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PUBLIC TRANSPORT AUTHORITY

NORTHERN RAIL EXTENSION
ROMEO ROAD TO YANCHEP

GROUND VIBRATION ASSESSMENT

NOVEMBER 2012

OUR REFERENCE: 15438-1-12160

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GROUND VIBRATION ASSESSMENT
NORTHERN RAIL EXTENSION

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A Ground Vibration Measurement Locations

B Sample of Ground Vibration Measurements

1. INTRODUCTION

Herring Storer Acoustics was commissioned by the Public Transport Authority to undertake a vibration study and assessment relating to the extension of the northern suburbs passenger railway line between Butler and Yanchep. As part of the study, the following was carried out:

- Measure ground vibration from passing passenger trains on the Perth – Mandurah line.
- Assess the predicted vibration levels for compliance with the appropriate criteria.
- Provide advice on appropriate controls.

For information, a plan indicating the general study area is attached in Appendix A.

2. SUMMARY

We believe that the "Target" criteria for ground vibration from passing passenger trains would be base curve x 1.4 as defined in AS 2670.2-1990 *"Evaluation of human exposure to whole-body vibration; Part 2: Continuous and shock-induced vibration in buildings (1 to 80 Hz)"*.

Giving due consideration to the data available, we believe that the following buffer distances are required:

Near Station	-	50 metres
Inside bend	-	55 metres
Outside bend	-	40 metres
Straight Track	-	40 metres

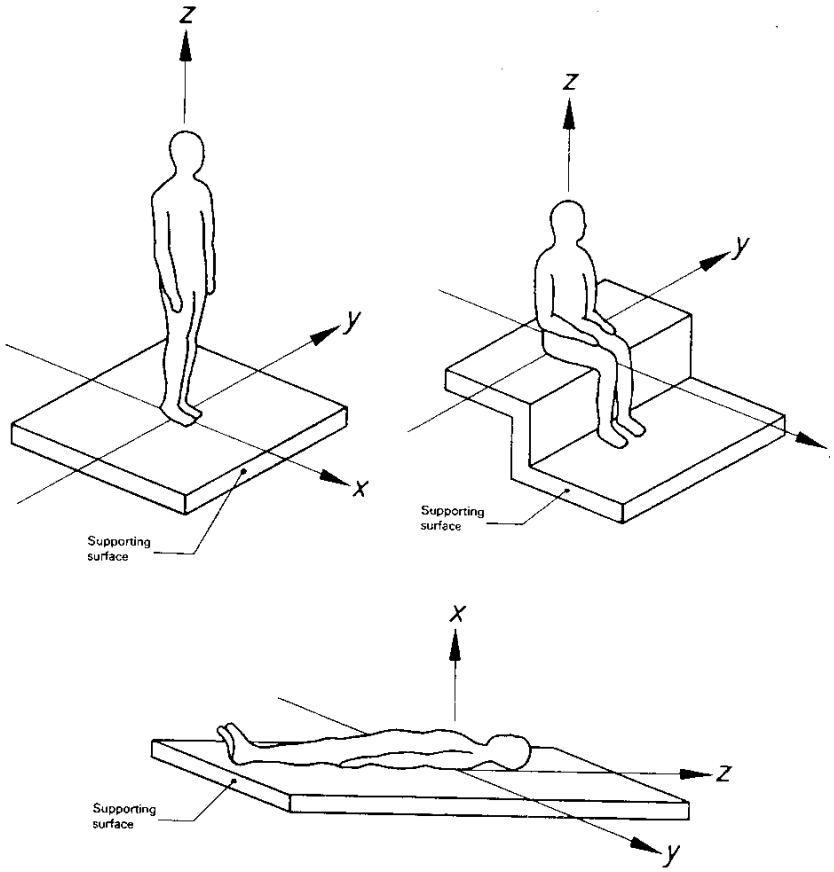
The above distances are approximate and will vary due to differences in geology. Given that this extension of the passenger railway service is generally in-cut, the potential for the rail to be laid on solid limestone is reasonably high. It is known that limestone is an excellent medium for the transmission of ground borne vibration. Therefore, given the higher speeds (i.e. 130km/hr), the results of the base distance given above, and the difficulty in applying vibration isolation after the railway line is in operation, it is recommended that vibration isolation be installed in all locations where noise sensitive premises could be built within 60 metres of the nearest track.

3. CRITERIA

From previous projects we understand that AS 2670.2-1990 *"Evaluation of human exposure to whole-body vibration; Part 2: Continuous and shock-induced vibration in buildings (1 to 80 Hz)"* (AS2670.2-1990) and uses acceleration with units of m/s^2. These criteria are outlined below.

Ground vibration generated by train movements is caused by the impact of the train wheels with the rail. This impact causes the ground under the rail to vibrate, which then radiates through the ground.

