Regional Connector Transit Corridor
Final Environmental Impact Statement/
Environmental Impact Report

APPENDIX 2

UPDATED LOCALLY PREFERRED ALTERNATIVE NOISE AND VIBRATION ANALYSIS

State Clearinghouse Number: 2009031043

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Appendix 2 Updated Locally Preferred Alternative Noise and Vibration Analysis

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MEMORANDUM

DATE: 11 July 2011 Revised 12 July 2011

TO: John Prizner, Connector Partnership

FROM: Deborah Jue, Richard Carman

SUBJECT: Noise and Vibration - Preliminary Engineering Update
Walt Disney Concert Hall
Construction and Operational Vibration Impact – Updated Results
WIA#10-088

Executive Summary

This memorandum addresses the updated analysis for the Walt Disney Concert Hall (WDCH) based on field tests conducted in May 2011. Our preliminary impacts analysis for the WDCH was previously presented in a memorandum on Historic Resources[1]. Field tests have been conducted to quantify some outstanding issues identified during the FEIS/FEIR analysis. Two of the main issues were a) how would vibration propagate from the alignment tunnel depth to the WDCH building, and b) how would vibration propagate through the WDCH building into the sensitive spaces. This preliminary engineering analysis includes results from recent sound and vibration measurements conducted at and near the WDCH, and it indicates that there would be a potential noise impact for a single train passby at the Choral Hall, a performance, rehearsal and recording space, which has an unusually high level of amplification, and there would also be potential noise impact during construction in the Choral Hall and in the Main Auditorium, the audience seating area for the primary performance, rehearsal and recording space within WDCH, and in the LA Philharmonic Association (LAPA) conference room. Thus, some form of vibration mitigation such as suspension rail fasteners or isolated slab track in the tunnel would be required to eliminate the operational groundborne noise impacts, and scheduling coordination, slow tunnel train speed, use of conveyor or mitigations similar to the method listed above would be required to eliminate the effect of groundborne noise impacts during construction. The infrequent case of two trains in the tunnels would generate a noise impact at the Main Auditorium and the Choral Hall, but these impacts would be mitigated with the methods listed above. This revision includes changes to Table 5 and 6 to correct erroneously entered data and some corresponding updates in the construction impact section.

Introduction

During the FEIS/FEIR analysis, the potential for noise and vibration impacts at the WDCH was identified, based on conservative assumptions regarding a) how vibration would propagate from the alignment tunnel depth to the WDCH building, and b) how vibration would propagate

[1] Prepared for Task 6.1.4.4, revision date 7 April 2011

through the WDCH building into the sensitive spaces. Thus, in May 2011, field tests were conducted with the cooperation of the Music Center Staff and tenants. These tests were primarily done during the late night/early morning hours, so as to minimize disruption with operations and activities at the WDCH, and to minimize the effects of ambient noise and vibration on the measurement results.

A test plan document was prepared, and a copy of that document is included in Appendix A for reference. In the test plan, a matrix of potentially noise sensitive spaces was listed, as identified by Music Center staff. That matrix is reproduced below in Table 1 with a few updates.

Figure 1 illustrates a schematic cross section of the field test measurements in relation to the WDCH building. Additional drawings showing the test locations within the parking structure and WDCH are provided in the Appendix. The Track Plan and Profile drawings dated 6/29/2011 were used for this analysis. Drawings of the parking structure and WDCH construction were received on 4/13 2011. Representative plan and cross section drawings used for this analysis are included in the Appendix

