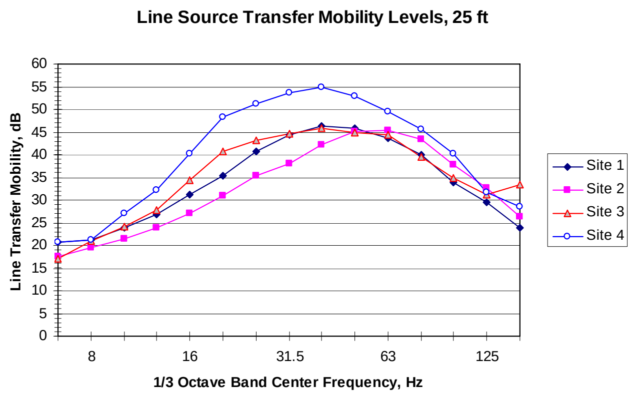
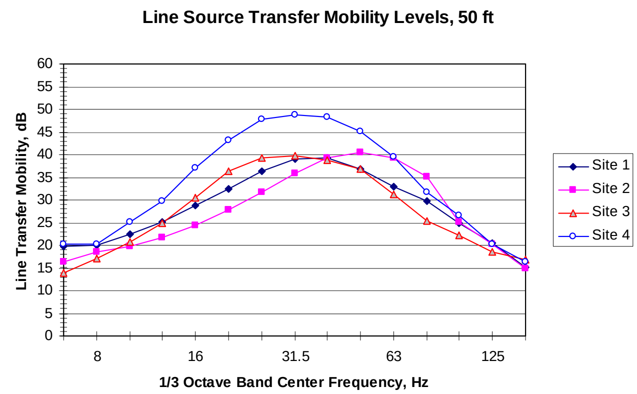
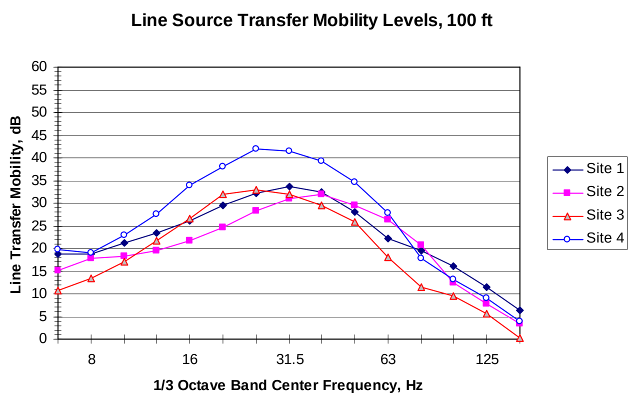
Notes: Portland Vibration Predictions
Hugh Saurenman, August 8, 2007

All the graphs in this document come from file "CRC Lv Vs Distance.xls".

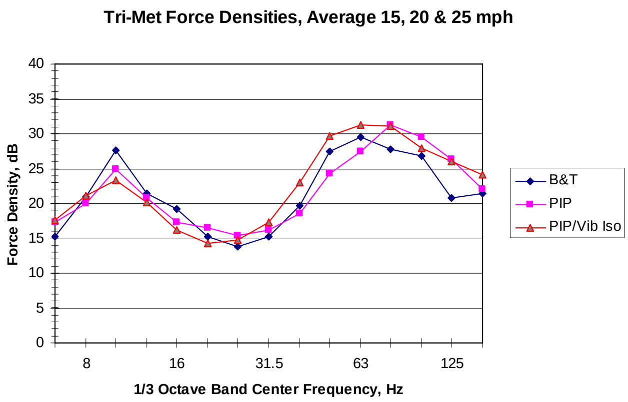
1. The transfer mobilities for Sites 1-3 are very similar. The TM for Site 4 is 5 to 10 dB higher than for the other sites. Because there are no residences or other sensitive receptors near Site 4, the entire alignment can be characterized by the average result for Site 3.