As a building may be used for many different human activities, for example standing, sitting, lying or a combination of all three, vertical vibration of the building may enter the body as either z-axis, x-axis or y-axis vibration, as shown in Figure 1.**Figure 1 – Axis of Vibration**



a_x, a_y, a_z = acceleration in the directions of the x-, y-, z-axes
x-axis = back-to-chest
y-axis = right side to left side
z-axis = foot-(or buttocks-)to-head

Figure 1 — Directions of basicentric coordinate systems for mechanical vibrations influencing humans

(Extract from AS2670.2-1990)

As it is not clear which direction vibration would enter the body, a combination curve of the base curves is used. The combination curve combines the worst-case combination of the z-axis, x-axis and y-axis curves.

The combined base curve from AS2670.2-1990 is shown in Figure 2. This base curve represents magnitudes of approximately equal human response with respect to human annoyance and/or complaints about interference with activities. The satisfactory vibration magnitudes in rooms and building are specified as multiples of this base curve.

Figure 2 – Combined Direction Base Curve

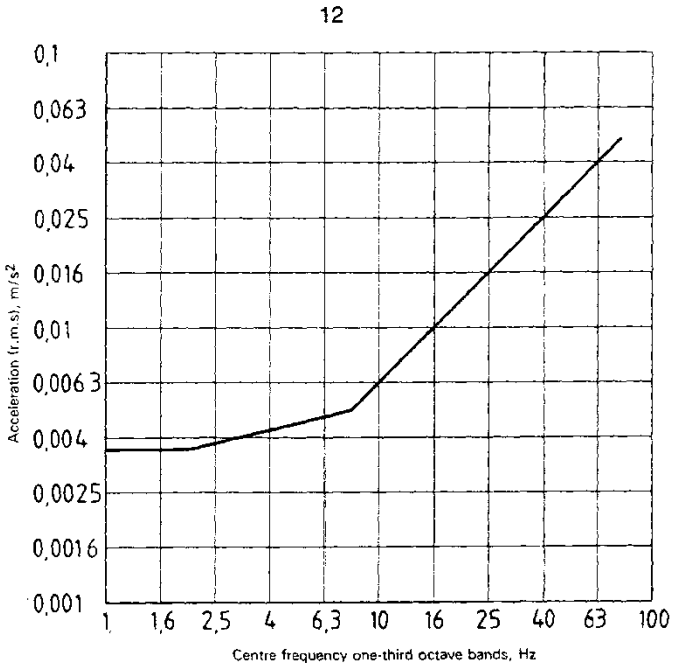


Figure 4a — Building vibration combined direction (*x-* , *y-* , *z*-axis) acceleration base curve (this curve shall be used when the direction of the human occupants varies or is unknown with respect to the most interfering or annoying vibration. See 4.2.3)

The multiplying factors used within the AS2670.2-1990 standard, specify satisfactory magnitudes of building vibration within residential buildings with respect to human response and are listed in Table 2 of Annex A of the standard. The residential section of Table 2 of Annex A is summarised in Table 3.1 below.

Table 3.1 – Summary of Multiplying Factors within Residential Buildings

Place	Time	Continuous or Intermittent Vibration	Transient Vibration Excitation With Several Occurrences
Residential	Day	2 to 4	30 to 90
	Night	1.4	1.4 to 20

We understand that in previous projects, the PTA has nominated the 1.4 curve as the criteria for vibration.

Table 2 in Appendix A of the standard lists the acceptable criteria. In this situation the passing trains would be considered as transient vibration. As such the recommended range of multiplying factors range from 1.4 to 2.0. From previous studies, we believe that the 1.4 times the base curve is used as the “Target” criteria, with the 2.0 times the base curve used as a “Limit”. Therefore, for this study, the 1.4 times the base curve has been used as criteria for assessment.

4. PREVIOUS MEASUREMENTS

Previously Herring Storer Acoustics have carried out ground vibration measurements as part of the acoustic study for the Northern Suburbs Railway Extension from Clarkson to Romeo Road. These measurements were carried out of the existing trains on a curve as they passed the public open space east of Christchurch Terrace, located on the between Joondalup and Currambine Stations. These results showed compliance with the x1.4 curve at a distance of approximately 30 metres.

Additional to the above, a study undertaken by Lloyd Acoustics in 2005 correlated ground vibration measurements undertaken to that time and concluded that the buffer distances to comply with the x1.4 curve is 35 metres.

5. CURRENT MEASUREMENTS

As part of this study, additional vibration measurements were undertaken, using tri-axial accelerometers connected to 4-channel 1/3 octave band analysers. For this study ground vibrations were recorded for the following locations:

Location 1 - Trains entering and leaving Hillman Station at a distance of 160metres from the station.

Location 2 - Outside a curve.

Location 3 - Inside a curve.

Location 4 - Straight section.

