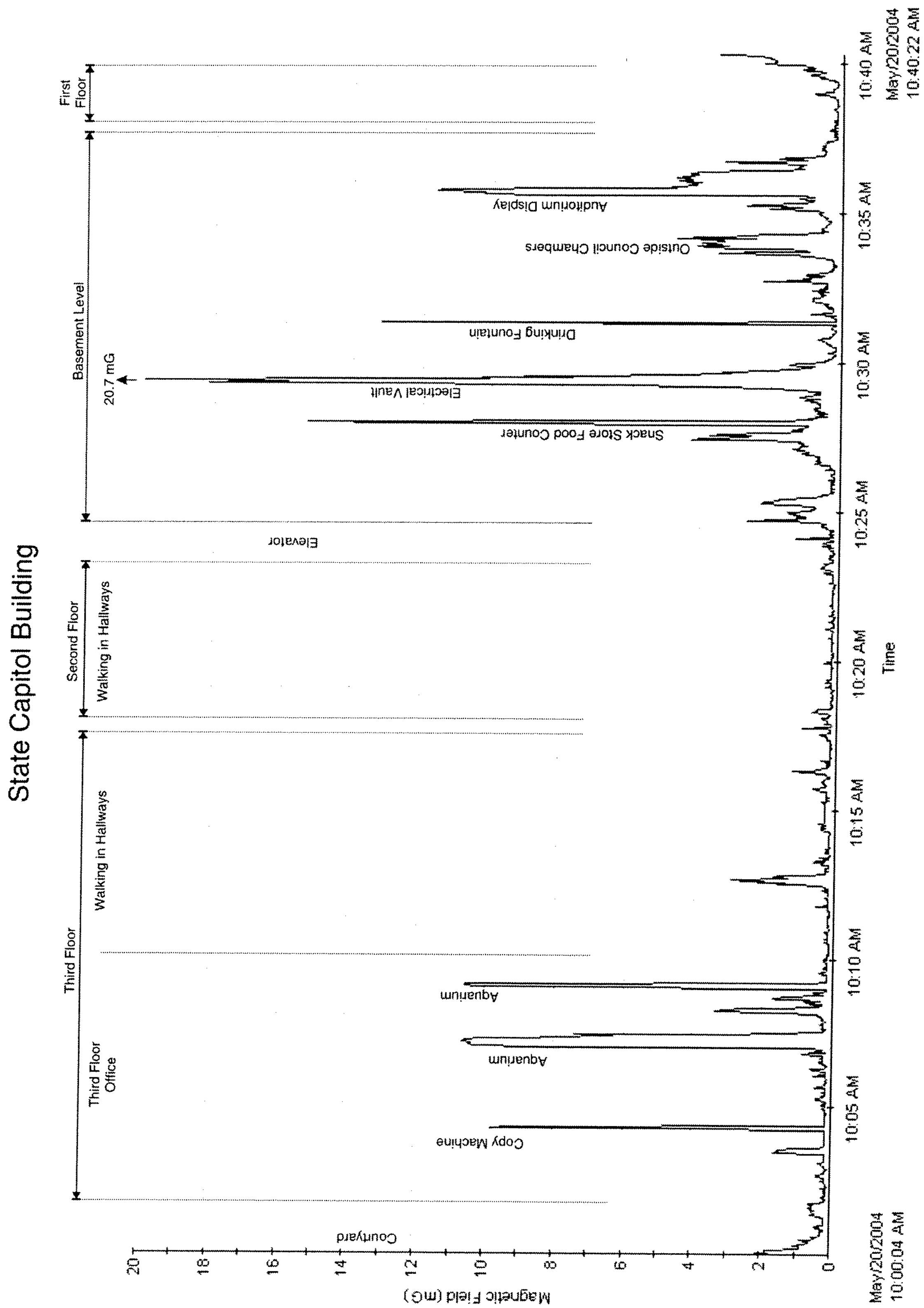


Figure F-10. Magnetic Field Measurements at State Capitol Building

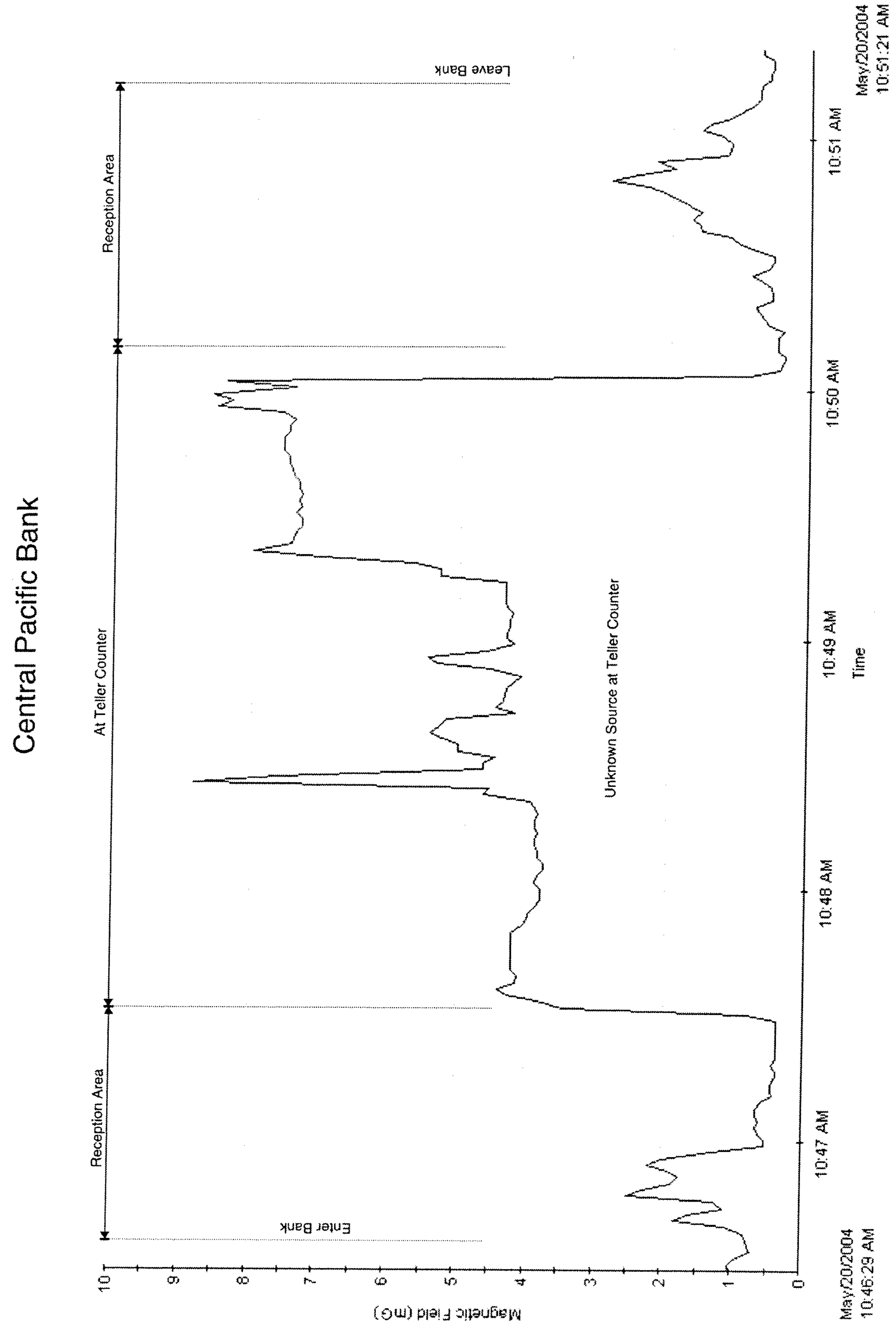