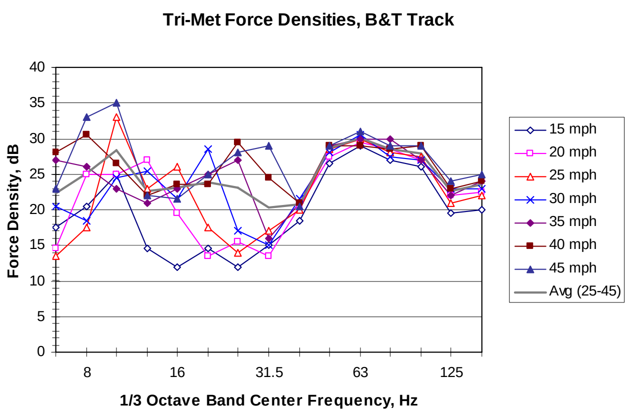
2. The force densities that Jim Nelson at Wilson, Ihrig measured in the late 90's are the best available data for Tri-Met force density. Many of the measurements were at relatively low speed, particularly for the various flavors of embedded track. The figure below shows the average results for ballast and tie track, booted track (PIP in figure), and booted track with vibration isolation for speeds of 15, 20 and 25 mph. The maximum difference is about 5 dB. The conclusion is that the force densities are essentially equivalent. Therefore, we used the ballast and tie data for all of the force densities because it is the only track form where testing at higher speeds was performed.

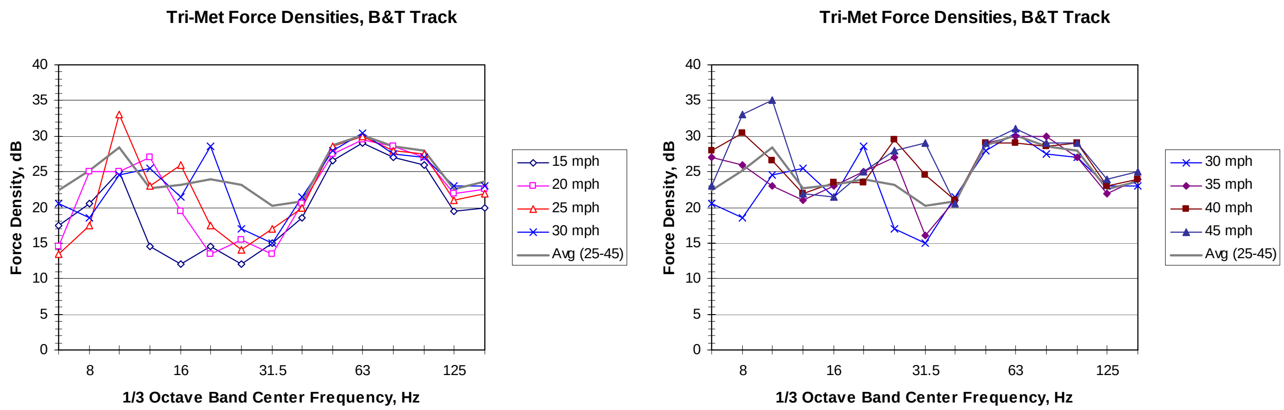


3. The tests with b&t track were performed at speeds of 15 to 45 mph at 5 mph increments (see figures below). This data does not support the standard assumption of a speed dependence of 20log(speed). The figures below show that there is little change with speed for the 40 to 160 Hz bands, and some big, inconsistent, changes for the lower frequencies. The changes are probably related to forcing functions that are a function of speed (e.g., wheel rotation frequency, tie passage frequency, etc.). The question is how to estimate the force densities for other speeds.