For each location, measurements were recorded at three different distances from the track. The locations and distances from the track for each location are shown Figures attached in Appendix A.

Additionally, measurements were recorded for a number of train movements at each location.

As expected, there were reasonable variations in the results. The results in relation to the base curve are summarised in Table 5.1. These results are the maximum levels recorded.

Table 5.1 – Summary of Results

	Distance From Nearest Rail – Metres	**x Base Curve 4a**
Location 1 - Near Train Station		
South Bound (Stopping)	A (12m)	16
South Bound (Stopping)	B (22m)	45
South Bound (Stopping)	C (32m)	41
North Bound (Accelerating)	A (12m)	11
North Bound (Accelerating)	B (22m)	29
North Bound (Accelerating)	C (32m)	70
Location 2 - Outside of Curve		
South Bound	A (10m)	53
South Bound	B (20m)	148
South Bound	C (30m)	87
Location 3 - Inside of Curve		
South Bound	A (17m)	236
South Bound	B (27m)	109
South Bound	C (35m)	115
Location 4 - Straight Section		
South Bound	A (15m)	28
South Bound	B (25m)	16
South Bound	C (35m)	4

For information a sample of the measurement results for Location 1 are attached in Appendix B.

Based on the measurements recorded, the following distance from the edge of the closest track to comply with the 1.4 times the base curve were determined :

Near Station	-	50 metres
Inside bend	-	55 metres
Outside bend	-	40 metres
Straight Track	-	40 metres

The above distances were based on parabolic curves of best fit.

6. DISCUSSION / RECOMMENDATIONS

We believe that the "Target" criteria for ground vibration from passing passenger trains would be base curve x 1.4 as defined in AS 2670.2-1990 *"Evaluation of human exposure to whole-body vibration; Part 2: Continuous and shock-induced vibration in buildings (1 to 80 Hz)"*.

Previous studies have stated that the distance to comply with the x1.4 the base curve is around 30 – 35 metres.

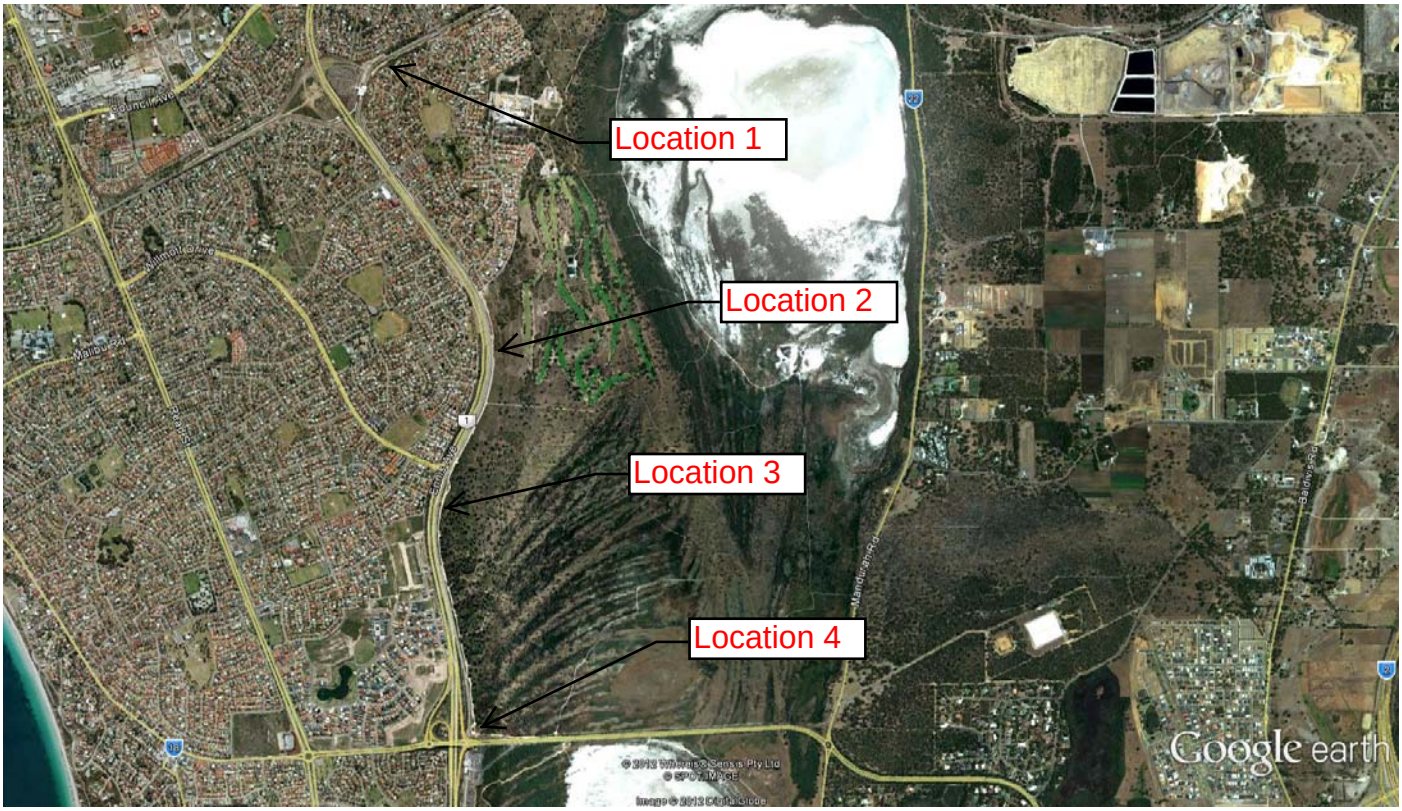
We understand that the current PTA policy for trains travelling at 130 km/hr is to:

