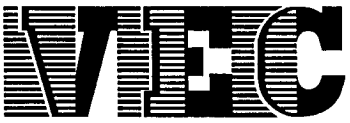

Vibration Engineering
*consultants, inc.*

October 29, 1997

# EVALUATION OF GROUND VIBRATION AT THE MEADOWVILLE SITE

Prepared for:

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## *TABLE OF CONTENTS*

## Executive Summary

A survey was conducted to measure existing ground vibration levels at the Meadowville Site in Chesterfield County, Virginia. Vibration sensitive processes, such as semiconductor manufacturing, may take place on the site in the future. The survey was conducted on October 23 and 24, 1997 by Vibration Engineering Consultants of Woburn, Massachusetts. The measured ground vibration levels (those that would be transmitted to buildings through their foundation) were compared to the expected requirements of a semiconductor manufacturing facility.

The Meadowville Site is near the junction of Hundred Road and I 295 approximately 15 miles southeast of downtown Richmond. The site is mostly wooded but is bordered by developed areas. There is a Reynolds Corporation facility (Corporate Technology Center) next to the eastern boundary of the site. Other adjacent land and interior land is used mainly for single family homes or agriculture. Interstate 295 runs along the western edge of the site; the James river runs along the northern boundary of the site.

The existing ground vibration levels at the interior of the site were found to be low and would allow the operation of a typical semiconductor manufacturing plant. Ground vibration was found to be higher at points near I295, therefore it is beneficial to maintain an appropriate distance between the highway and vibration sensitive tooling. In addition, occasional truck traffic was observed on Enon Church Road. Based on the survey results and past experience, distance of 750' would provide an effective buffer against traffic induced vibration. The survey results should be compared to project-specific vibration criteria when siting a facility.

Measurements were made at the soil surface where vibration levels tend to be highest. Embedded footings or piles have the capability to reduce the vibration input to a structure. A suitable design analysis, one that considers vibration control requirements, should be conducted to determine an acceptable foundation scheme.

To help maintain the quality of the vibration environment, the owner should be aware that future activities within adjacent parcels can produce undesirable vibration. Construction activities such as pile driving and blasting are of most concern. Manufacturing operations making use of large stamping machines and large piston compressors, or other large equipment are also of concern.

# 1 Introduction

A survey was conducted to measure existing ground vibration levels at the Meadowville Site in Chesterfield County, Virginia. Vibration sensitive processes, such as semiconductor manufacturing, may take place on the site in the future. The survey was conducted on October 23 and 24, 1997 by Vibration Engineering Consultants of Woburn, Massachusetts.

The extremely small geometry of state-of-the-art semiconductors requires the associated production and test tools to maintain strict dimensional stability. Ground vibration transmitted to these tools can be a factor in the quality of the product since it may degrade that stability, even when vibration levels are low by conventional standards.

The measured ground vibration levels (those that would be transmitted to buildings through their foundation) were compared to the expected requirements of a semiconductor manufacturing facility. A qualitative assessment of the site was also conducted, whereby the nearby conditions were evaluated.

The Meadowville Site is near the junction of Hundred Road and I 295 approximately 15 miles southeast of downtown Richmond. The site is mostly wooded but is bordered by developed areas. There is a Reynolds Corporation facility (Corporate Technology Center) next to the eastern boundary of the site. Other adjacent land and interior land is used mainly for single family homes or agriculture. Interstate 295 runs along the western edge of the site; the James river runs along the northern boundary of the site.

At the time of the survey there was no significant activity on the site. During measurements, the sky was clear and there was little wind.

# 2 Survey Method

An Ono Sokki CF350 dynamic signal analyzer and highly sensitive Wilcoxon Model 731 seismic accelerometers were used to measure vibration. The dual channel CF350 has 400 lines of resolution and a dynamic range of about 70 dB. Based on the sensitivity of the tools under consideration, a frequency range of 0 to 100 Hertz was measured.

The single axis accelerometers were placed on ground at the location of interest. Motion in two of three orthogonal directions was measured simultaneously (vertical and one of two horizontals). Typically 20 measurements were taken and averaged. Motion was recorded as acceleration power spectra and saved on diskette. The procedure was repeated for the other

horizontal direction. The acceleration data can be converted to velocity or displacement values. Table 2.1 summarizes the measurement set-up.

| | |
|---|---|
| **Analyzer measurement method** | Frequency range: 0-100 Hz, Constant bandwidth of 0.25 Hz, Hanning window |
| **Averaging method** | Linear, 20 averages per record |
| **Engineering units** | inches and seconds |

Table 2.1 - Power spectrum measurement set-up

Measurements were conducted at 13 points within the site. Figure 1 shows the location of survey points. Survey points were located in the field by reference to aerial photographs and topographic maps.

# 3 Survey Results

Table 3.1 presents the results of the vibration survey in a summary form. In the table, vibration levels are presented as peak spectral velocity, where the spectrum is summed into 1/3 octave bands from 4 to 100 Hertz. This procedure, per IES-RP-CC012.1 (3), is a general way to assess vibration severity when no specific tool vibration criteria is available. A level below about 250 μin/sec RMS is postulated in IES-RP-CC012.1 as a limit for 0.3 micron line width operations, although many tools (those with good vibration isolation) can tolerate substantially higher levels. No specific vibration criteria has been specified at this time, therefore the 250 μin/second criterion of IES-RP-CC012.1 is used as a reference level.

Figures 2 to 14 display the one-third octave band velocity spectra for the thirteen survey points. The values in Table 3.1 correspond to the peaks of these spectra. The one-third octave band spectra were obtained by processing the survey data. The raw survey data (acceleration power spectra) are included as an appendix.

The typical existing background vibration levels were found to be low at points in the interior of the site. Levels increased as distance to I295 decreased, but remained below 150 μin/second at all survey points. The vibration was generally broad-band, i.e. without any high narrow peaks. A narrow peak indicates the presence of a man-made vibration source such as a compressor or pump.

Near the highway, the most noticeable increase in energy content was in the low frequency bands (12.5 Hertz and below, e.g., see Figure 6). Observation during the survey indicates that this energy is mostly the result of truck traffic on I295. It is likely that the dynamic forces associated with a truck pass induce soil surface waves which decay over distance.

The vibration levels near the Reynolds facility were low and did not indicate the presence of a constant problematic vibration sources. The baseline survey conducted would not capture vibration associated with intermittent operation of heavy equipment. If the facility did contain such equipment it would require special investigation.

| | Peak Spectral Velocity (μin/sec RMS) | | |
|---|---|---|---|
| **Point** | **Vertical** | **N/S** | **E/W** |
| 1 | 35 | 47 | 42 |
| 2 | 65 | 41 | 48 |
| 3 | 19 | 34 | 38 |
| 4 | 65 | 88 | 23 |
| 5 | 144 | 88 | 54 |
| 6 | 21 | 34 | 26 |
| 7 | 12 | 21 | 8 |
| 8 | 17 | 8 | 8 |
| 9 | 6 | 10 | 8 |
| 10 | 27 | 72 | 35 |
| 11 | 72 | 40 | 25 |
| 12 | 7 | 11 | 9 |
| 13 | 10 | 22 | 27 |

Table 3.1: Measured peak spectral velocity, for 1/3 octave bands from 4 to 100 Hertz

# 4 Conclusion

The existing ground vibration levels at the interior of the site were found to be low and would allow the operation of a typical semiconductor manufacturing plant. Ground vibration was found to be higher at points near I295, therefore it is beneficial to maintain an appropriate distance between the highway and vibration sensitive tooling. In addition, occasional truck traffic was observed on Enon Church Road.

Based on the survey results and past experience, distance of 750' would provide an effective buffer against traffic induced vibration. At this distance, peak spectral velocity was typically less than 100 μin/second, significantly below the reference level of 250 μin/second (one-third octave band spectra). This buffer provides margin to accommodate vibration sources associated with operation of the plant. Plant sources typically produce the majority of the vibration. The survey results should be compared to project-specific vibration criteria when siting a facility.

Measurements were made at the soil surface where vibration levels tend to be highest. Embedded footings or piles have the capability to reduce the vibration input to a structure. A suitable design analysis, one that considers vibration control requirements, should be conducted to determine an acceptable foundation scheme.

To help maintain the quality of the vibration environment, the owner should be aware that activities within adjacent parcels can produce undesirable vibration. Construction activities such as pile driving and blasting are of most concern. Manufacturing operations making use of large stamping machines and large piston compressors, or other large equipment are also of concern.

# 5 References

1. "Measuring and Reporting Vibration in Microelectronics Facilities", Institute of Environmental Sciences, 1994. IES-RP-CC024.1
2. "Considerations in Cleanroom Design", Institute of Environmental Sciences, 1993. IES-RP-CC012.1