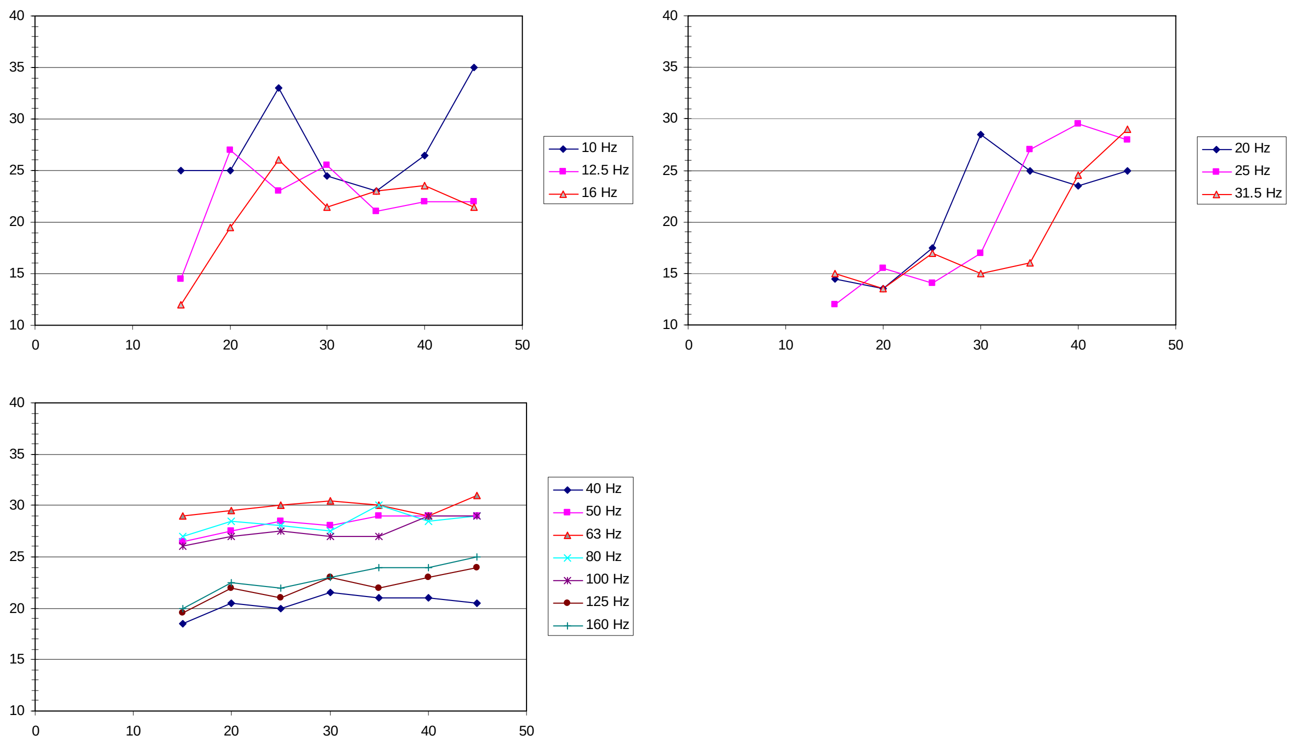
   The approach I used was to interpolate for speeds below 45 mph. For speeds greater than 45 mph I used the slopes from the best fit curves and extrapolated to the speed from the 45 mph data and from the 40 mph data and then used the maximum of the two extrapolation curves for each band. This avoids unrealistically amplifying the peaks that show up at 45 mph but are not in the 40 mph FD.

   The only problem I see with this is that it leaves a dip in the 50 and 55 mph FD at 16 Hz and at 40 Hz that may not actually occur. I don't think this will be a problem when predicting overall levels, but it is something to keep in mind if looking at mitigation measures.