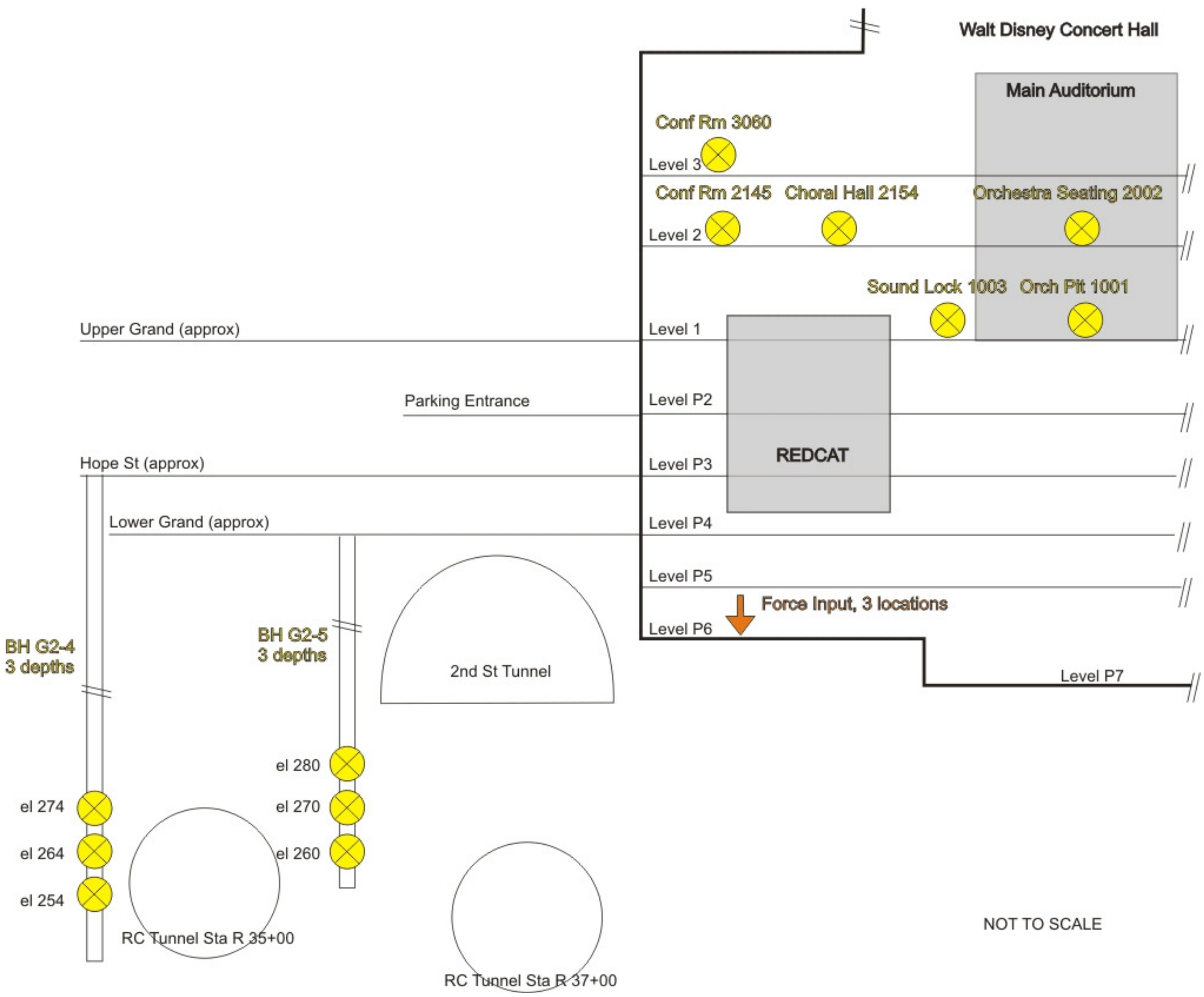


FIGURE 1 Schematic Cross Section, Field Tests Conducted May 2011

TABLE 1 Areas of Interest – Music Center and Walt Disney Concert Hall

Room	Space	Usage	Expected Level Basis	Comment
1st level	Main Entrance	Lobby	see 1001	far less sensitive than Main Auditorium
1001	Platform Pits	Stage Lift Equipment	Calculation	below stage; far less sensitive than Main Auditorium, some horizontal decoupling for final pour under lifts
1003	Sound Lock	Back of house	Calculation	Below staging areas; far less sensitive than Main Auditorium, has different response than 1001
1111	Tenant Space	Retail	see 1001	far less sensitive than Main Auditorium
1111	Tenant Space	Patina Restaurant	see 1001	far less sensitive than Main Auditorium
2nd level	Terrace	Outdoor	see 2145	Vibration only
2001	behind chorus loft	Stage/Main Aud.	see 2002	
2001	Concert platform	Stage/Main Aud.	see 2002	
2002	Orchestra Seating	Main Auditorium	Calculation	
2008	recording	control booth/Main Aud.	see 2002	
2011	Assembly Area	pre-stage	see 2002	less sensitive than Main Auditorium
2058	Dressing Room		see 2145	less sensitive than Main Auditorium
2068	Dressing Room		see 2145	less sensitive than Main Auditorium
2073	Dressing Room	Concert Master	see 2145	less sensitive than Main Auditorium
2083	Director	pre-stage	see 2145	less sensitive than Main Auditorium
2092	Stage Door Waiting	pre-stage	see 2145	less sensitive than Main Auditorium
2119	Orchestra Café	dining	see 2154	far less sensitive than Main Auditorium
2143	LAPA	Conference Room	see 2145	less sensitive than Main Auditorium
2145	LAPA	Conference Room	Calculation	less sensitive than Main Auditorium
2144	LAPA (1)	open office	see 2145	less sensitive than Main Auditorium
2144	LAPA (2)	board president	see 2145	less sensitive than Main Auditorium
2154	Choral Hall	Rehearsal, performance, some recording	Calculation	less sensitive than Main Auditorium
2170	Ante Room	Practice/warm up	see 2154	less sensitive than Main Auditorium
2178	Ante Room	Practice/warm up	see 2154	less sensitive than Main Auditorium
2190	founders room	function	see 2002	far less sensitive than Main Auditorium
3rd level	garden	outdoors	see 3060	Vibration only; less sensitive than interior spaces
3rd level	Keck Amphitheater	outdoors	see 3060	Vibration only; less sensitive than interior spaces
3001	Center Orchestra	Main Auditorium	see 2002	
3rd level	Main Auditorium wall(s)		n/a	Wall panels are installed with decoupling hardware.
3023	announce/control		see 2002	
3028	organ	Stage/Main Aud.	see 2002	
3060	LAPA	Conference Room	Calculation	less sensitive than Main Auditorium
3061	LAPA (1)	open office	less than 2144	less sensitive than Main Auditorium
3061	LAPA (2)	open office	less than 2144	less sensitive than Main Auditorium
4th level	Keck audience (2)	outdoors	less than 2144	Vibration only; far less sensitive than Main Auditorium

Operational Noise and Vibration

This analysis follows the Federal Transit Administration (FTA) methodology for "Detailed Analysis"[2] which uses the following equation for vibration:

(1) $L_V(\text{in building}) = L_F\ (\text{speed}) + TM_{Line}\ (\text{distance from track centerline}) + C_{Tunnel} + C_{Build}$

Where

L_V = Vibration at a specific horizontal distance from the alignment in decibels re 1 micro-inch/second

L_F = Force density or system input spectrum of the LRV on the track structure. This is a function of parameters such as

- Speed
- Wheel/Rail condition (corrugation, wear, etc.)
- Rail configuration (joints, special trackwork, tangent, curved, etc.)
- Track structure (direct fixation on invert, ballasted track, resilient fasteners, floating slab, etc.)

TM_{Line} = Transfer mobility of the intervening ground or subsurface layers for a line input of a specified length (typically the length of a train consist) as measured at the receiver.