> *"install vibration matting on the sections of track that are on limestone and where the receivers are within 30m of the nearest track and will extend 50m beyond the known extent of limestone."*

Recent measurements of ground vibration indicate that, depending on the configuration of the track, buffer distances of between 40 and 55 metres are required. Given that this extension of the passenger railway service is generally in-cut, the potential for the rail to be laid on solid limestone is reasonably high. It is known that limestone is an excellent medium for the transmission of ground borne vibration. Therefore, given the higher speeds (i.e. 130km/hr) results of the base distance given above and the difficulty in applying vibration isolation after the railway line is in operation, it is recommended that vibration isolation be installed in all locations where noise sensitive premises could be built within 60 metres of the nearest track.

APPENDIX A

GROUND VIBRATION MEASUREMENT LOCATIONS



Google earth

miles 2
km 4

PASSENGER TRAINS
LOCALITY PLAN

Figure A1
Appendix A

PASSENGER TRAIN
GROUND VIBRATION MEASURMENT LOCATION 1

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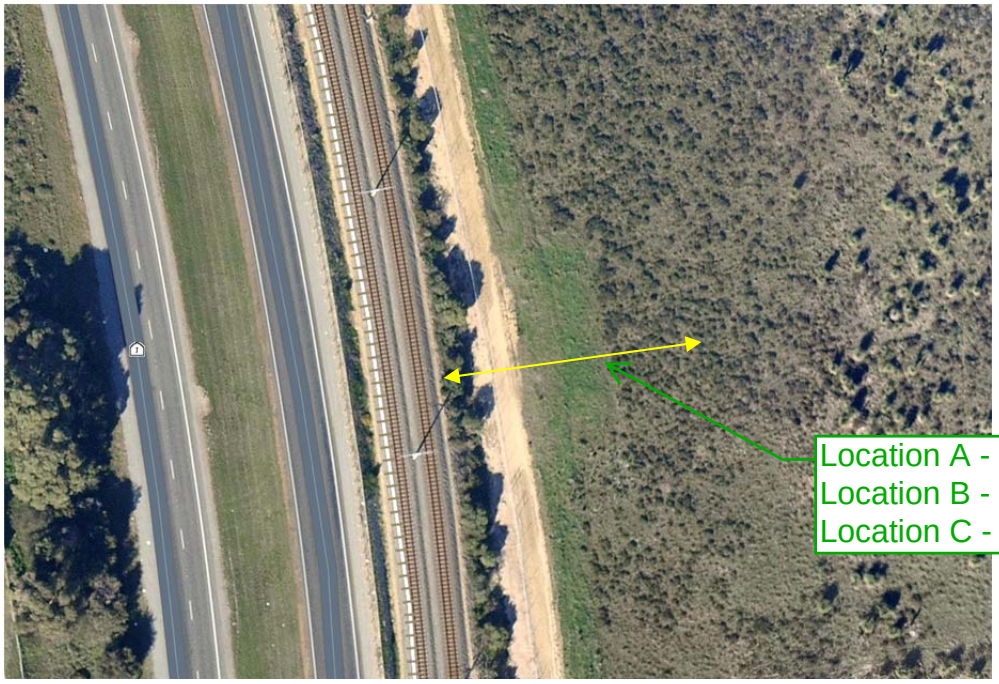
Date : 14 November 2012