# 6 Figures


Figure 1: Meadowville Site survey points

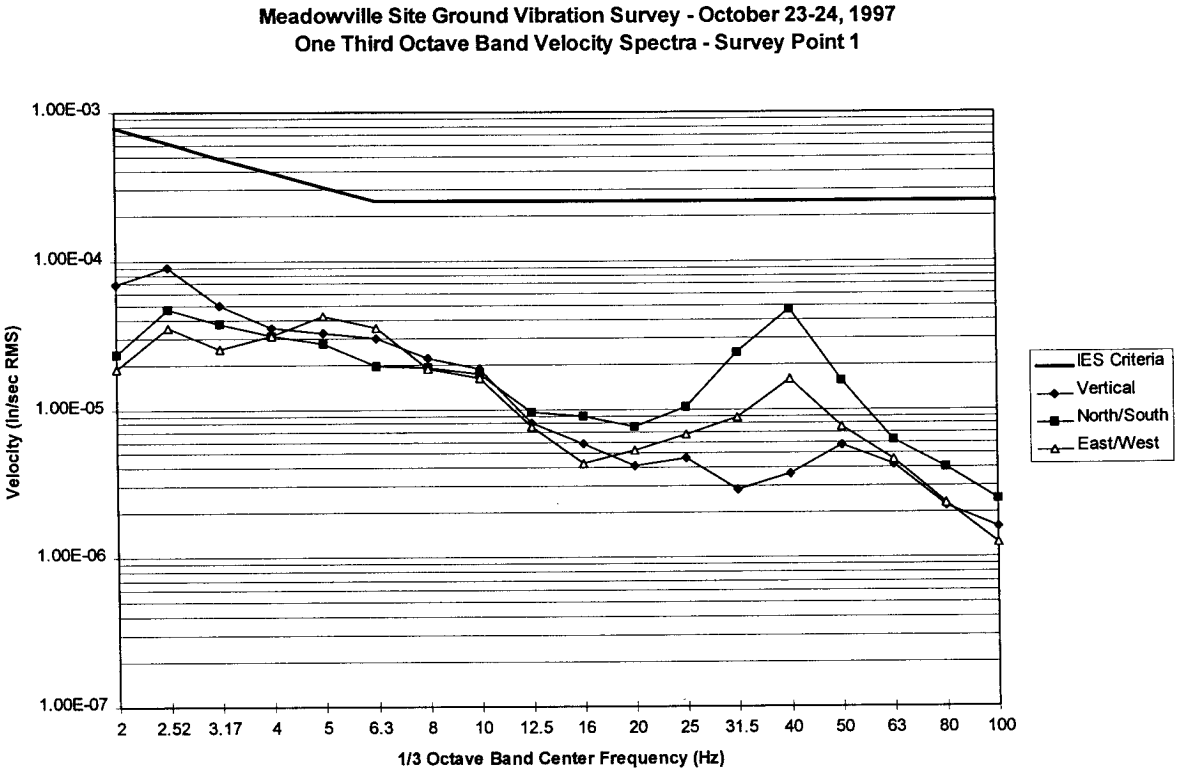



Figure 2: Survey Point 1, one-third octave band velocity spectra

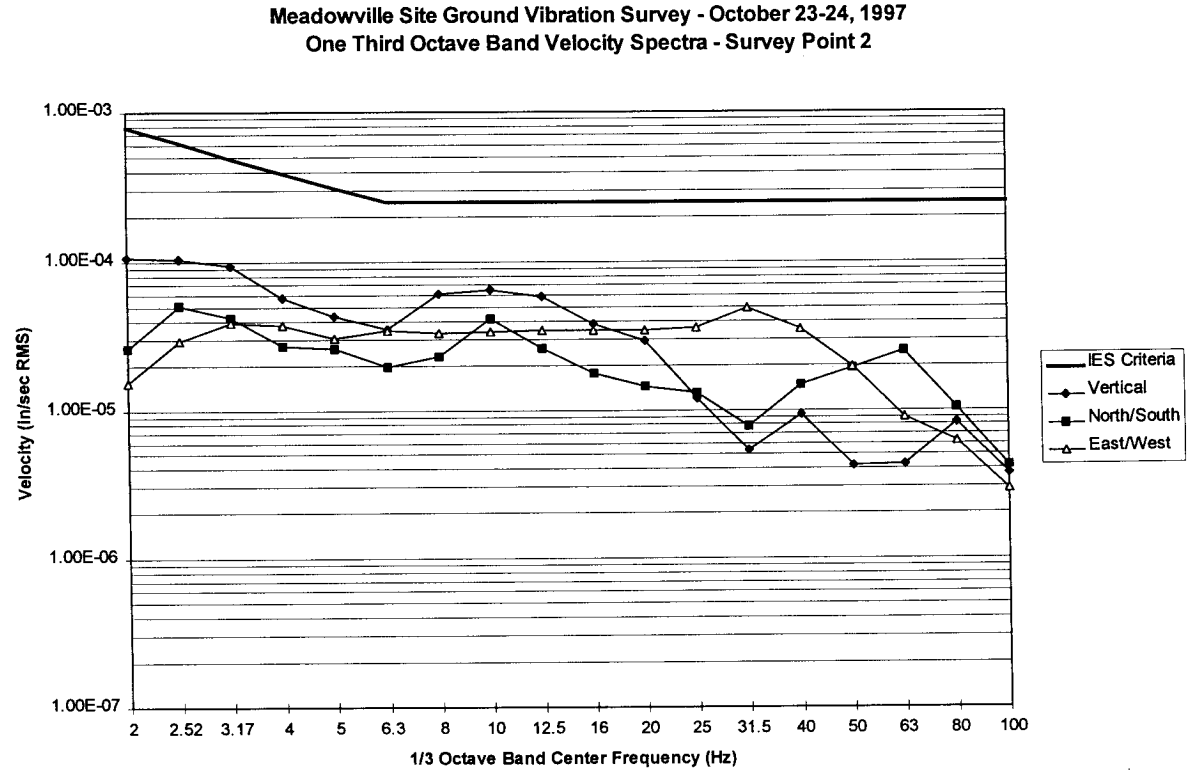



Figure 3: Survey Point 2, one-third octave band velocity spectra

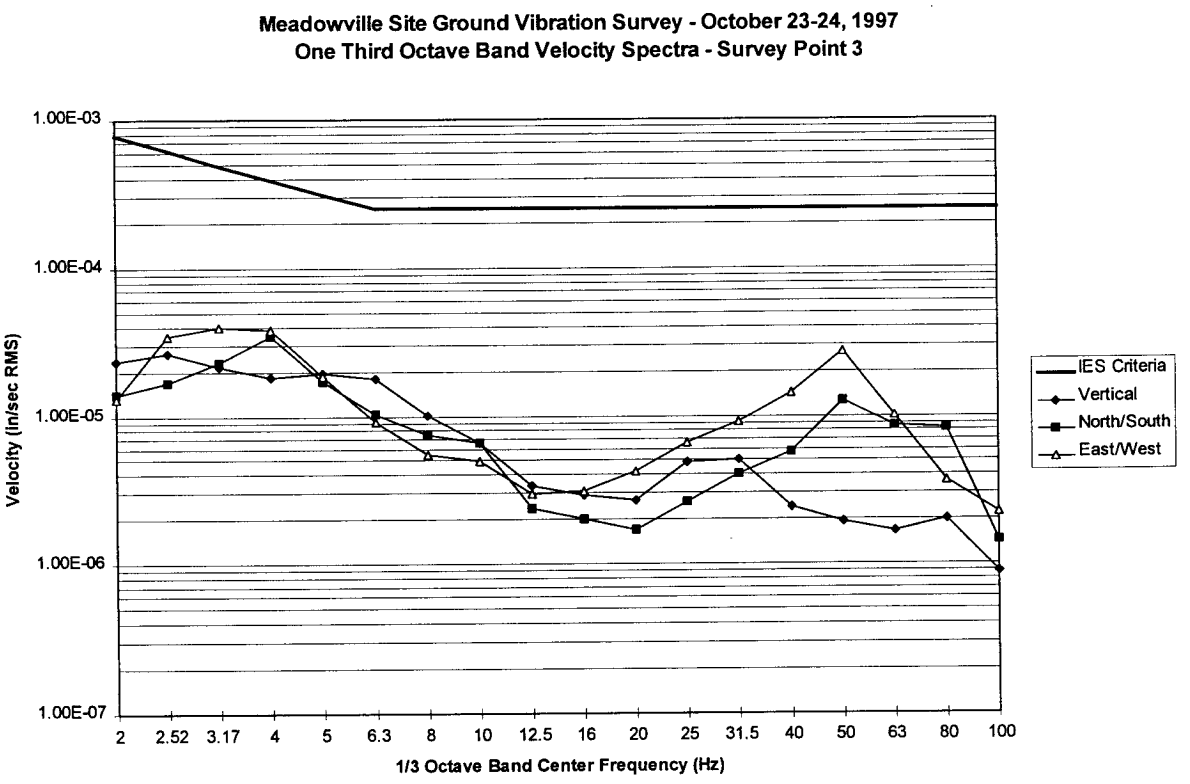



Figure 4: Survey Point 3, one-third octave band velocity spectra

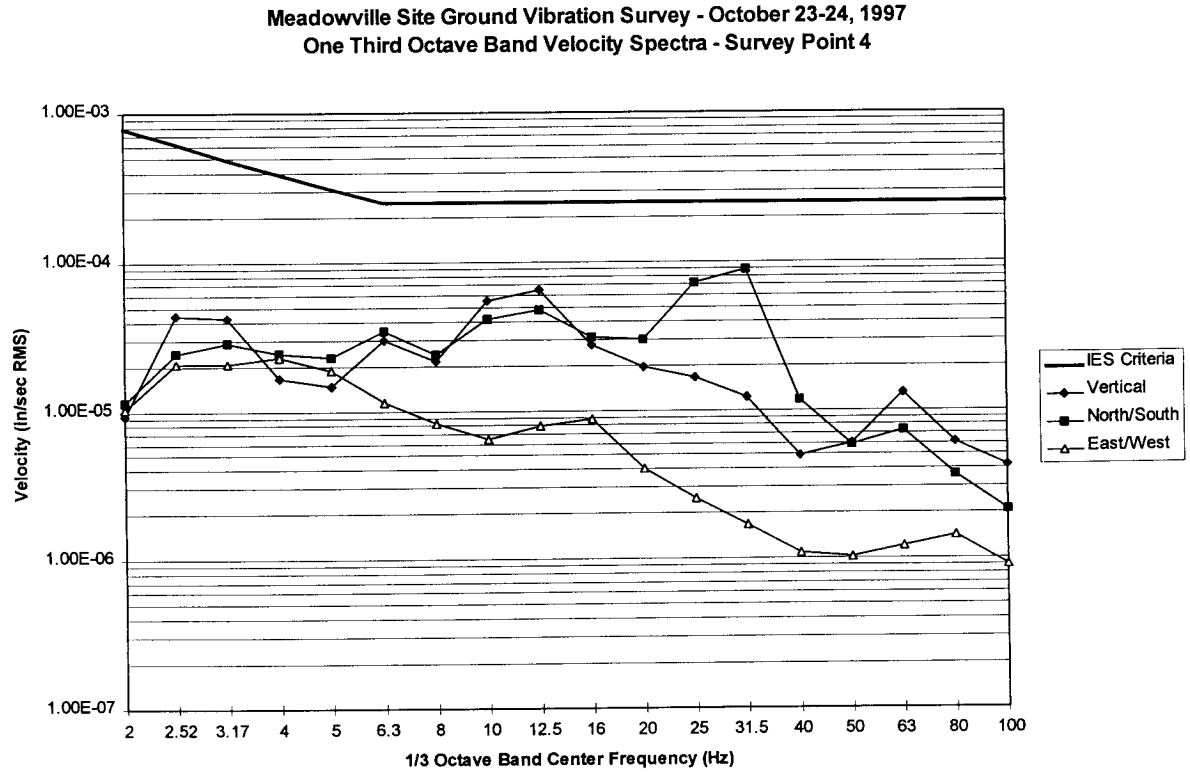