C_{Tunnel} = Although this factor is not explicitly called out in the FTA methodology, it is used to account for coupling loss between the tunnel structure and the surrounding soil.

C_{Build} = Adjustments to account for ground-to-building coupling losses, floor to floor attenuation and room surfaces structural response to vibration

Groundborne noise is determined by the groundborne vibration level, and it is calculated as follows:

(2) $L_A = L_V + K_{rad} + K_{A\text{-}wt}$

Where

L_A = A-weighted noise level in dB re 20 micro-inch/second

K_{rad} = Adjustment for conversion of vibration velocity to sound pressure, taking into account the acoustical absorption in the room and the sound radiating characteristics of the room surfaces

$K_{A\text{-}wt}$ = A-weighting adjustment curve

The following parameters were used for this analysis:

- LRV
  - 3-car train
  - 15 mph maximum speed (limited by design speed of curves and nearby station)
  - Direct fixation (resilient fasteners on the order of 140,000 lb/in dynamic stiffness)
  - L_F in this case is taken from an energy-average of various similar LRV operating on direct fixation fasteners including LA Metro Blue Line (Nippon-Sharyo P865), LA Metro Goldline (Siemens P2000 or Breda P2550) and Sound Transit (Kinki-Sharyo). The Sound Transit L_F dominates the average in the 50 and 63 Hz 1/3 octave bands and includes the effect of a curve. The assumed L_F spectrum is shown in Figure 2.
  - One train or two trains passing in the tunnel structure.

[2] Originally developed in 1986 by WIA, this method has been incorporated into the FTA Guidance Manual.

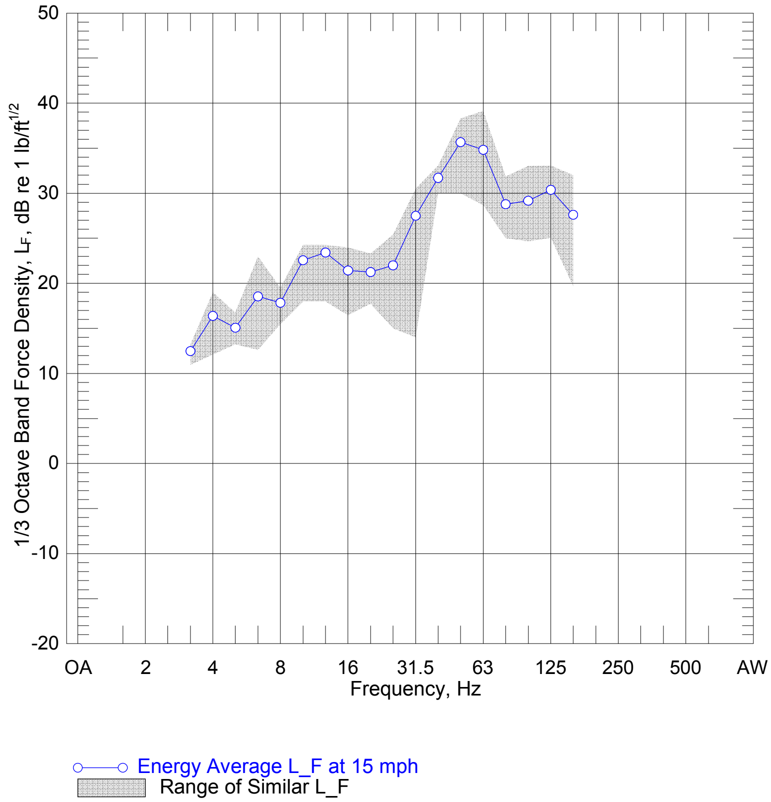


FIGURE 2 Range of Applicable Force Density (L_F) Spectra
15 mph Direct Fixation Fasteners

- Potential Mitigation Measures
  - High compliance fastener such as a Cologne Egg or HA-LVT (50kips/in static stiffness with a dynamic to static stiffness ratio of 1.2)
  - Rail suspension fastener systems such as Delta DFF manufactured by Advanced Track Products or Panguard manufactured by Pandrol (14 to 16kips/in static stiffness with a dynamic to static stiffness ratio of 1.4 or less)
  - Isolated slab trackbed using a 1" resilient mat between the tunnel invert and the concrete trackbed such as the Sylomer mat manufactured by Getzner e.g., 64 lb/in^2 dynamic stiffness modulus)
  - For optimal performance, the dynamic/static stiffness ratio (k_d/k_s) a bonded DF fastener should ideally fall within the range of 1.0 to 1.3 for natural rubbers; synthetic rubber, the optimal ratio is typically within the range of 1.4 to 1.8. The above ratios indicated are obtainable from manufacturers.
  - The expected performance for these systems in shown in Figure 3.
- Tunnel
  - Bored tunnel – the analysis assumes no coupling loss with the Fernando Formation
  - At station R 34+40 the top-of-rail is near 250 ft elevation and at station T2 37+00 the top-of-rail is near 240 ft elevation.
  - Thus, the top-of-rail at R 37+00 is about 115 ft below Lower Grand Avenue.