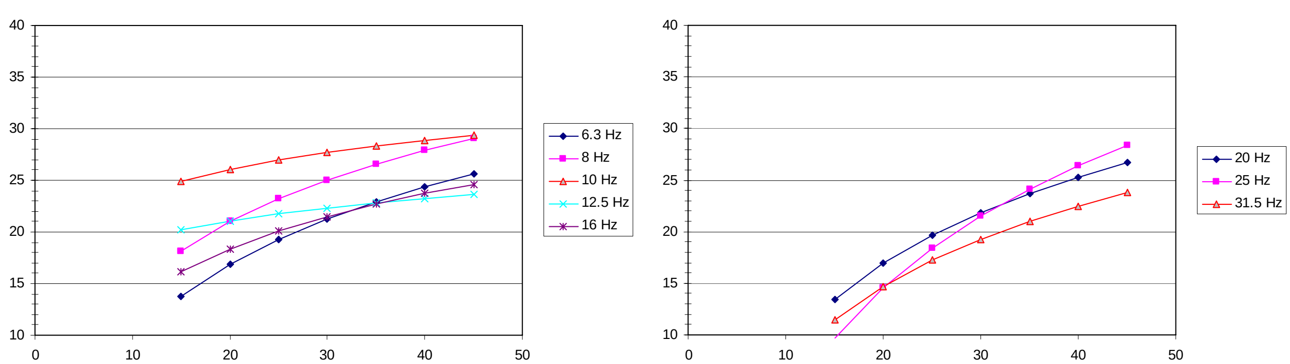


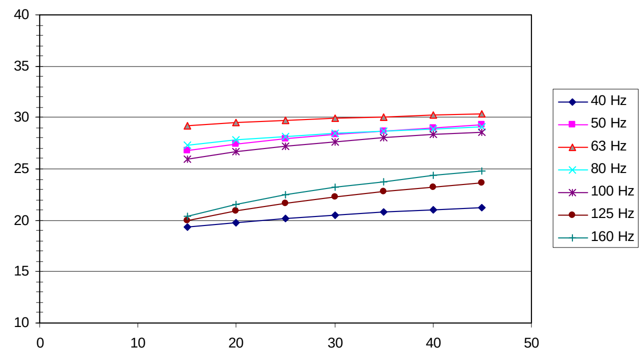


Measured Force Densities for Ballast & Tie Track

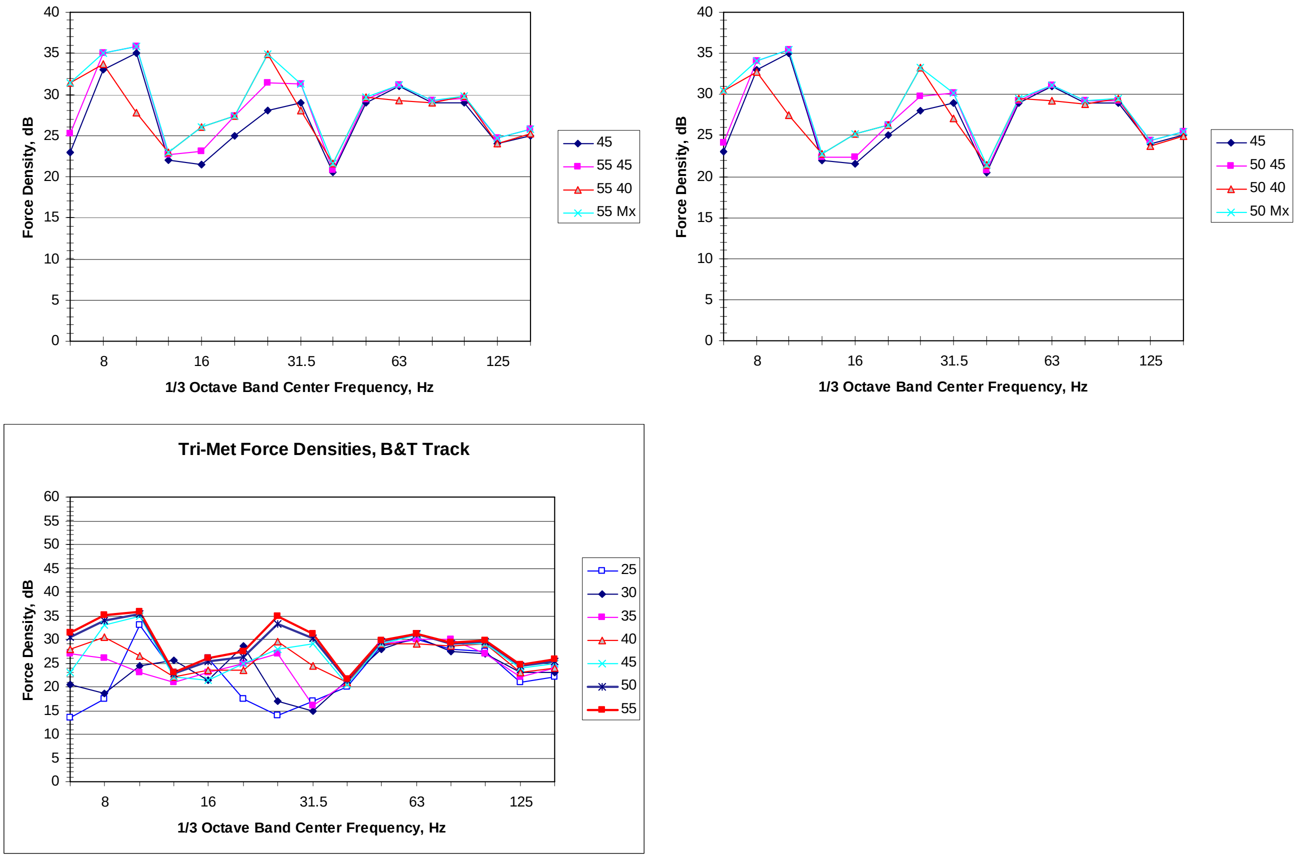


Force Density Levels vs. Speed for each 1/3 Octave Band