Figure 5: Survey Point 4, one-third octave band velocity spectra

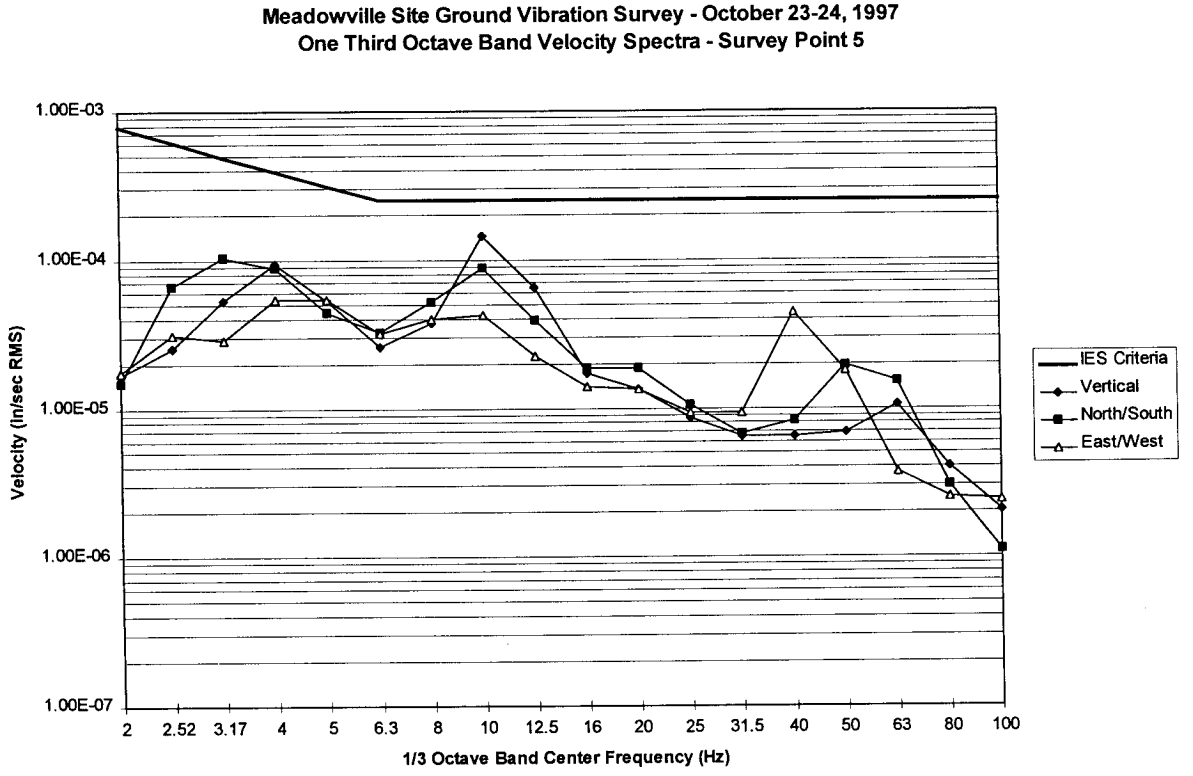



Figure 6: Survey Point 5, one-third octave band velocity spectra

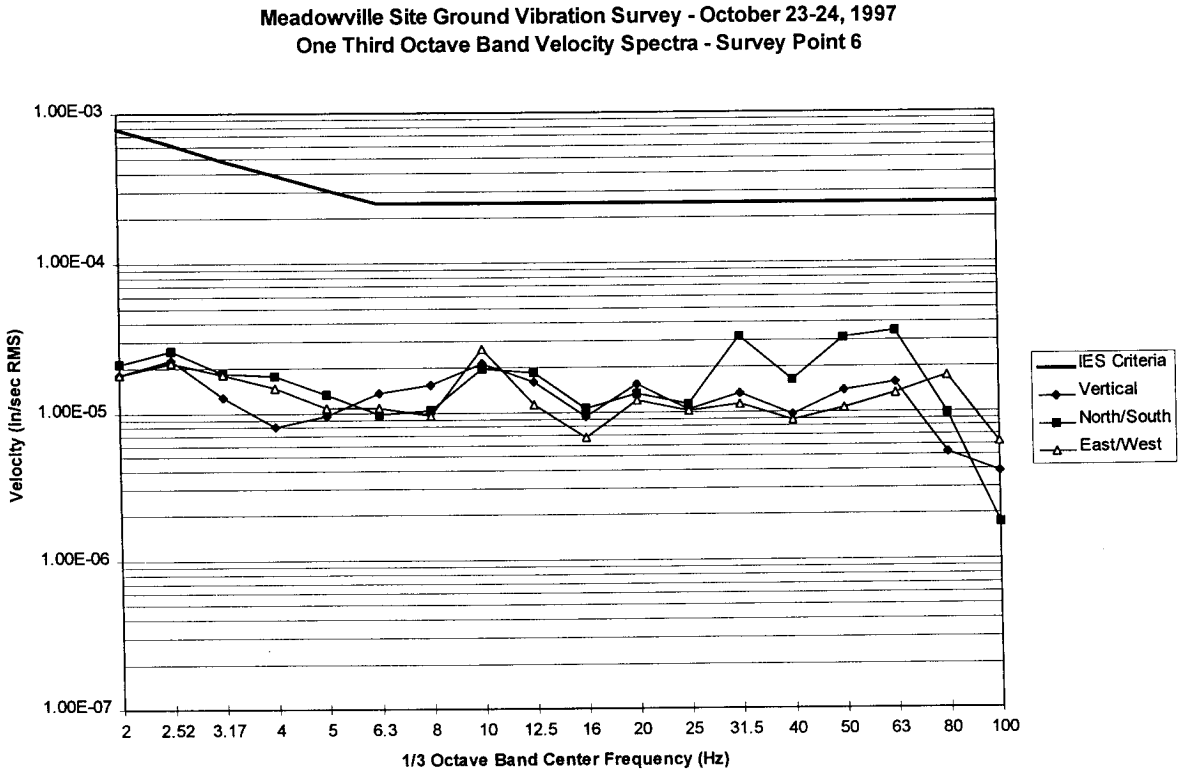



Figure 7: Survey Point 6, one-third octave band velocity spectra

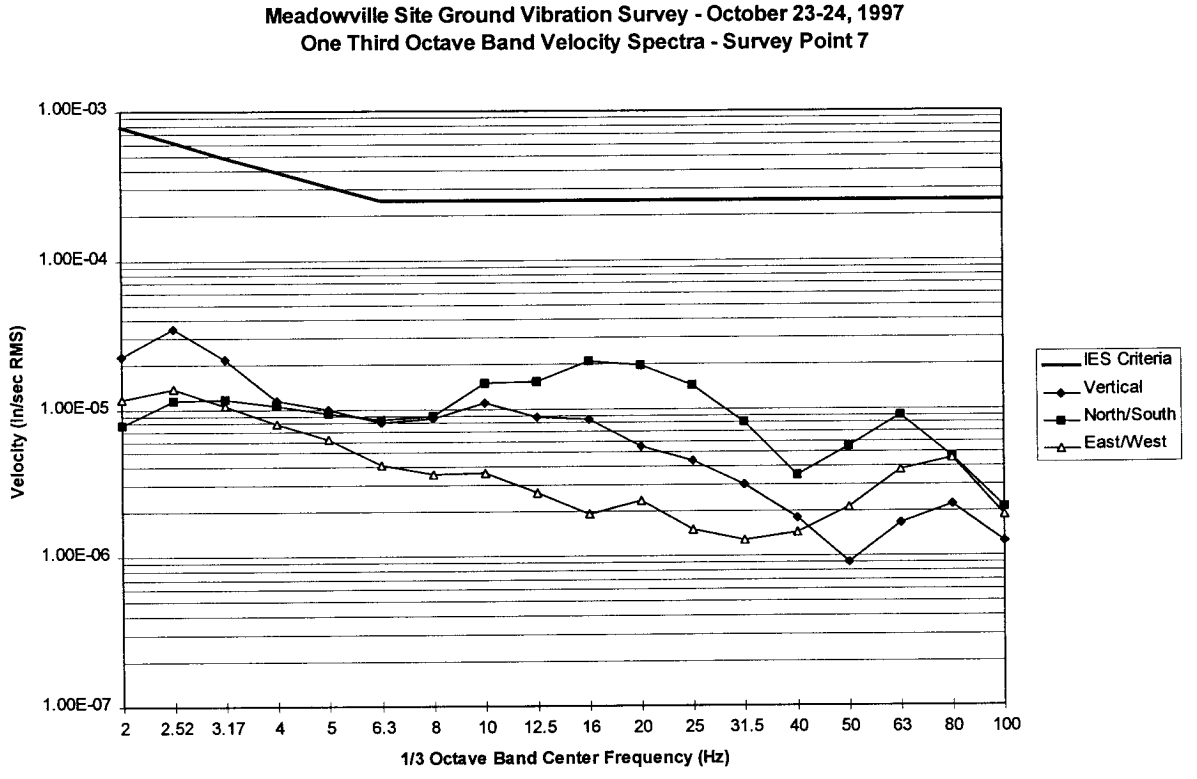



Figure 8: Survey Point 7, one-third octave band velocity spectra

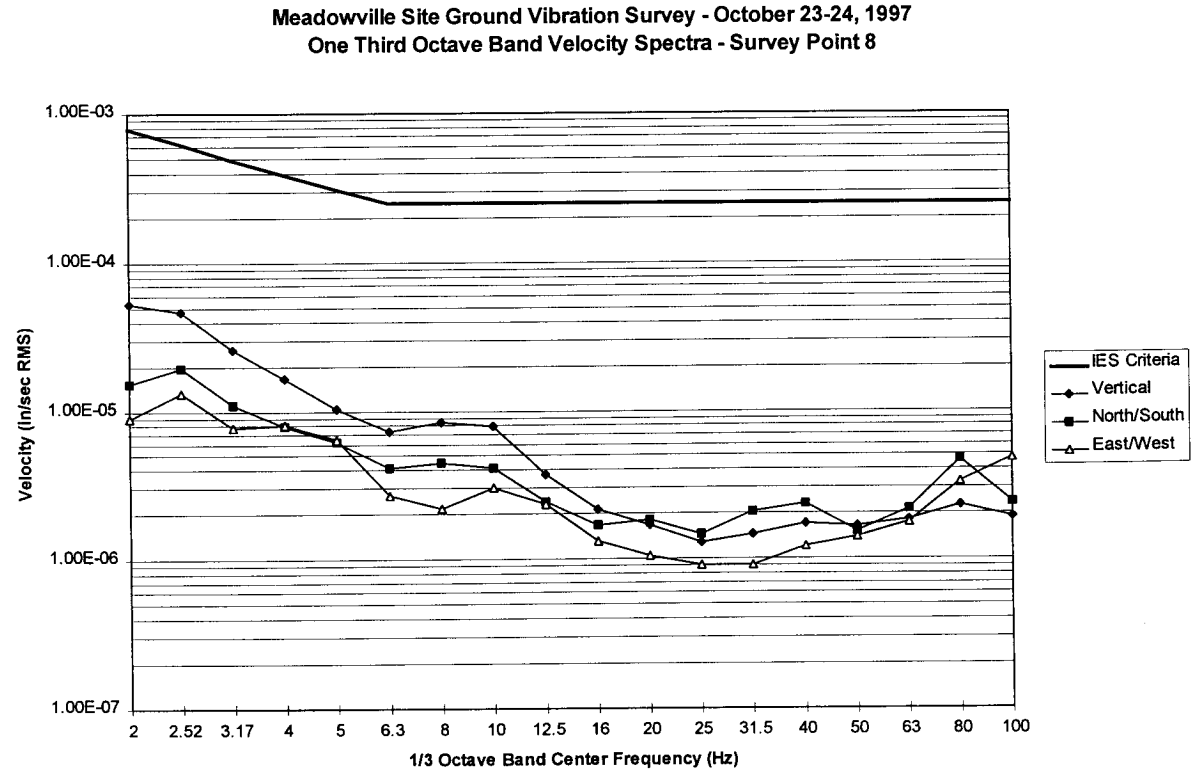