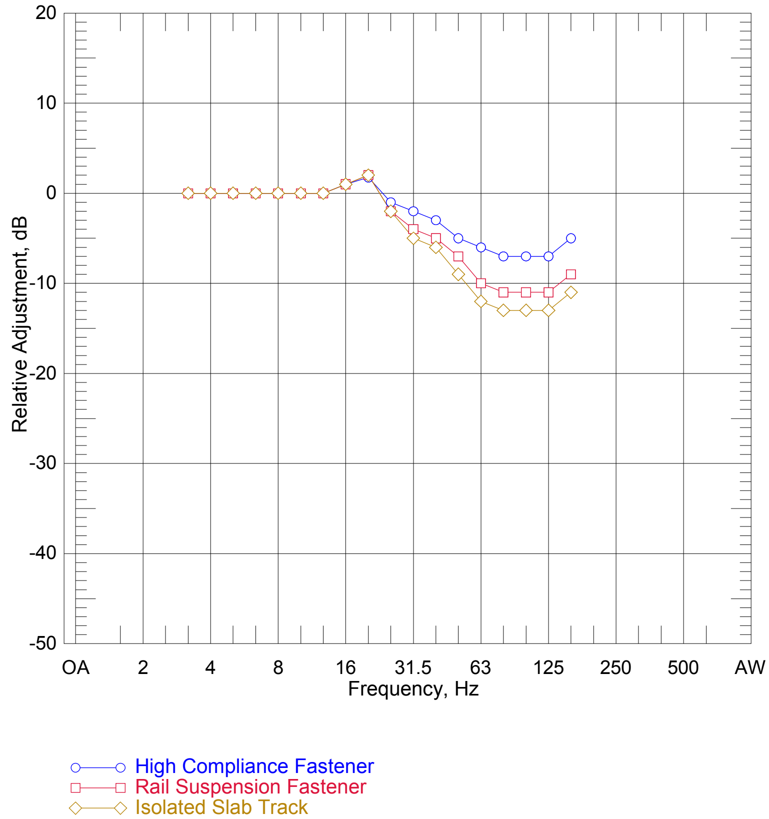


FIGURE 3 Mitigation Options – Relative Vibration Performance

- Subsurface conditions
  - The geotechnical studies indicate that the alignment tunnel would be founded in Fernando Formation in this area[3]
  - Fernando Formation is exposed at the ground surface of nearby Broad building site
  - Transfer mobility derived from field tests conducted in May 2011 from tunnel depths to P6 level within WDCH.
  - See Figure 4 for the transfer mobilities derived from the WDCH measurements.
    - TM at 30 ft horizontal distance used for worst case condition with train centered at southwest corner of WDCH, near Sta R 37+00 and top-of-rail about 84 ft below P6 level.
    - TM at 95 ft horizontal distance used for worst case condition at Choral Hall with train centered south of the WDCH, near Sta R 34+40 and top of rail about 74 ft below P6 level.
  - A comparison of field test results with previous Transfer Mobility models is contained in the Appendix.

[3] Preliminary geologic profiles (1/5/11) prepared by MACTEC Engineering and Consulting, and updated geologic plan and profile from field borings (6/29/11)