Figure F-11. Magnetic Field Measurements at Central Pacific Bank

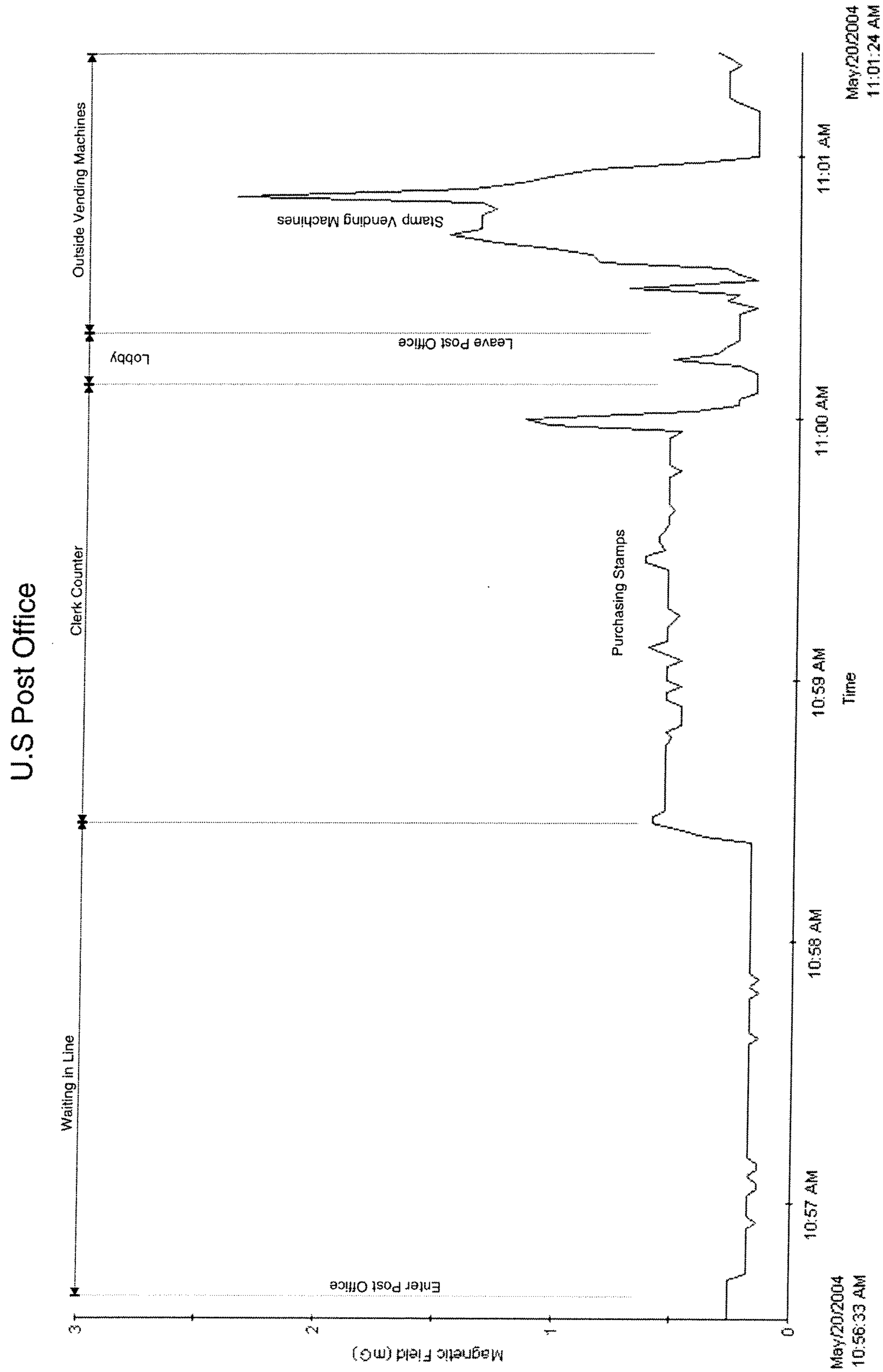


Figure F-12. Magnetic Field Measurements at U.S. Post Office

APPENDIX G

HECO Documentation of Electrical Facilities,
Loading, and Selection of Segment Locations

INTEROFFICE CORRESPONDENCE

Hawaiian Electric Co., Inc.