Figure 9: Survey Point 8, one-third octave band velocity spectra

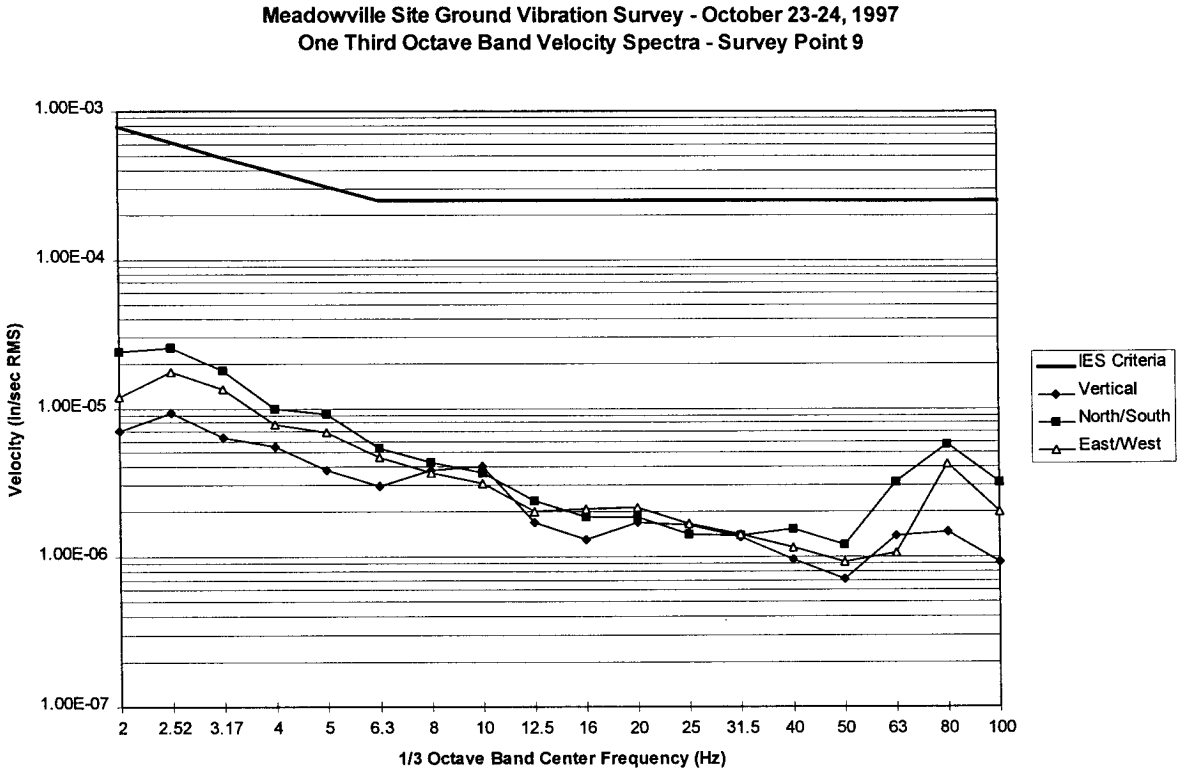



Figure 10: Survey Point 9, one-third octave band velocity spectra

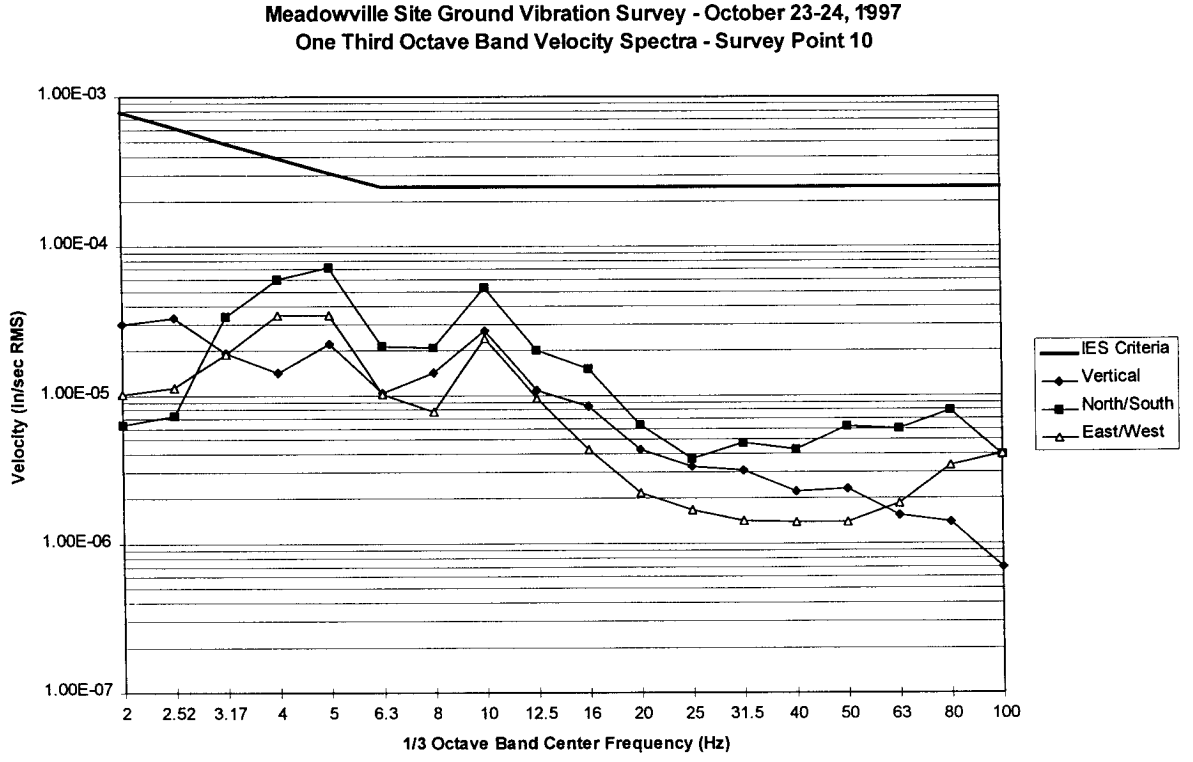



Figure 11: Survey Point 10, one-third octave band velocity spectra

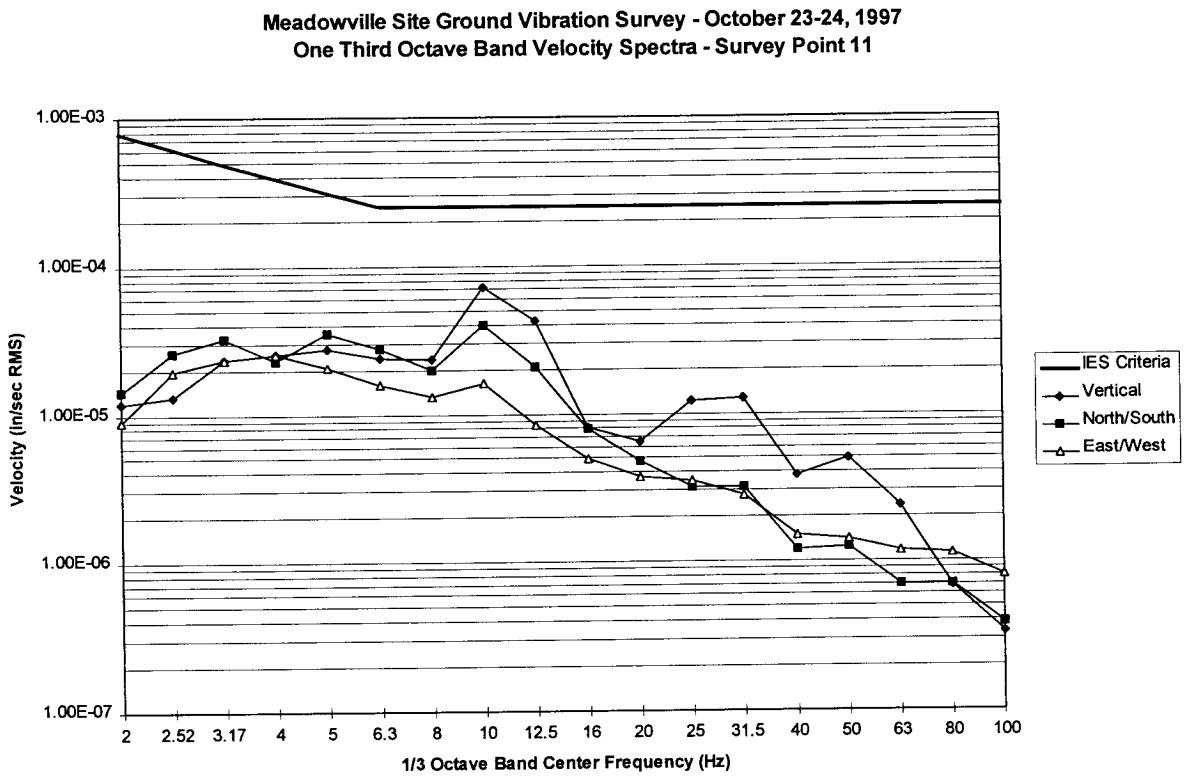



Figure 12: Survey Point 11, one-third octave band velocity spectra

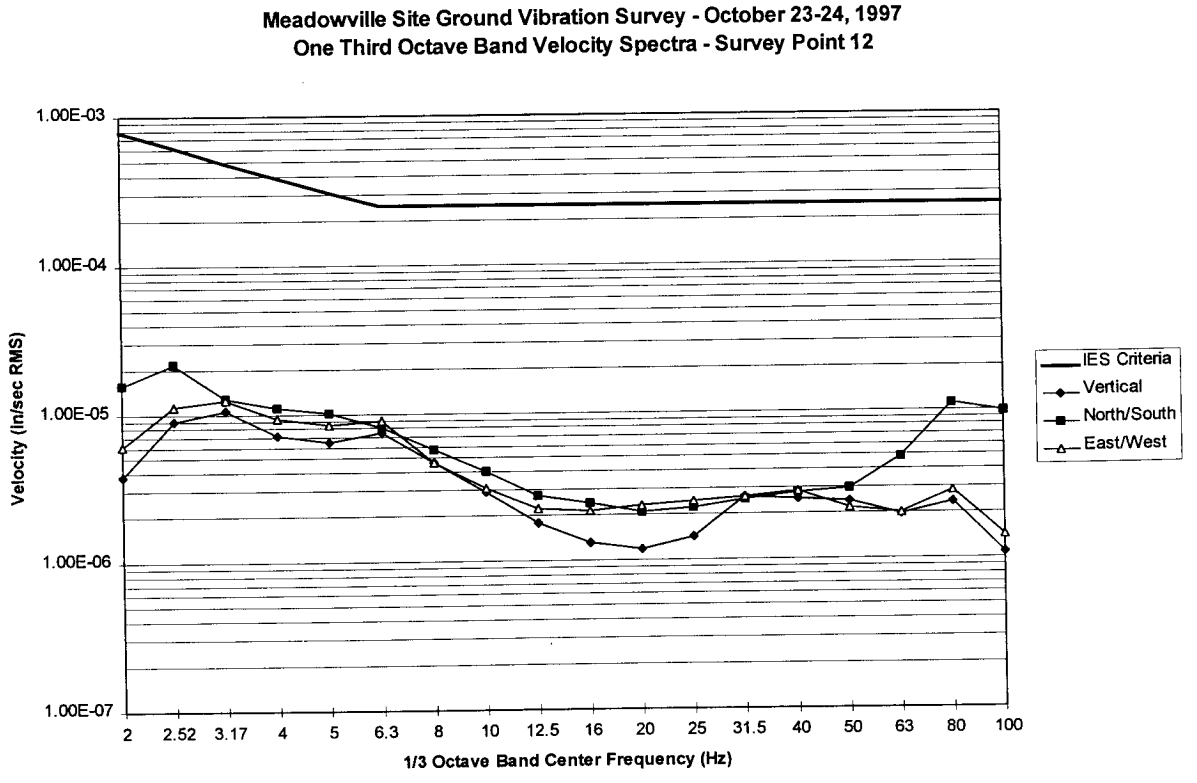