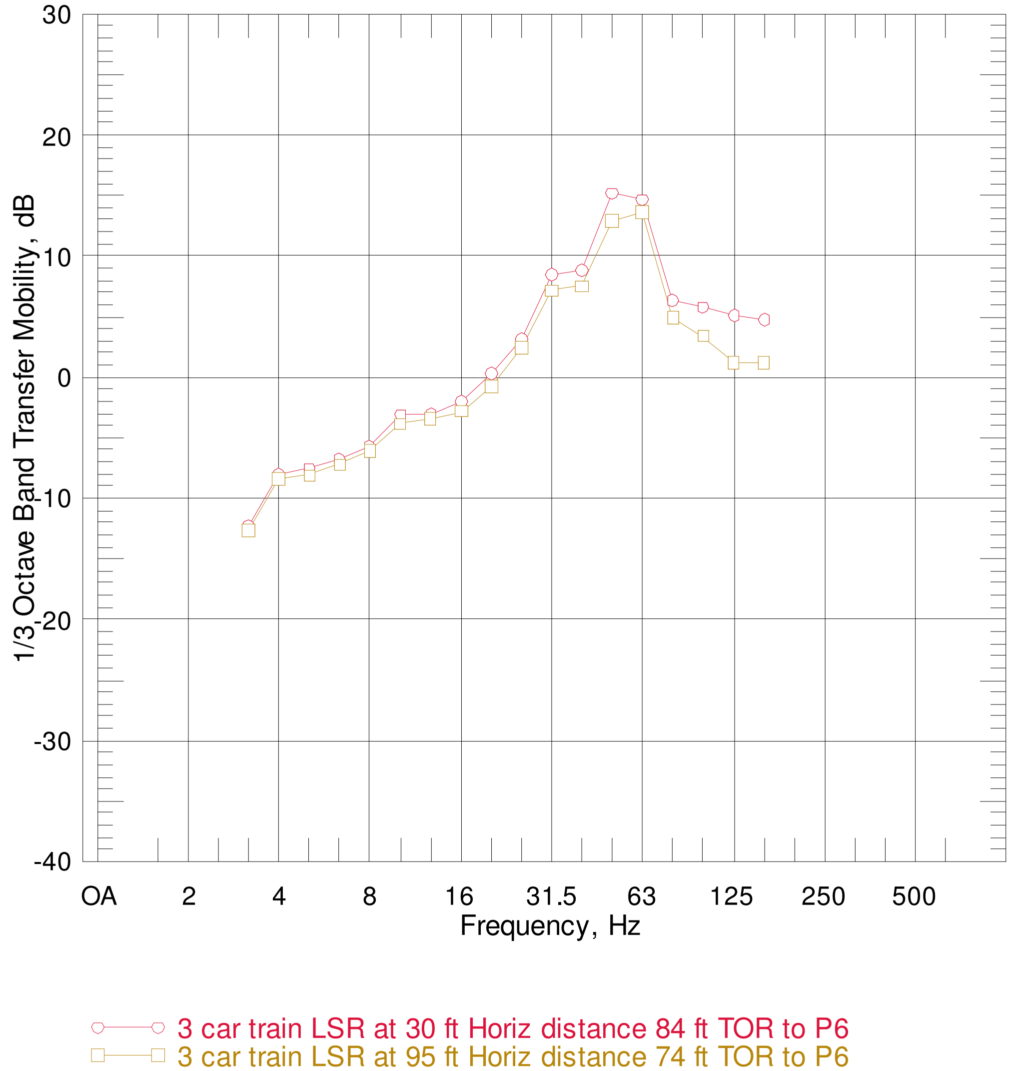


FIGURE 4 Transfer Mobility for Line Source – Fernando Formation

- Walt Disney Concert Hall
  - Along the 2nd Street, the original seven-level parking structure was founded on piles at the 6th level (P6) for the south perimeter. However, the 7th level does not extend as far south and appears to have a slab-on-grade foundation, ending around column line 5.3, as shown schematically in Figure 1.
  - The elevation of P6 is approximately 318 ft, so that the Project tunnel would be about 68 to 78 ft below P6.
  - Portions of the upper floors of the parking structure were demolished for construction of the WDCH and the Roy and Edna Disney/CalArts Theater (REDCAT)
  - Correction Factors included in C_{Build}:
    - Measured loss from P6 parking level to representative spaces within WDCH. (Figure 5)
      - The maximum response was used for each location
      - In most cases the range response was well clustered, regardless of P6 impact location. See Appendix.

- At the Choral Hall, a significantly higher response was measured when the source impact was done at the southwest corner of P6. This response was used with 95 ft horizontal distance transfer mobility, as discussed above.

- Room response factor assumes only minor acoustical absorption in the spaces (Figure 6); were unable to generate a sufficient level of vibration to measure the actual relationship between groundborne vibration and groundborne noise within the Main Auditorium, so this (conservative) factor has been retained from the preliminary analysis.
- Measured insertion loss between structure and REDCAT auditorium, across the isolation joint (Figure 7)