July 21, 2004

To: K. J. Wong

From: E. F. Oshiro

Subject: East Oahu Transmission Project (EOTP) – Phase 1 & 2
Line Loadings for EMF Analysis

Since magnetic fields are a function of line current, an increase in line loading can increase the magnetic fields in an area. HECO evaluated projected power line loadings in 2009 to determine which segments had the greatest increase in current flow after the installation of the EOTP. Enertech Consultants evaluated magnetic field levels at these segments, as well as the segments in which construction would take place. This memo describes the methodology used to determine the line current loadings used in the EMF analysis and the selection of EMF measurement locations.

Load Flow Simulation

Power System Simulator for Engineering (PSS/E) is an integrated, interactive program for simulating, analyzing, and optimizing power system performance. PSS/E is the most comprehensive, technically advanced, and widely used power system simulation computer program. Using electrical system characteristics and forecasted area loads, PSS/E simulates current flow in power lines.

Forecasted Normal Loads

The 2009 normal load is based on the 2003 recorded load demand escalated to 2009. To be more specific, the 2003 load demand for the substations in the study area at the time of the annual system day peak is multiplied by the day peak load growth factor in the HECO August 2002 Long Term Sales and Peak Forecast.

Areas with Line Current Increases

Four areas were determined to have the greatest line current increases although no new lines are planned for construction. These areas are as follows:

- Kapiolani Boulevard between Clayton and Kamakee Streets – Loads currently fed from Pukele Substation are transferred to Archer Substation by the EOTP. The result is an increase in current flow in the 46kV circuits exiting Archer Substation.
- Sheridan Street between Kapiolani Boulevard and Makaloa Substation – Loads currently fed from Pukele Substation are transferred to Archer Substation by the EOTP. The result is an increase in current flow in the 46kV circuits exiting Archer Substation.
- Kapiolani Boulevard between Kamoku and Pumehana Streets – Loads currently fed from Pukele Substation are also transferred to the new transformer at Kamoku

Substation by the EOTP. The result is an increase in line current in the circuit from Kamoku Substation feeding loads in the Ewa direction.

- Date Street near Pumehana Street – The section of 46kV line along Date Street is presently at the end of a circuit. As a result, the load in the circuit is close to zero. With the construction of the EOTP, the connection of the Archer #46 to the Pukele #2 circuit near Date Street makes this segment of subtransmission line the middle of a circuit fed from Archer Substation.

On the HECO system, 138kV transmission lines originate from generating stations and feed 138kV transmission substations. In a radial configuration, such as in the proposed EOTP, 46kV subtransmission lines emanate from 138kV transmission substations and feed transformers at 46kV subtransmission substations downstream. Typically the current loading in these 46kV subtransmission lines is highest closest to the 138kV transmission substation and decreases downstream as loads are fed. Based on this, the identified locations of greatest increase in current flow are reasonable.

25 kV and 12 kV distribution loads were calculated based on the total connected load of service transformers on the circuit at the location where measurements and modeling would be done. Since loading on service transformers is not recorded, it was assumed that all transformers were loaded to their rated values. This represents the most conservative assumption for the EMF analysis.

<u>Pukele Outage Load</u>
If the EOTP is implemented, in the event of the loss of Pukele Substation, all 46kV loads fed from Pukele Substation are transferred to Archer or Kamoku Substations. Current flow for this scenario is represented as the "Pukele Outage Load". 25 kV and 12 kV distribution loads remained the same in the Pukele Outage Load since this already represented the most conservative assumption for the EMF analysis.

<u>Loads at the Time of EMF Measurements</u>
Enertech Consultants measured existing magnetic fields on May 17-18, 2004. 46kV subtransmission line loading at the time of the EMF measurements was determined using recorded data at the hour nearest to the time of measurement. These values were obtained from the ammeter charts located in the substation switchgear or the Energy Management System (EMS) located in the HECO load dispatch center.

Knowing the current reading at the 138kV transmission substations, the source side of the circuit, and the current loading at the connected 46kV subtransmission substations, the current flow in each line segment was calculated.

Similar to the forecasted loads, 25 kV and 12 kV distribution loads were calculated based on the total connected load from service transformers on the circuit at the location where measurements were taken.

<u>Conclusion</u>
The method used to determine forecasted current loading and at the time of the EMF measurements was reasonable and conservative.