Figure 13: Survey Point 12, one-third octave band velocity spectra

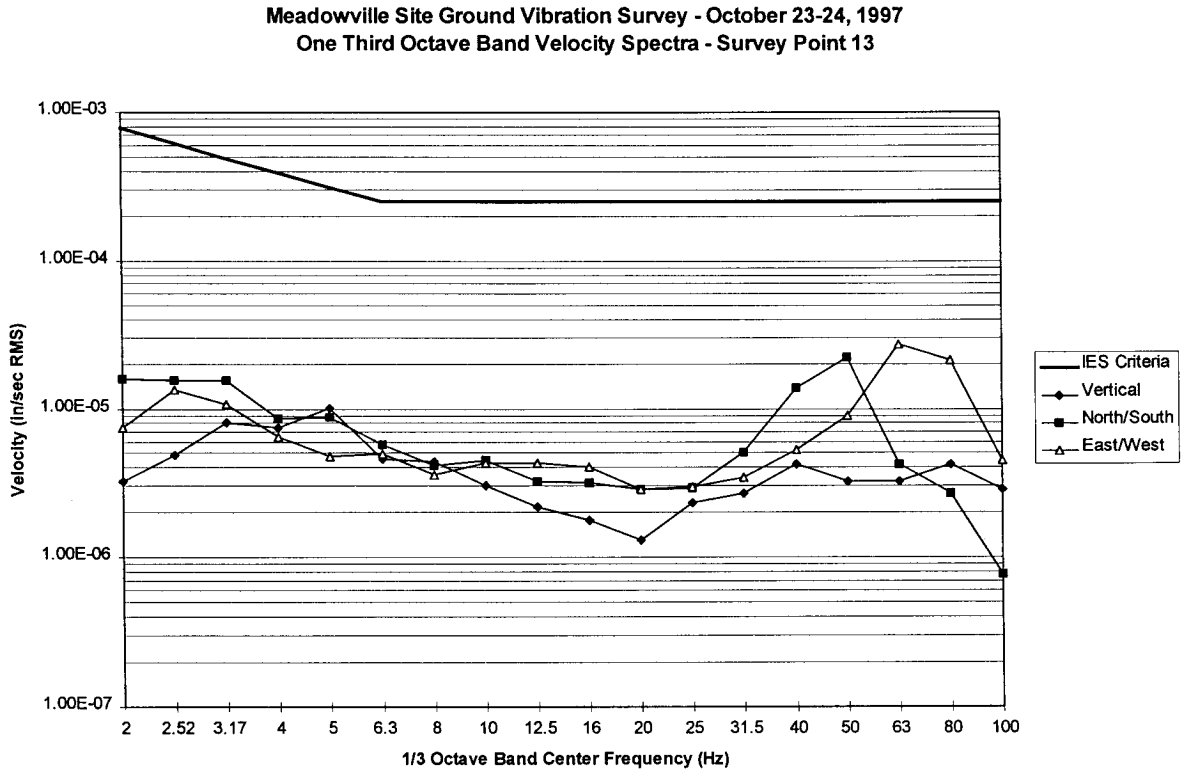



Figure 14: Survey Point 13, one-third octave band velocity spectra

## Appendix

Acceleration power spectra, Figures A.1 to A.13, see Section 2.0 for measurement set-up.

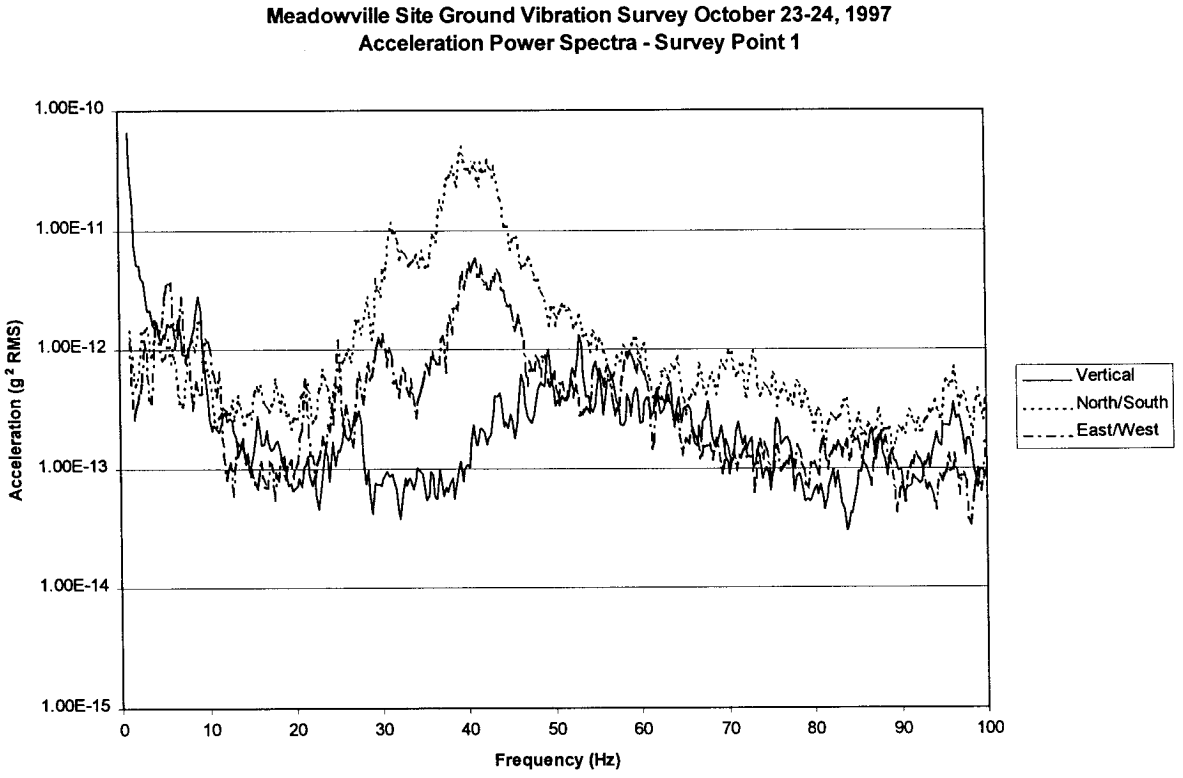



Figure A.1

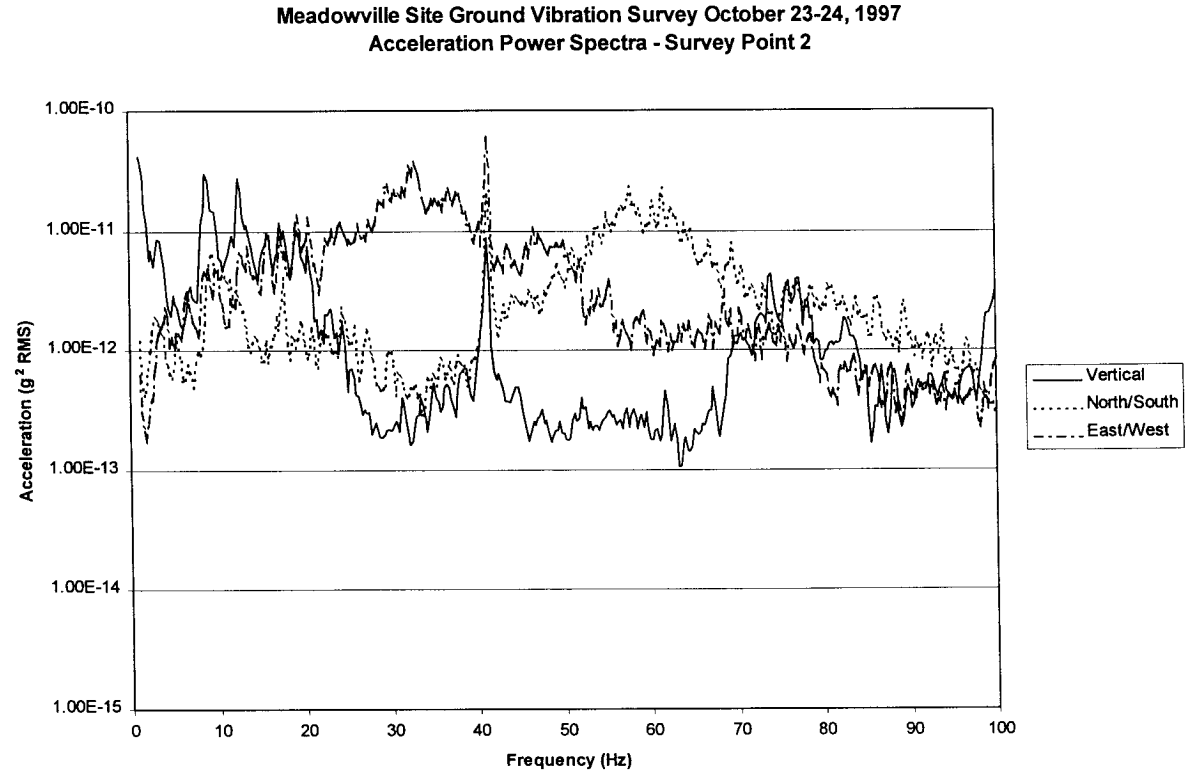
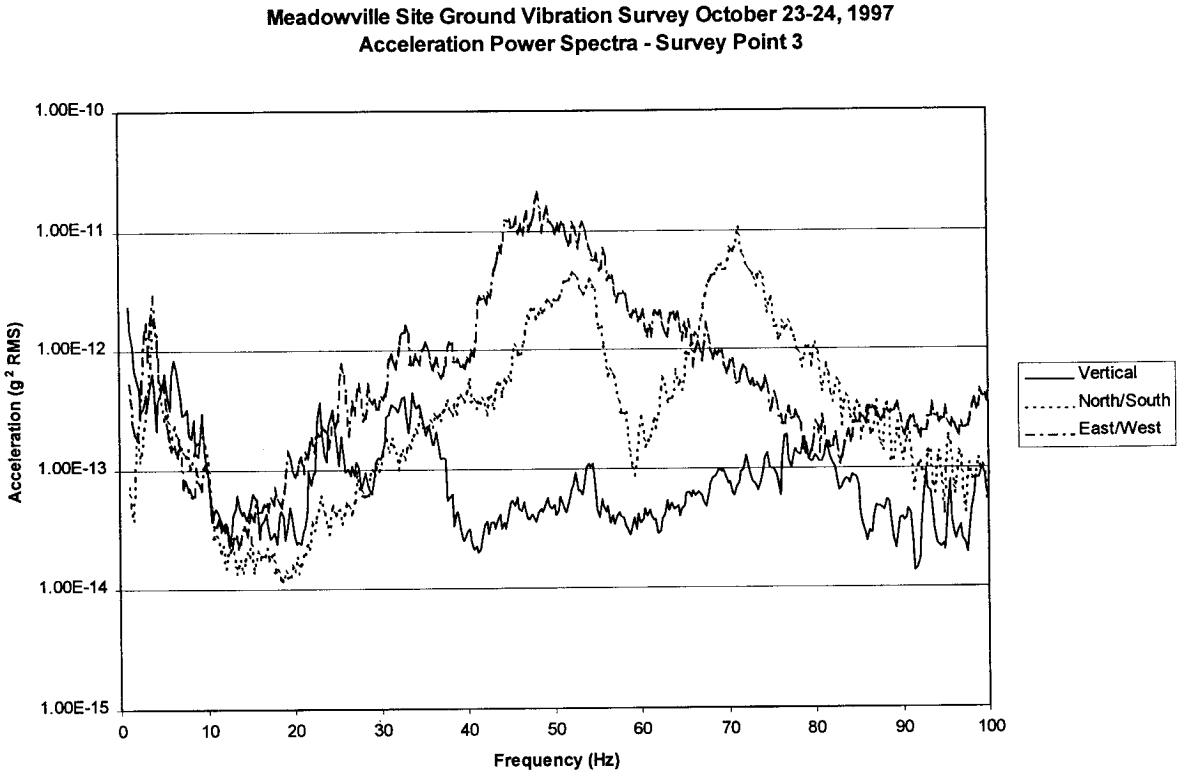