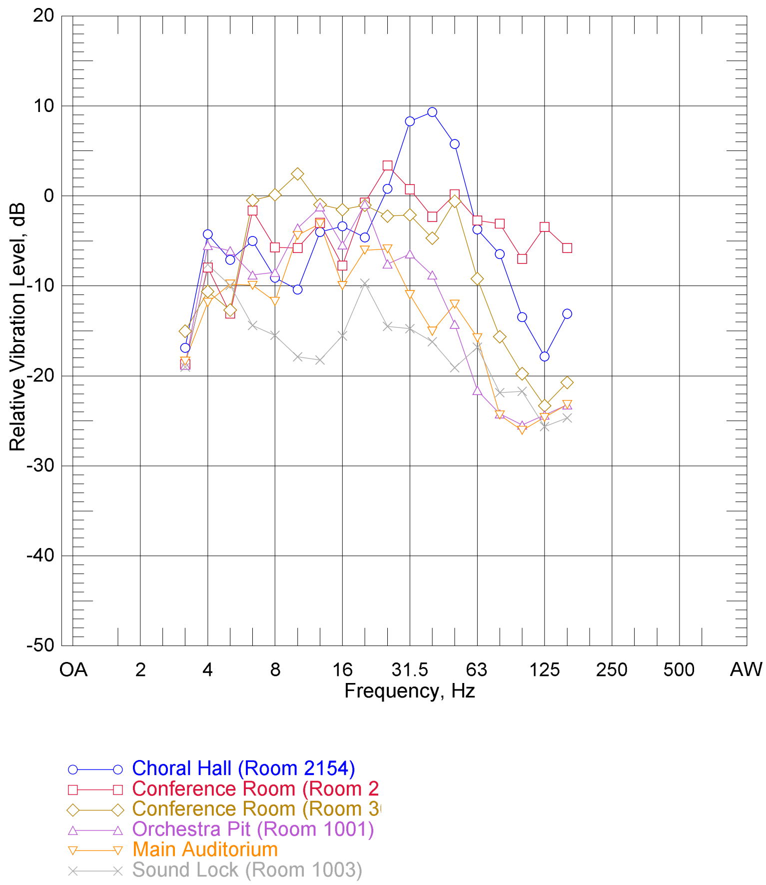


FIGURE 5 Building Response Factors WDCH

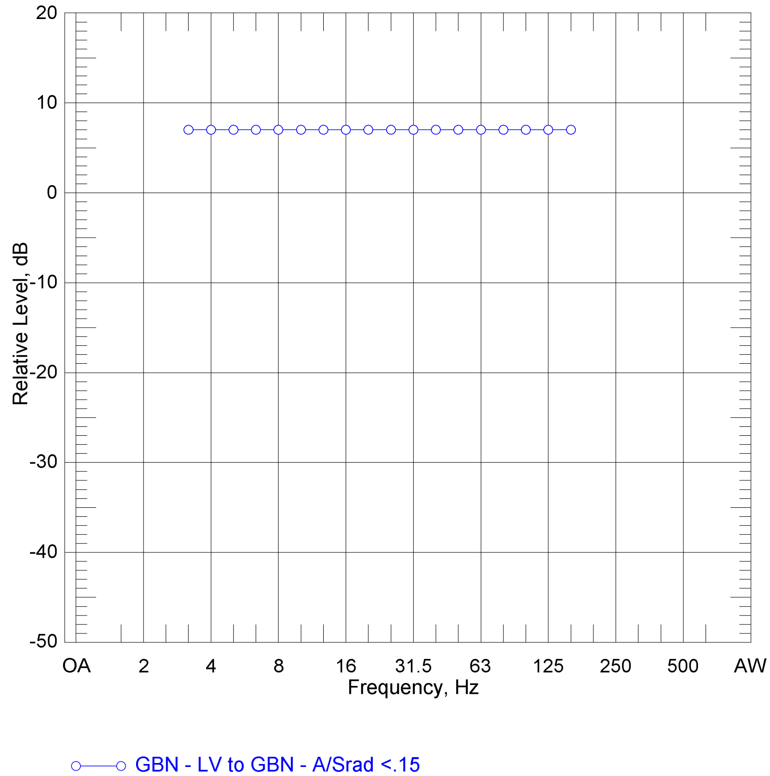


FIGURE 6 **Vibration to Noise Conversion Factor**

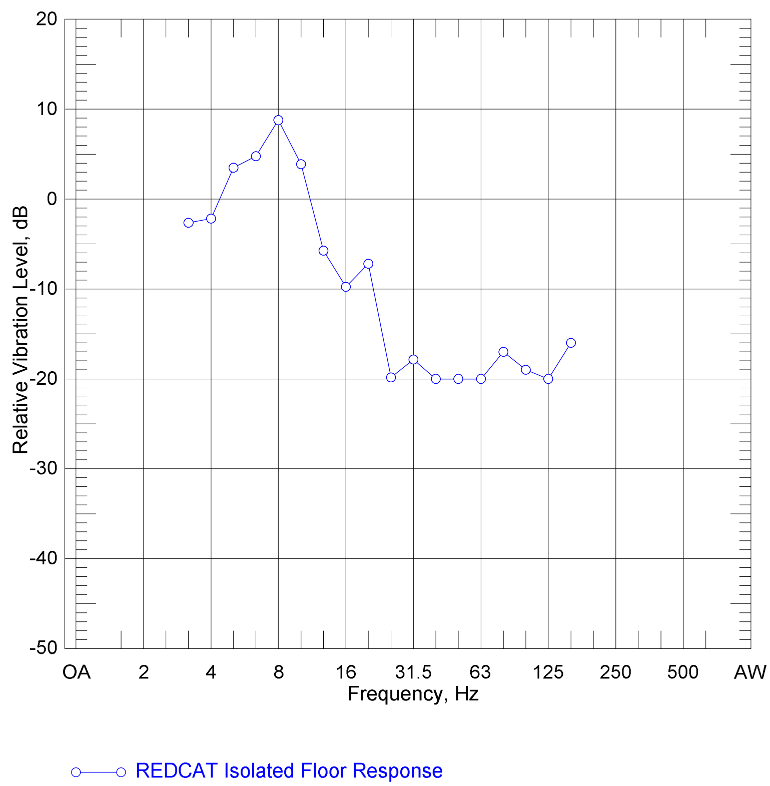


FIGURE 7 **Vibration Isolation, REDCAT**

- Criteria (FTA)
    - FTA Criteria were developed to address the typical needs and expectations within different categories of buildings. The specific categories and criteria applicable to WDCH are indicated below.
    - Frequent Events (greater than 70 events per day)
        - Default: FTA Category 3 (Institutional)
            - 75 VdB for groundborne vibration
            - 40 dBA for groundborne noise
            - For reference, a 35 dBA level would be just noticeable to the careful listener, a 30 dBA level would generally not be audible in a live performance setting, and a 25 dBA level could be measured, but would not be audible to the naked ear.
        - REDCAT
            - FTA Special Buildings (Theater):
                - 72 VdB for groundborne vibration
                - 35 dBA for groundborne noise
        - Choral Hall
            - FTA Special Buildings (Auditoriums)
                - 72 VdB for groundborne vibration
                - 30 dBA for groundborne noise
                - This space is used for rehearsals with some recitals/chamber performances and archival recordings
        - Main Auditorium
            - FTA Special Buildings (Concert Halls and Recording):
                - 65 VdB for groundborne vibration
                - 25 dBA for groundborne noise
                - This space is used for rehearsals, performances, archival recordings and some commercial recordings.
                - This is the most sensitive space within the WDCH complex, due to number of performances and performer and audience expectations
    - Occasional Events (from 30 to 70 event per day)
        - FTA Category 3: 78 VdB and 43 dBA
        - FTA Special Building (Theater): 80 VdB and 43 dBA
        - FTA Special Building (Auditorium): 80 VdB and 38 dBA
        - FTA Special Building (Concert Hall and Recording): 65 VdB and 25 dBA
    - Other information
        - Table 2 summarizes the ambient conditions and the corresponding NC levels.
        - The ambient noise results are included in the Appendix.
- Miscellaneous
    - The engineering design factor is shown in Figure 8. This curve is based on the estimated net uncertainty in derivation of L_F ,TM and other factors used in calculating groundborne noise and vibration
        - Based on our experience, the typical variability in the L_F for a given fleet of vehicles is small for reasonably well-maintained rails and wheels.

- Since the L_F in this analysis is based on measured data for both the Gold Line and Blue Line vehicles, we expect the actual L_F value to be within 1 or 3 dB of the curve shown in Figure 2 to account for differences in vehicle speeds, track conditions and fasteners.
- The typical variability in the field measured TM and coupling loss parameters also adds another 2 to 4 dB uncertainty for data between 12 and 160 Hz.
- The validity of using this design factor and the accuracy of the FTA prediction model has been examined in a paper presented by WIA to the American Public Transit Association in 1995[4].

- Further, some additional conservatism has been included:
  - In the effect of the curve on the L_F which could be overstated in Figure 2; this effect primarily influences the 50 and 63 Hz 1/3-octave bands which dominate the groundborne noise calculations.
  - In the groundborne noise prediction by assuming that the vibration of the wall and ceiling surfaces is the same level as the floor vibration. Typically there should be some loss from floor to ceiling and from horizontal plane (floor) to the vertical plane (walls).
  - In the groundborne noise prediction since it does not include the effect of resilient supports for the wall panels in the Main Auditorium; thus the conversion from vibration to noise could be less than predicted.
  - In the groundborne noise prediction by assuming only minor acoustical absorption as mentioned above.
- This model assumes reasonably well-maintained rails and wheels, and thus does not include the effects of occasional moderate flat wheels or poorly maintained rail.
- This model assumes that the potentially high variability in high frequency vibration would be controlled through regular rail grinding and wheel maintenance programs.