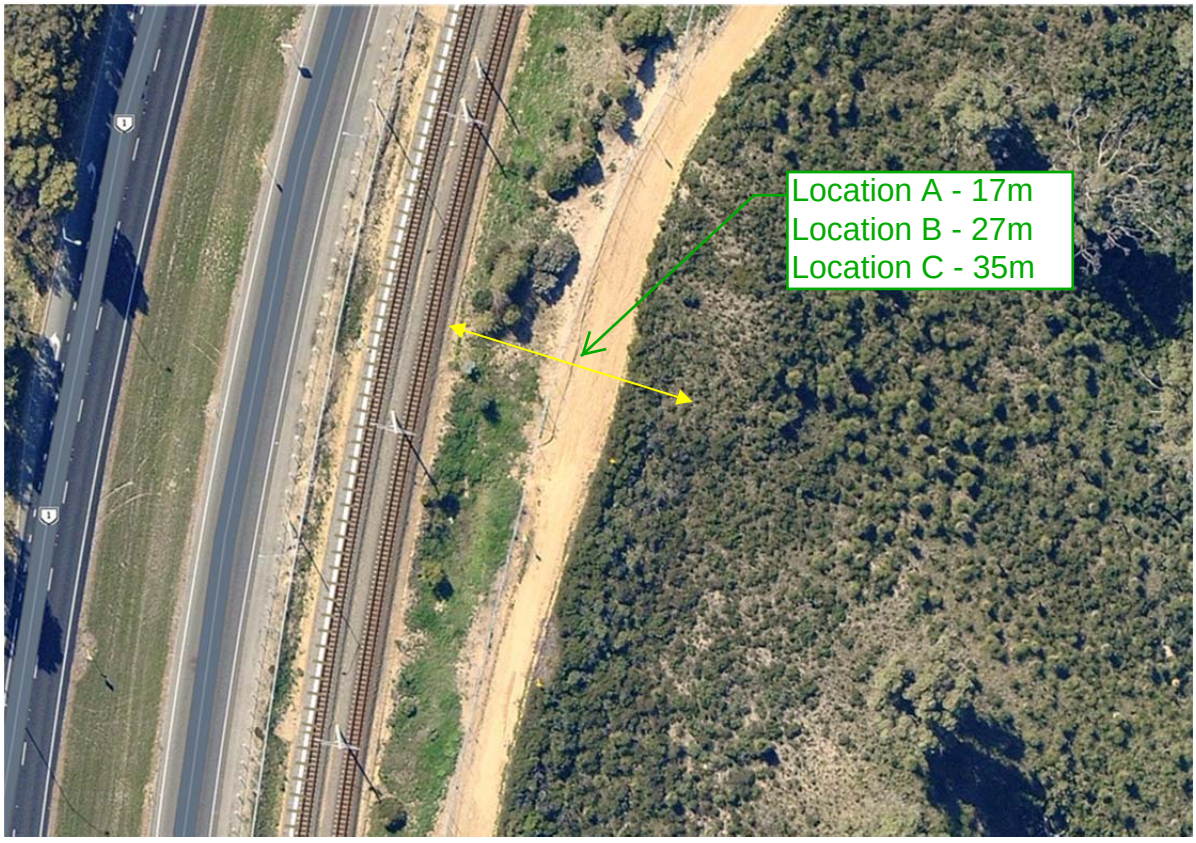
Figure A2
Appendix A



PASSENGER TRAIN
GROUND VIBRATION MEASURMENT LOCATION 2

Herring Storer Acoustics
Job No : 12160
Date : 14 November 2012

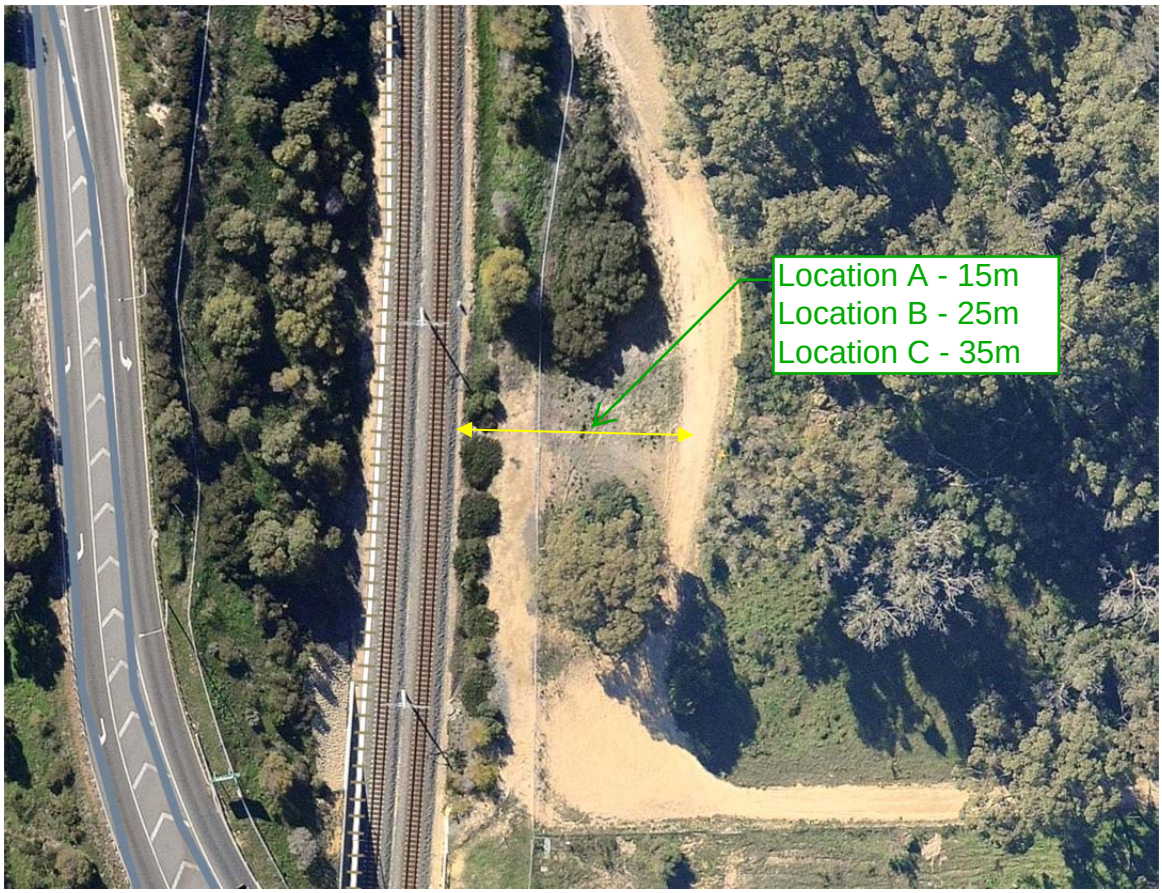
Figure A3
Appendix A



PASSENGER TRAIN