Figure A.2

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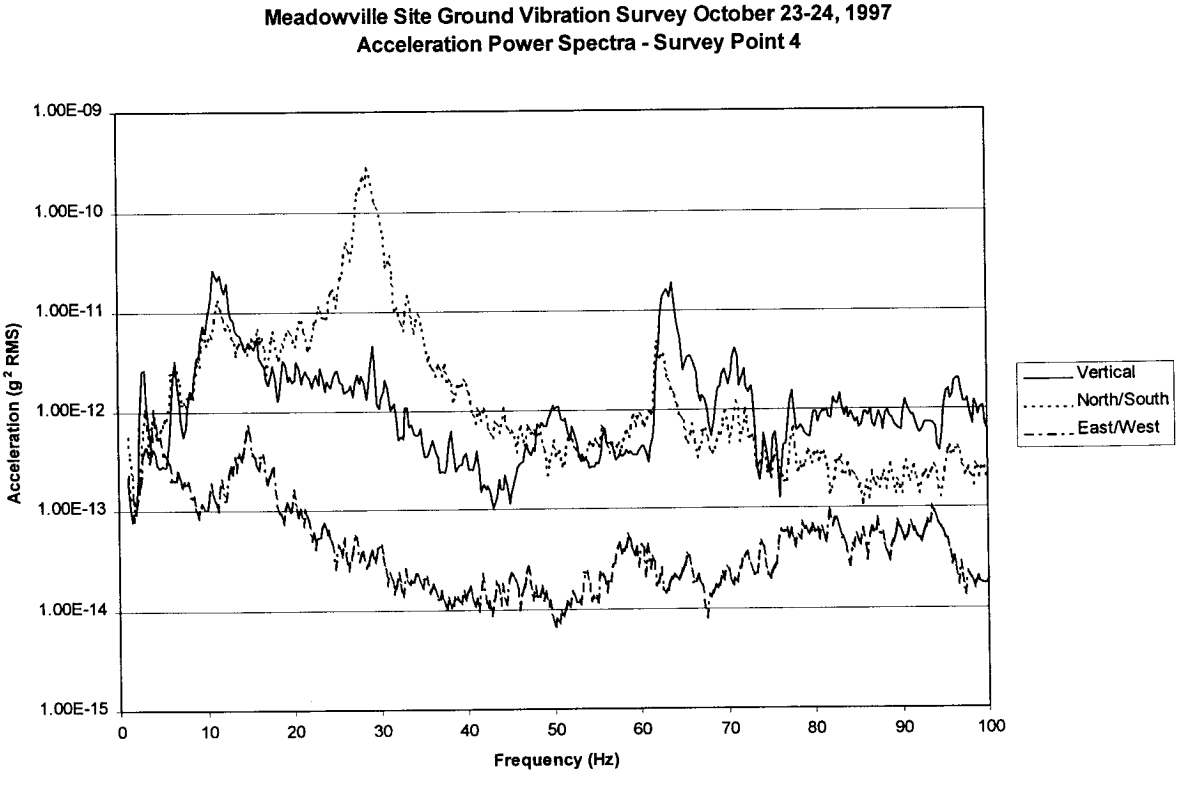


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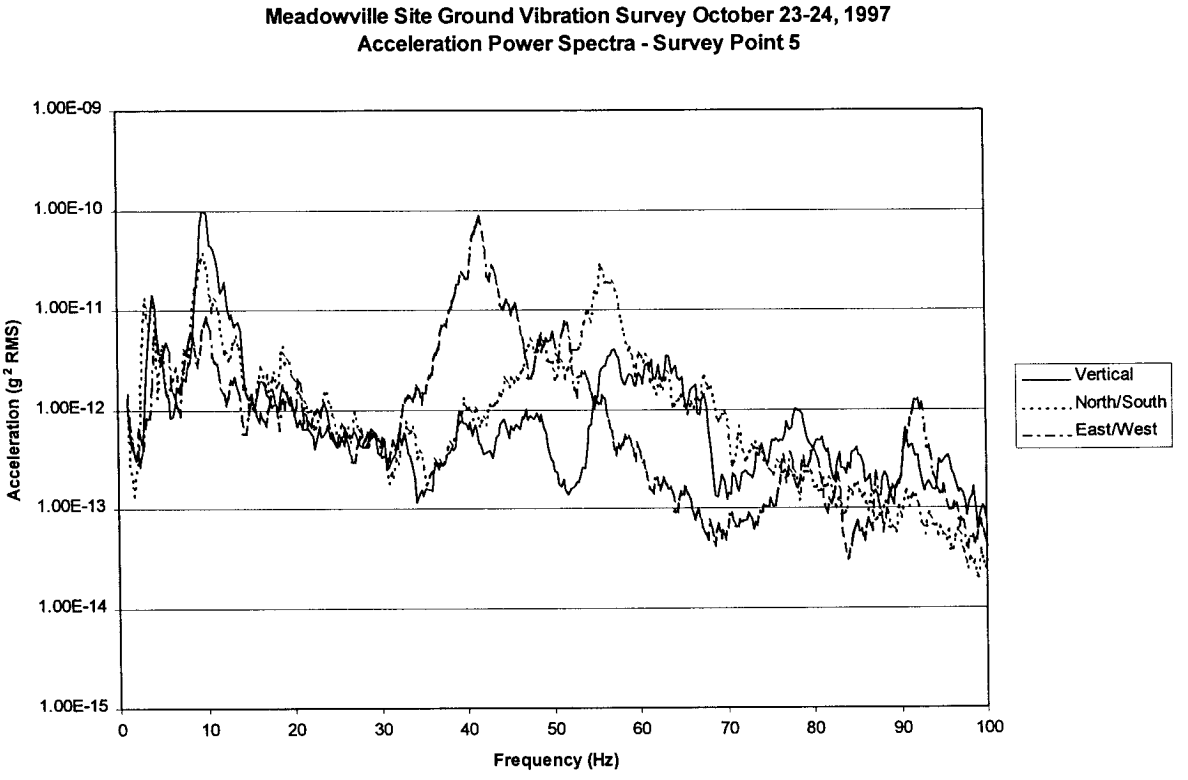
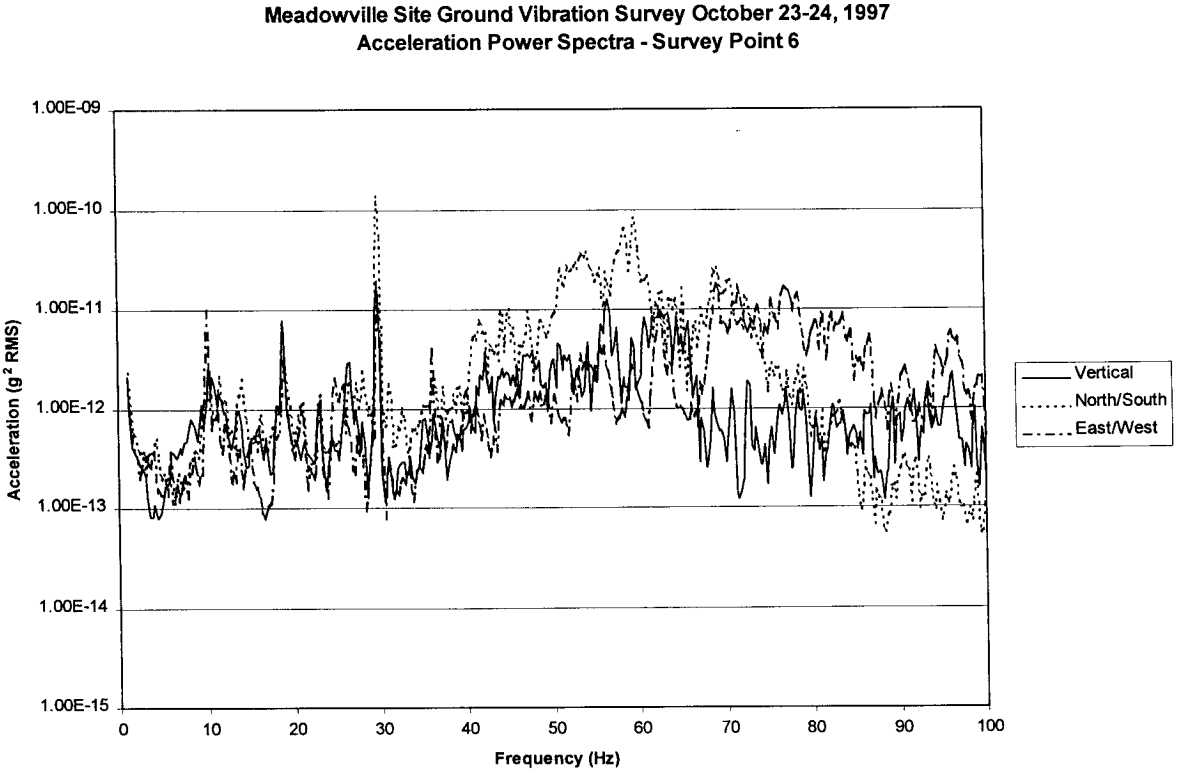