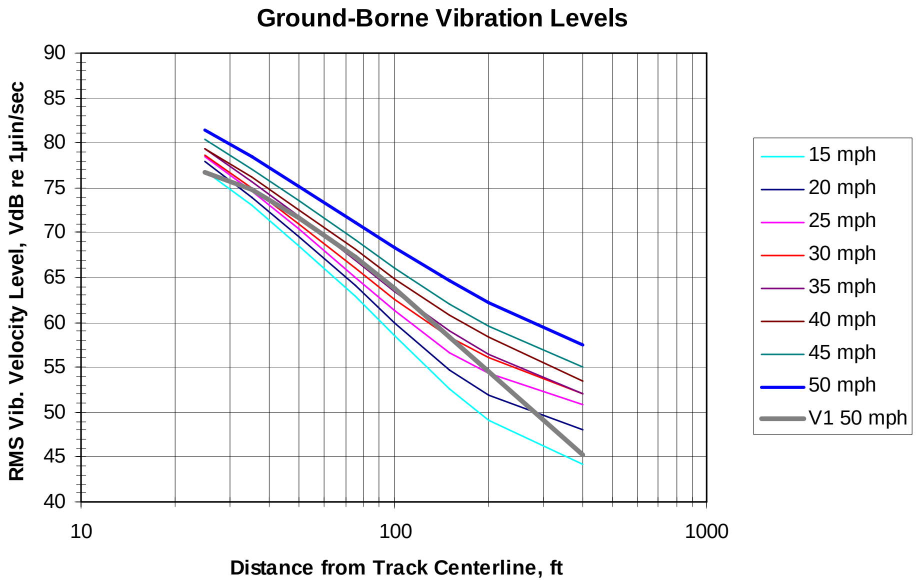
Force Density Levels vs. Speed for each 1/3 Octave Band, Best Fit Curves *(vs. log speed)*



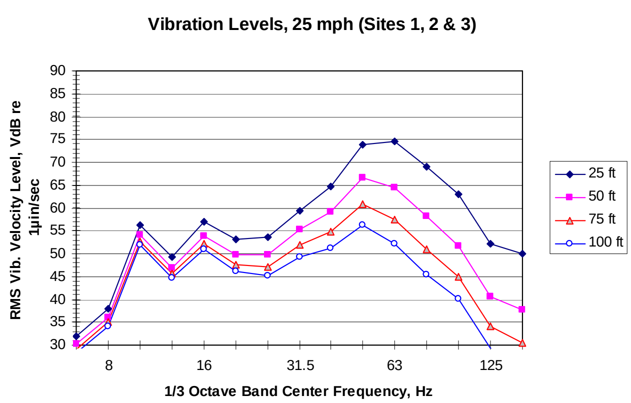
Force Density Curves Derived for 50 and 55 mph