[4] Carman, Richard, "Rail Transit – Groundborne Noise and Prediction Models, A Comparison of Predicted and Measured Data," June 1995.

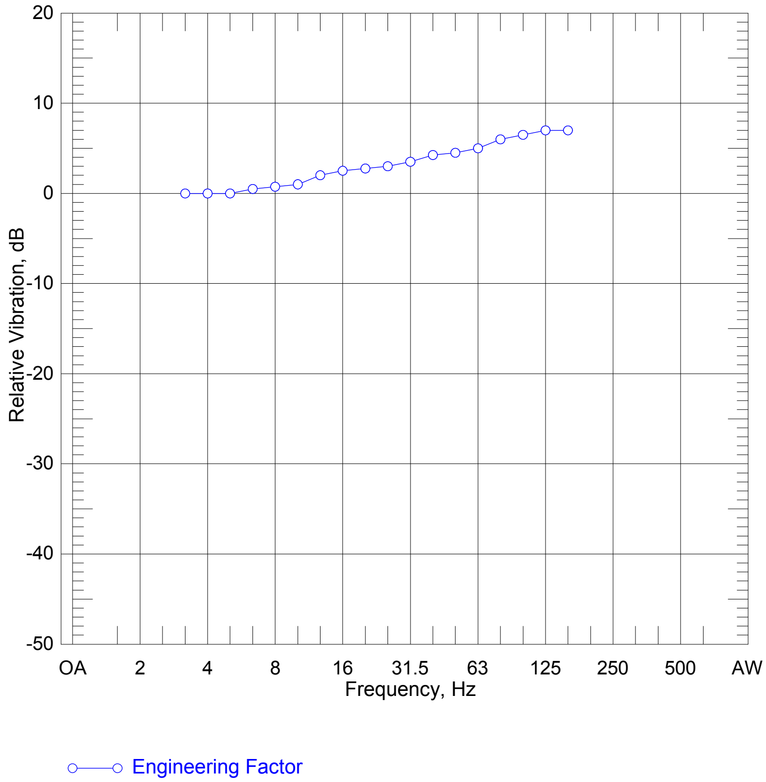


FIGURE 8 Engineering Design Factor
Groundborne Vibration Calculation

The predicted results for groundborne vibration at different spaces within the WDCH for a single train passby are shown in Figure 9, and the corresponding results for groundborne noise are shown in Figure 10. Results for the REDCAT have also been updated, and they are shown in Figures 11 and 12.

As shown in the left axis of Figure 9 and Figure 11, all groundborne vibration is expected to be less than 65 VdB.

The groundborne vibration calculations were converted to groundborne noise (Figure 10 and Figure 12), applying the highest vibration to noise conversion factor to the vibration estimate. As shown in the right axis, the groundborne noise range is expected to range from 22 dBA at the REDCAT to 37 dBA at the Choral Hall.