Figure A.5

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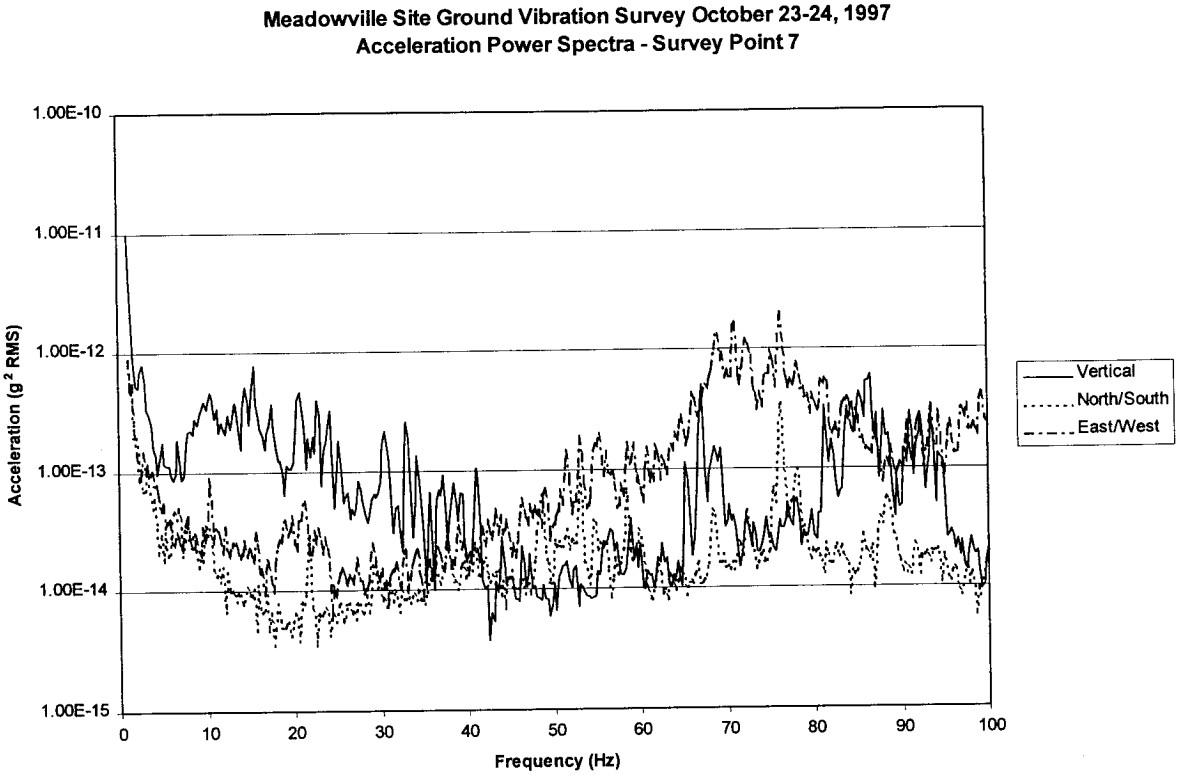


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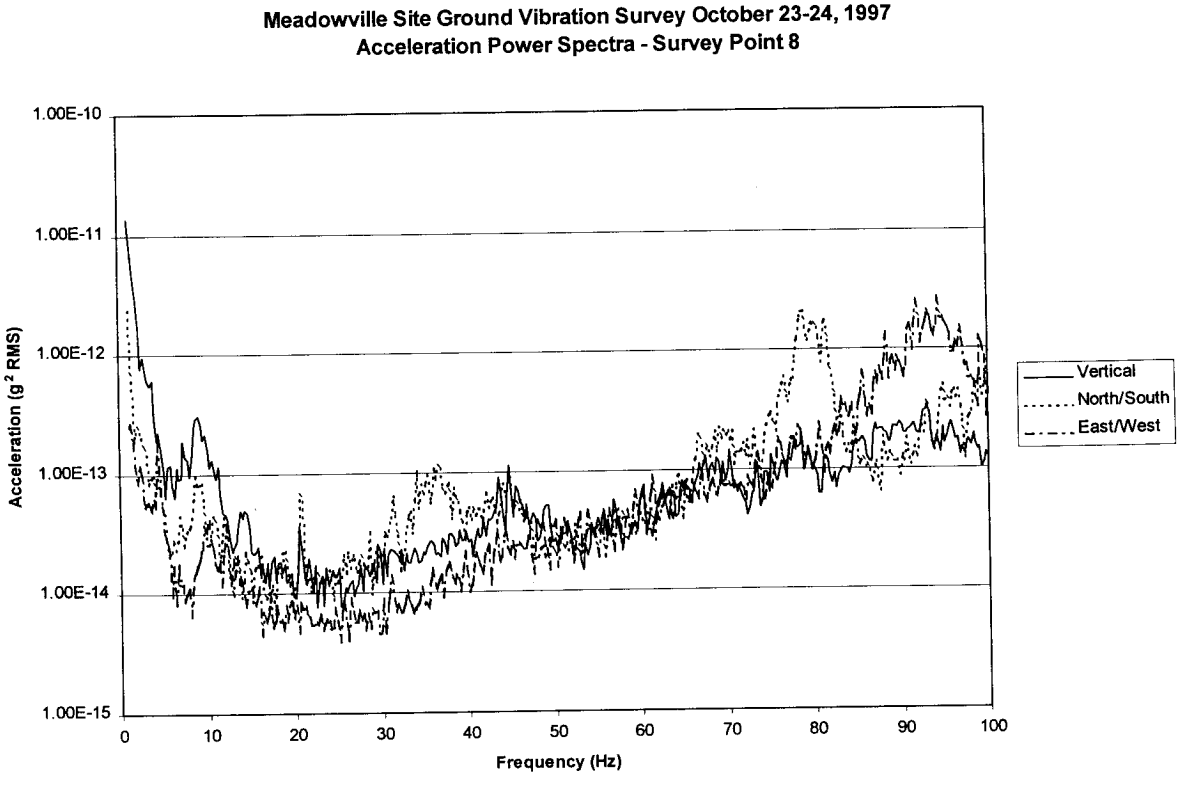
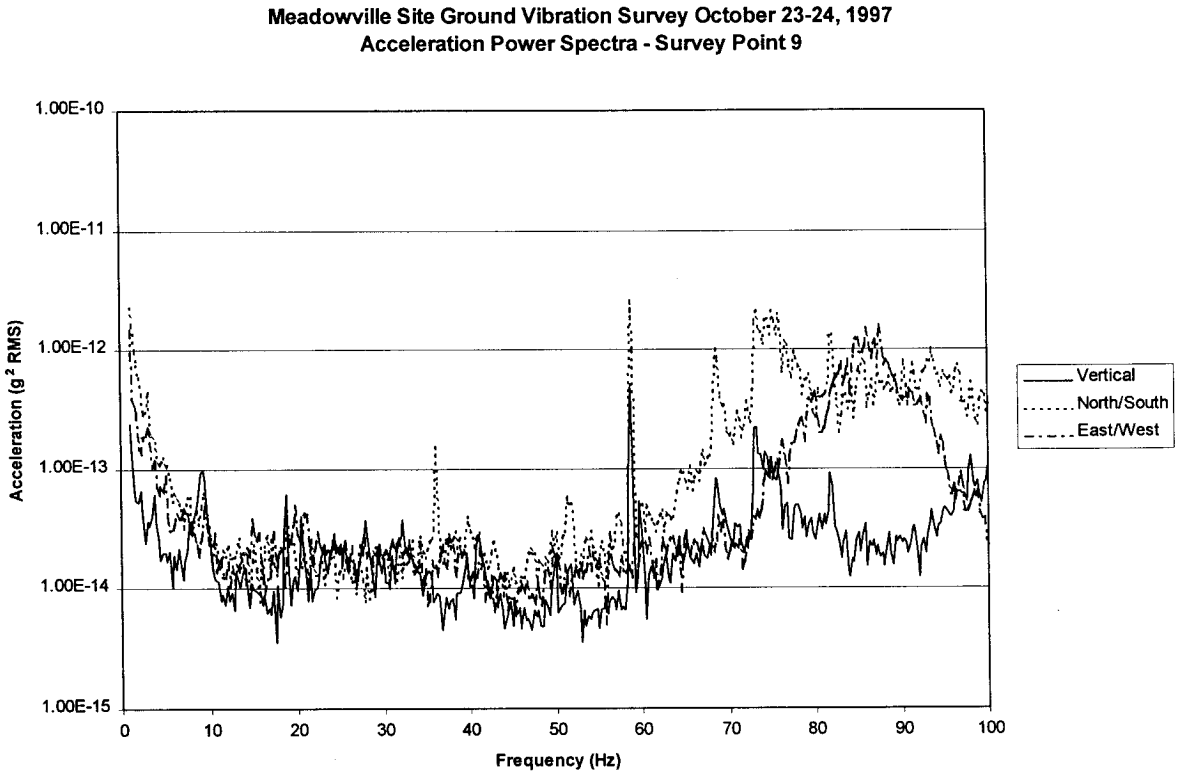