GROUND VIBRATION MEASURMENT LOCATION 3

Herring Storer Acoustics
Job No : 12160
Date : 14 November 2012

Figure A4
Appendix A



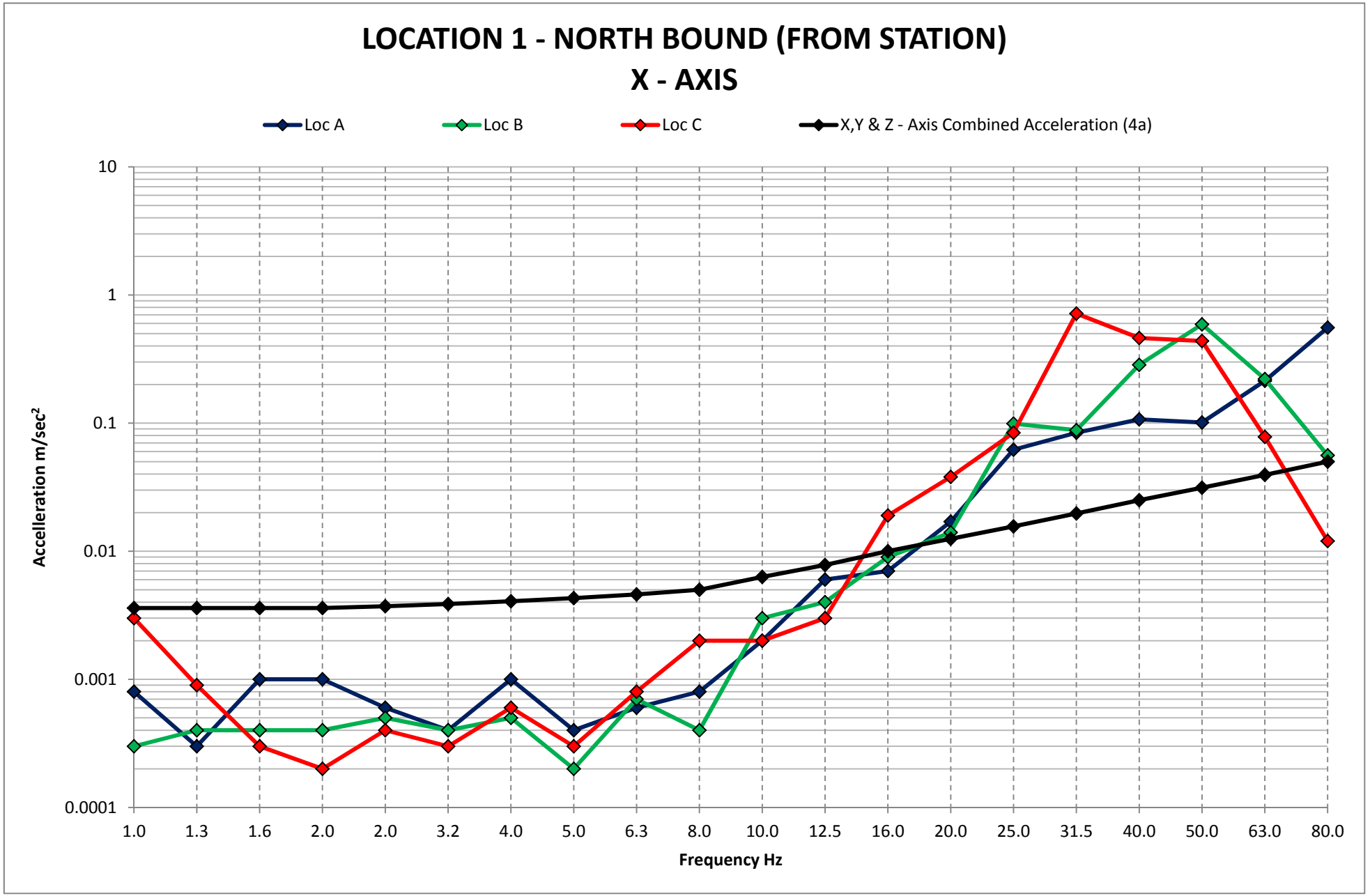
PASSENGER TRAIN
GROUND VIBRATION MEASURMENT LOCATION 4

Herring Storer Acoustics
Job No : 12160
Date : 14 November 2012