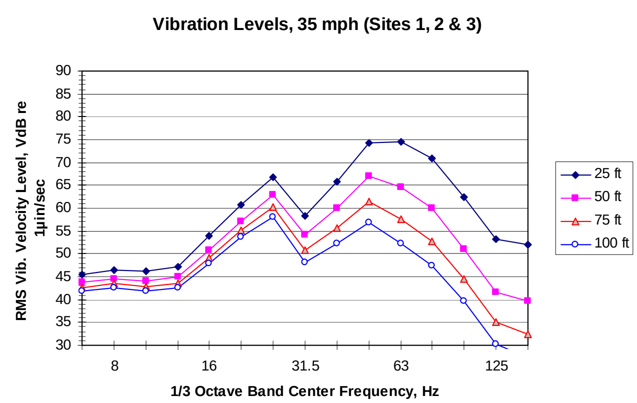
4. The force density curves and the LSTM were combined to predict vibration level as a function of distance, speed, and frequency. The figure below shows the curves using the average of the Sites 1-3 TM for speeds from 25 to 50 mph. It also shows the prediction curve that was used for the Vancouver area for the previous analysis (1996?). At distances less than 100 ft, the new curves are in the range of 3 to 5 VdB higher than the previous curve. If anything, this indicates that the new curve is a conservative estimate. It is interesting that the slopes of the level vs. distance curves change with speed. Note that the difference in the curve shapes for these measurements and the previous measurements may be related to the data analysis procedures. I believe that in the previous analysis the best fit curves were forced to turn down by eliminating some of the data from the more distant

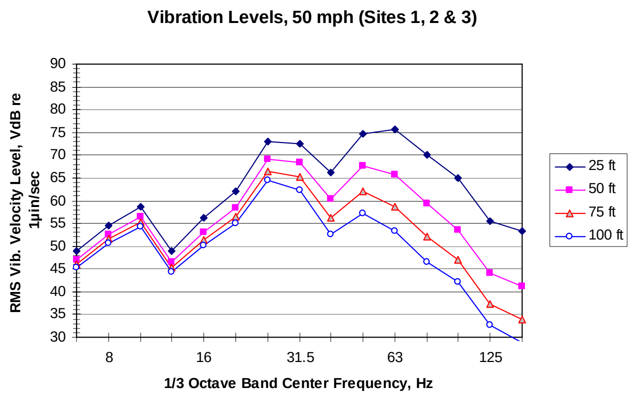
accelerometers. Since the levels at these distances are well below the impact threshold, it should not cause a problem.

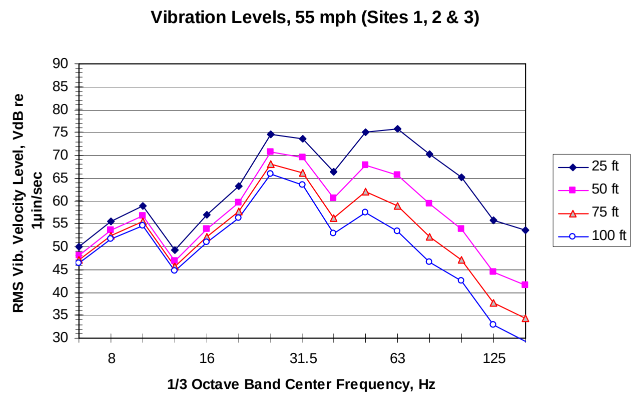


5. Predicted vibration spectra are shown below. As speed increases the high frequencies change slowly while the low frequencies increase relatively rapidly. The current FTA vibration criteria for a detailed vibration analysis (one where there have been propagation tests performed) is based on the ANSI S3.29 curve, which is flat in terms of velocity above 10 Hz. Using the more detailed curve, impact occurs when any 1/3 octave band level exceeds 72 VdB. From inspection of the curves it is evident that the predicted vibration levels will not exceed the impact threshold at distances greater than 50 ft from the tracks even at 55 mph. Correspondingly, at 25 ft, the predicted vibration levels exceed the threshold at all speeds.