Figure A.8

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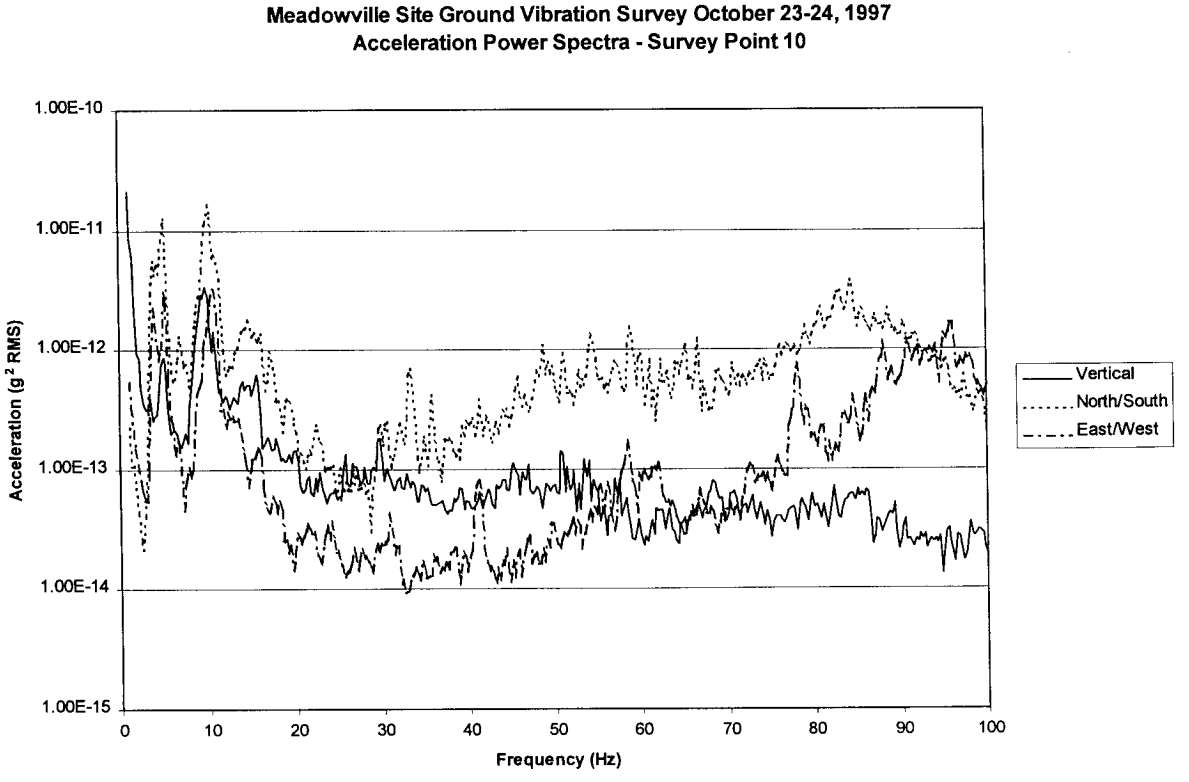



Figure A.10

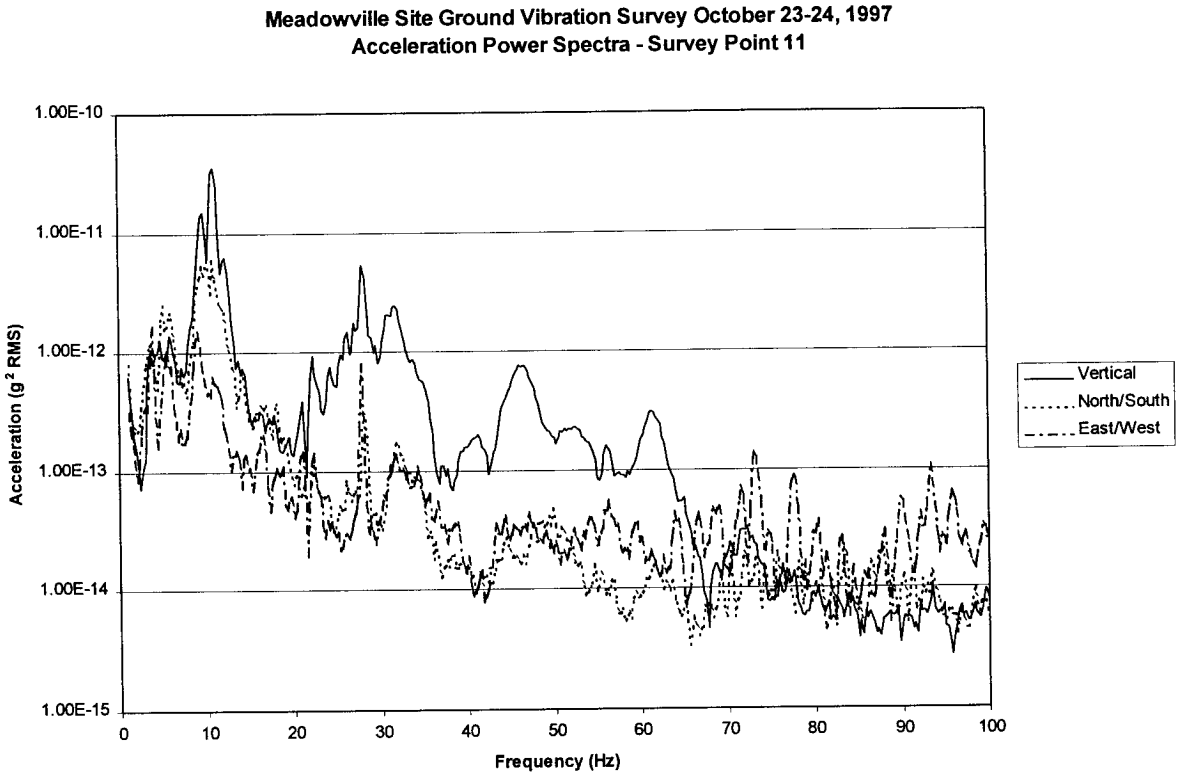
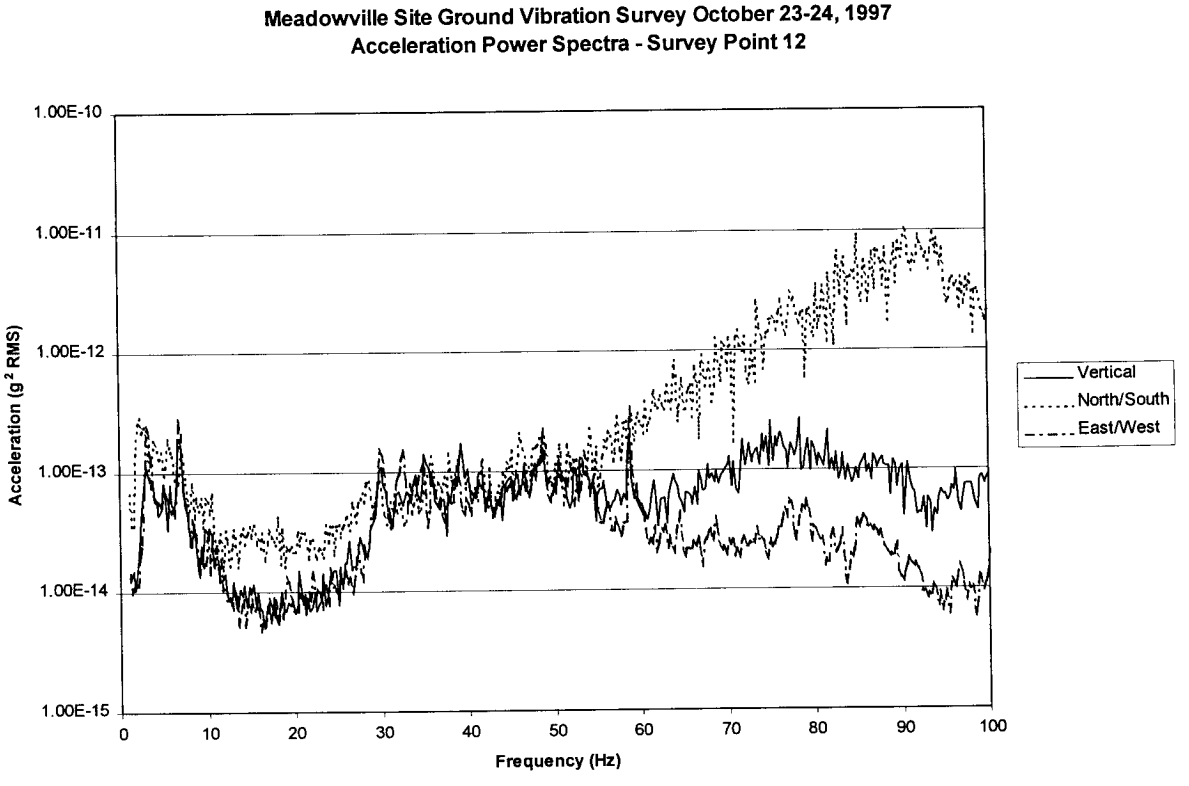



Figure A.11

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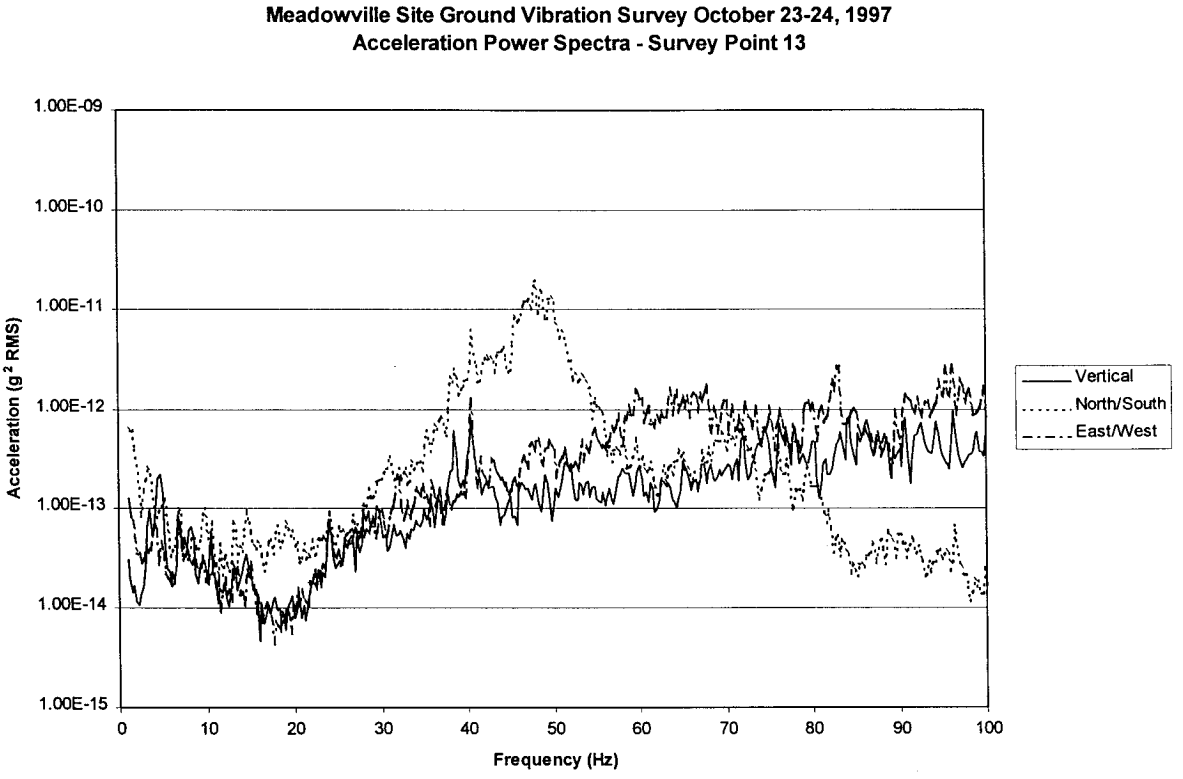
Meadowville Site Ground Vibration Survey October 23-24, 1997
Acceleration Power Spectra - Survey Point 13
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1.00E-10
1.00E-11
1.00E-12
1.00E-13
1.00E-14
1.00E-15
Acceleration (g² RMS)
0
10
20
30
40
50
60
70
80
90
100
Frequency (Hz)
Vertical
North/South
East/West

Figure A.13