Figure A5
Appendix A

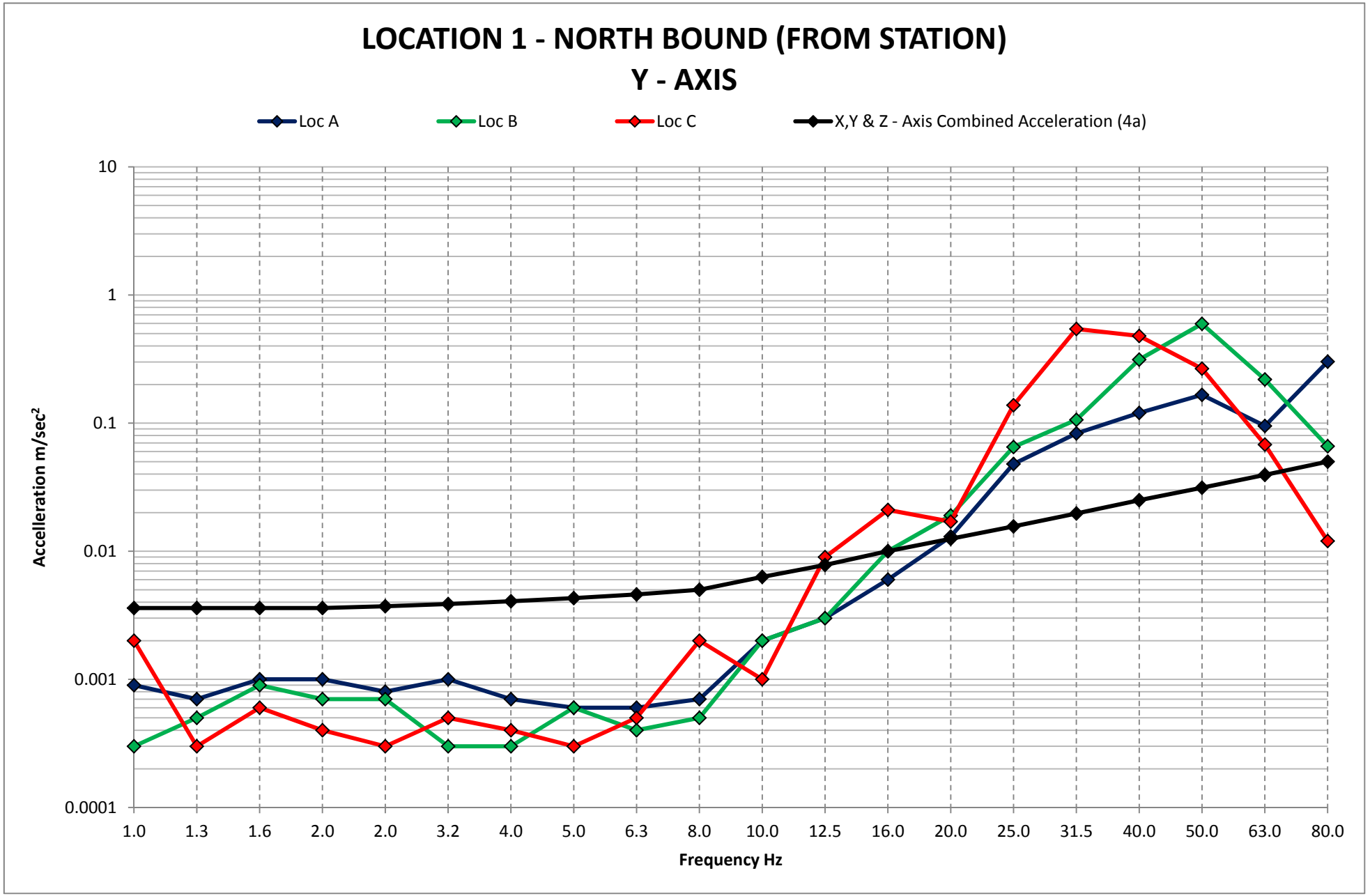
APPENDIX B

SAMPLE OF GROUND VIBRATION MEASUREMENTS



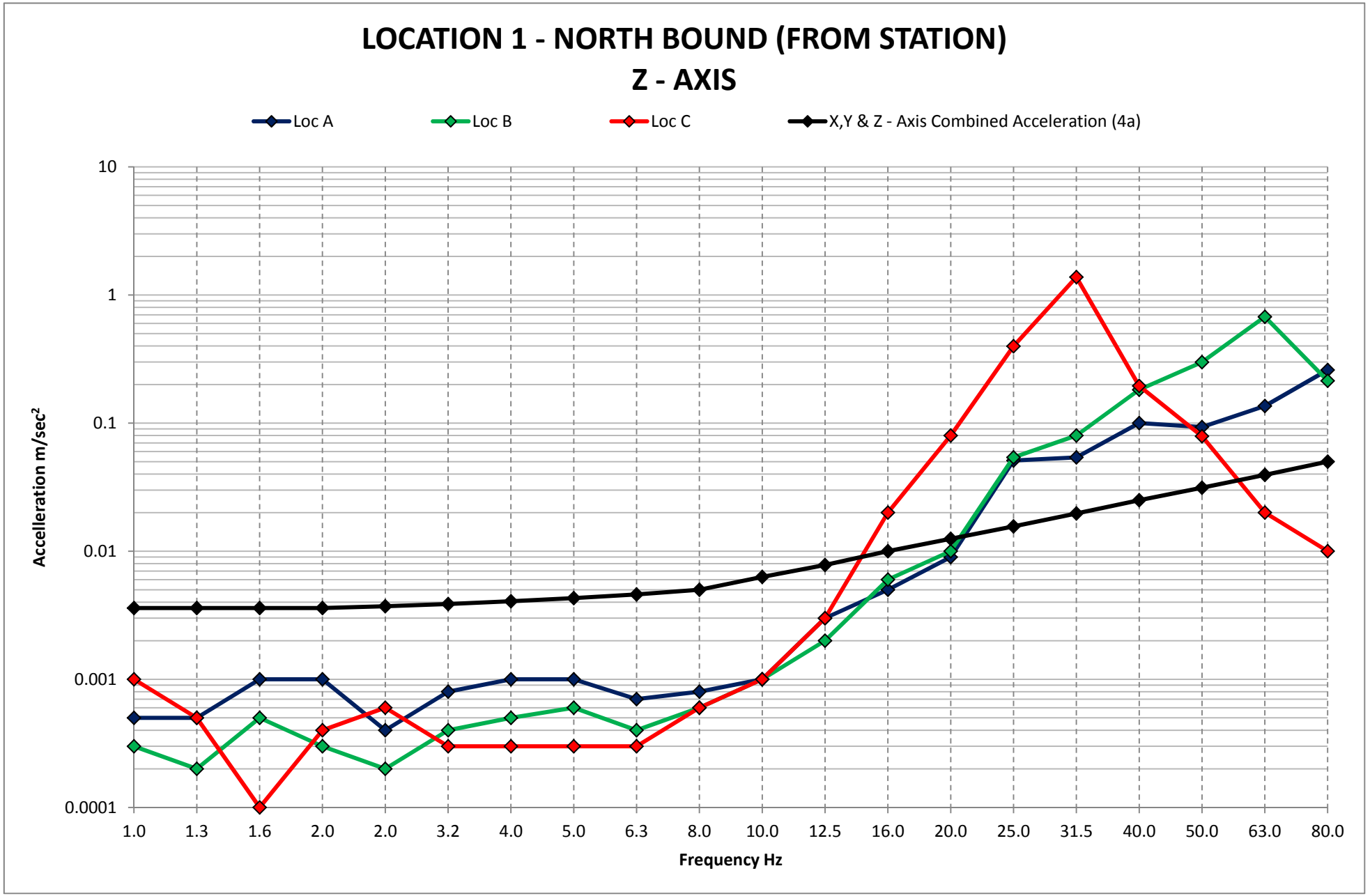
Herring Storer Acoustics
Date : 16 November 2012

Figure B1
Appendix B



Herring Storer Acoustics
Date : 16 November 2012

Figure B2
Appendix B


LOCATION 1 - NORTH BOUND (FROM STATION)
Z - AXIS
Loc A
Loc B
Loc C
X,Y & Z - Axis Combined Acceleration (4a)
Acceleration m/sec²
10
1
0.1
0.01
0.001
0.0001
1.0
1.3
1.6
2.0
2.0
3.2
4.0
5.0
6.3
8.0
10.0
12.5
16.0
20.0
25.0
31.5
40.0
50.0
63.0
80.0
Frequency Hz