Predicted Vibration

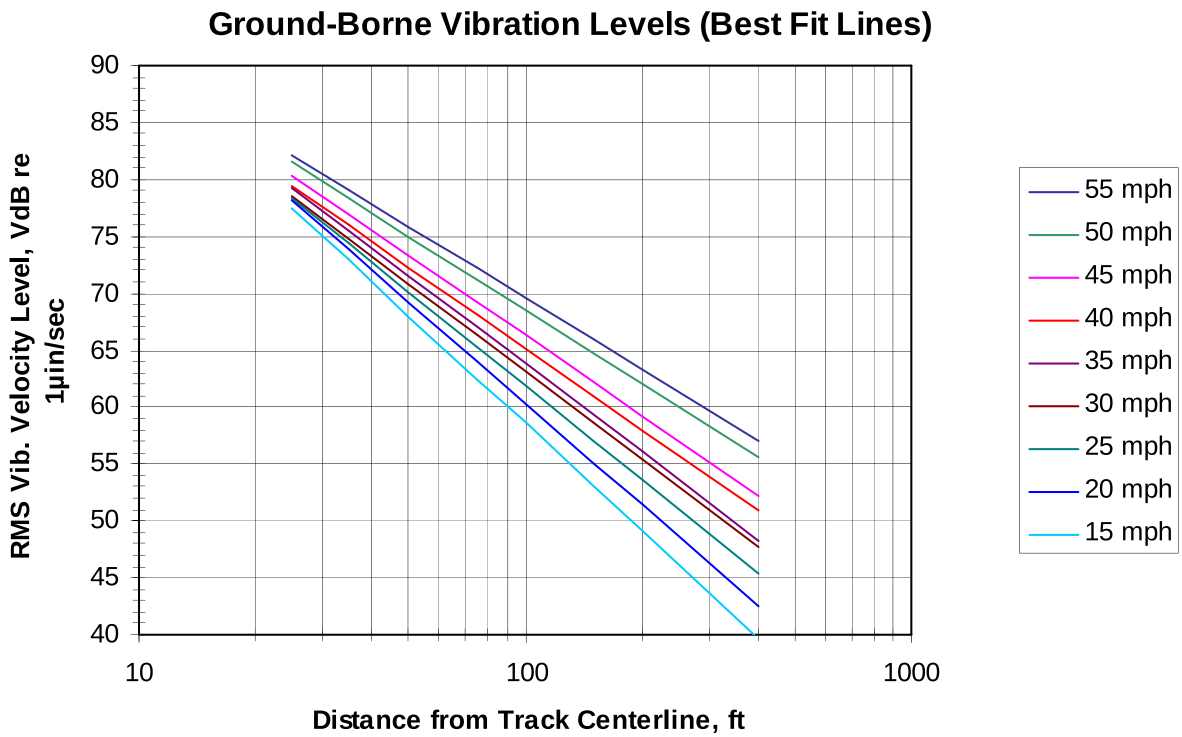
6. One question is how to determine impact using a curve of overall vibration level. The threshold for overall vibration is 72 VdB, but it is clear that a detailed analysis will not result in impact until higher overall levels. The differences between the maximum 1/3 octave band level and the overall level for each of the above below are:

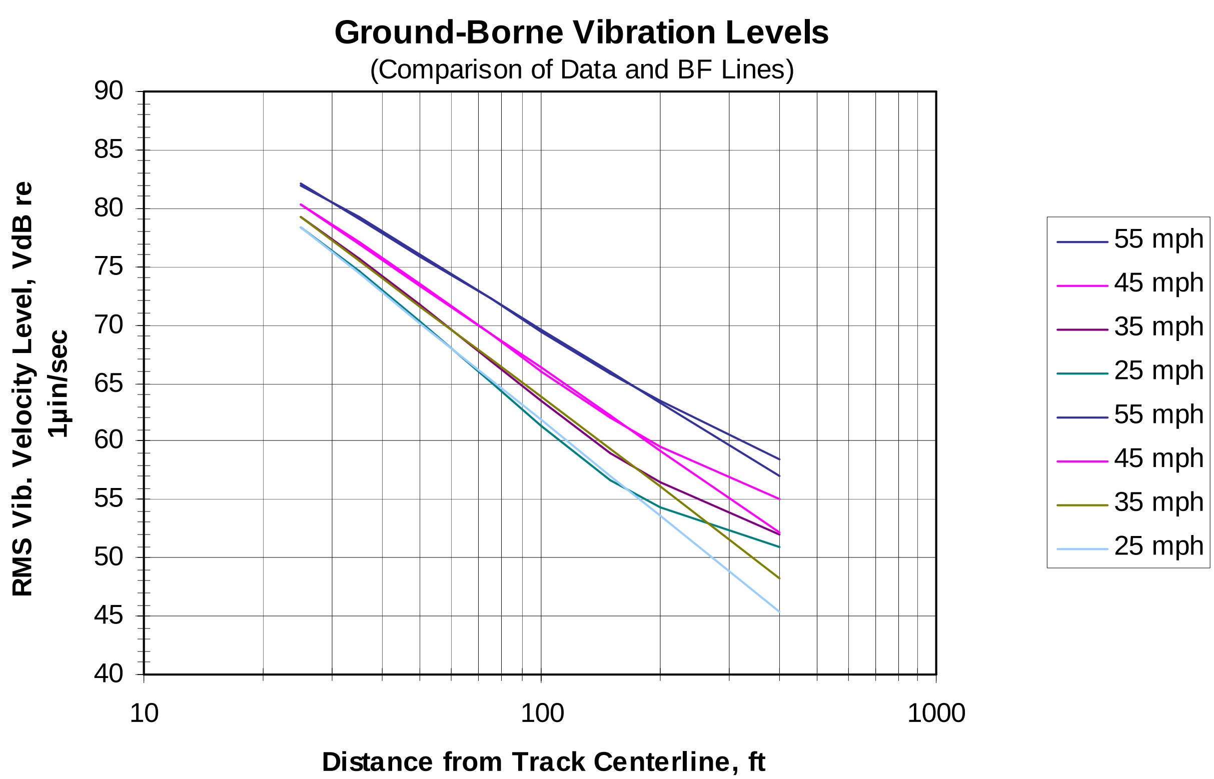
Dist	**Difference, VdB**			
	55 mph	**50 mph**	**35 mph**	**25 mph**
25 ft	5.9	5.4	4.6	3.8
50 ft	4.7	5.4	4.1	3.4
75 ft	3.7	4.2	4.8	3.7
100 ft	3.2	3.6	4.8	4.6

The maximum difference is 5.9 VdB and the minimum difference is 3.2 VdB. My conclusion is that using an overall threshold of 75 VdB will provide conservative estimate of the potential for impact.

7. The final vibration level vs. distance lines are shown below, both the raw curves and the best fit lines. Fro the best fit lines I used the data up to 200 ft. Including the 400 ft data reduces the slope and increases all the levels between 25 ft and 400 ft. The parameters for the lines are given below where the equation for the line is Lv = A + B*log(dist).

Speed	**A**	**B**
15 mph	121.4	-31.4
20 mph	119.4	-29.5
25 mph	116.8	-27.4
30 mph	114.5	-25.7
35 mph	115.3	-25.8
40 mph	112.6	-23.7
45 mph	113.2	-23.5
50 mph	111.6	-21.6
55 mph	111.3	-20.8


Ground-Borne Vibration Levels (Best Fit Lines)
RMS Vib. Velocity Level, VdB re 1µin/sec
90
85
80
75
70
65
60
55
50
45
40
10
100
1000
Distance from Track Centerline, ft
55 mph
50 mph
45 mph
40 mph
35 mph
30 mph
25 mph
20 mph
15 mph


Ground-Borne Vibration Levels
(Comparison of Data and BF Lines)
RMS Vib. Velocity Level, VdB re 1µin/sec
90
85
80
75
70
65
60
55
50
45
40
10
100
1000
Distance from Track Centerline, ft
55 mph
45 mph
35 mph
25 mph
55 mph
45 mph
35 mph
25 mph