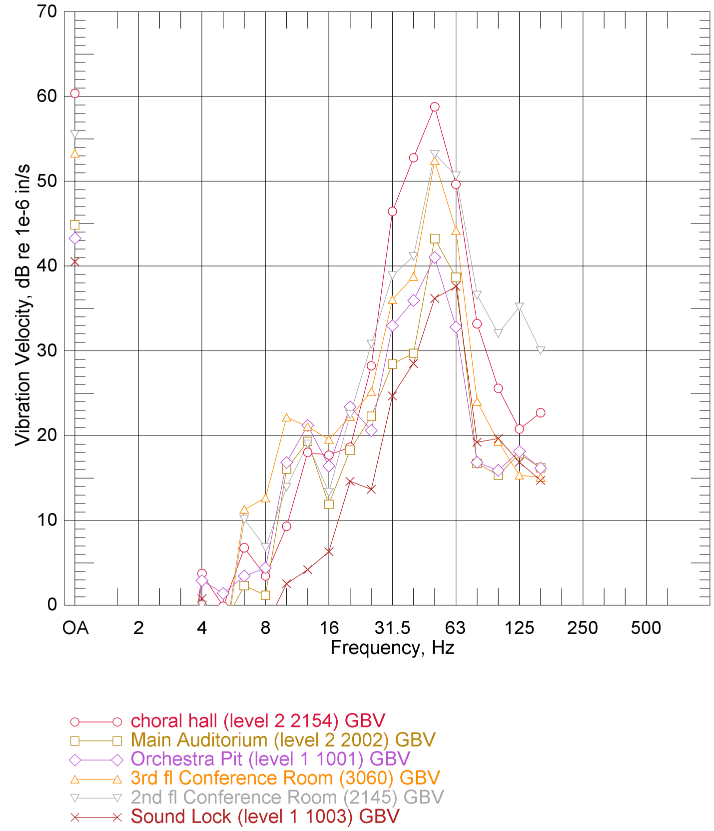


FIGURE 9 Predicted Groundborne Vibration at WDCH

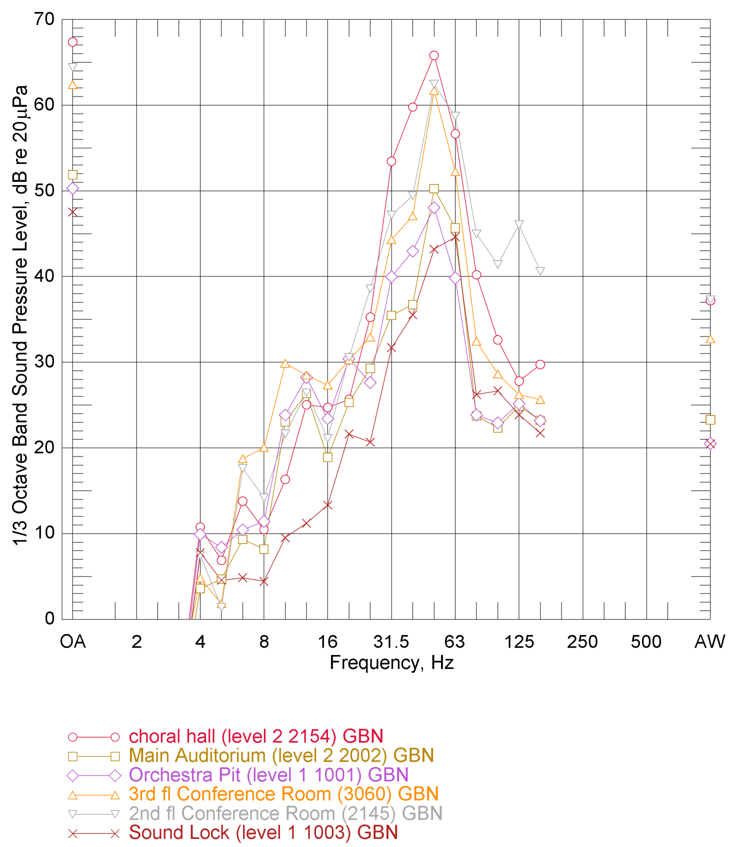


FIGURE 10 Predicted Groundborne Noise at WDCH

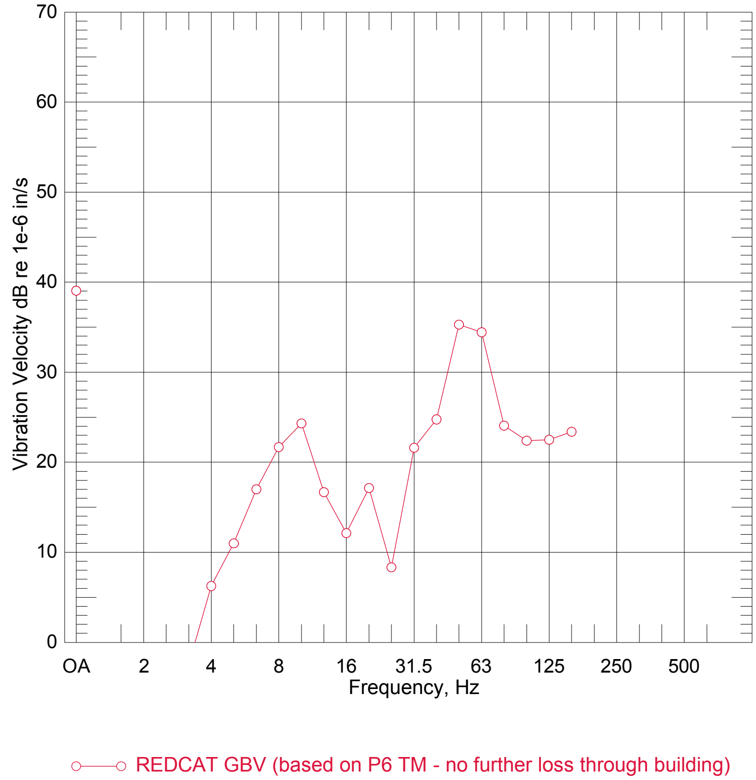


FIGURE 11 Predicted Groundborne Vibration at WDCH – REDCAT

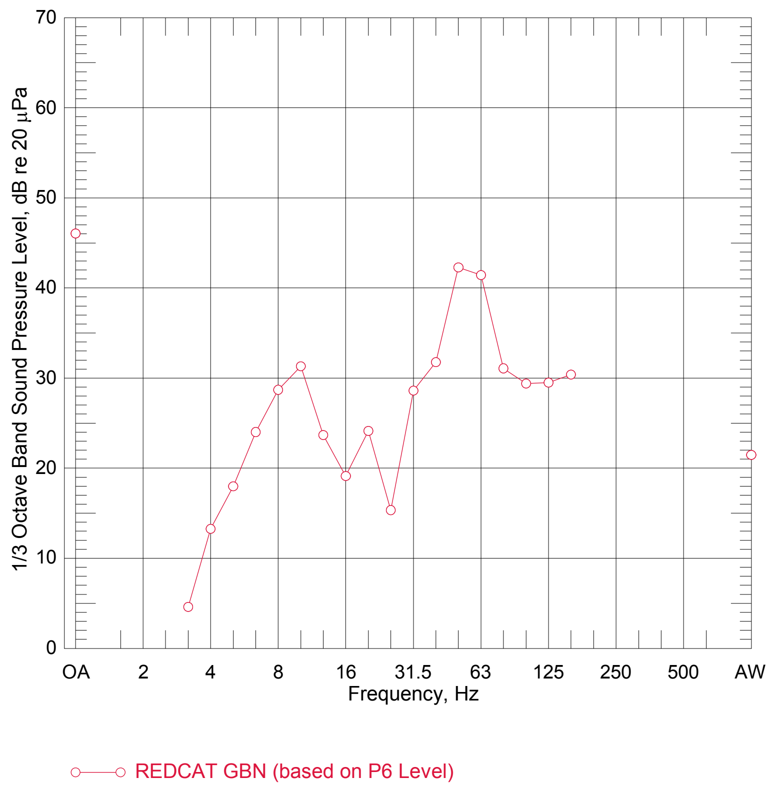


FIGURE 12 Predicted Groundborne Noise at WDCH - REDCAT

Figure 13 and Table 4 present the estimated results for the Choral Hall with the various mitigation options considered. As shown, the groundborne noise in the Choral Hall would be less than the 30 dBA criterion with several of these measures. Thus, for groundborne noise, the predicted result with mitigation measures such as a rail suspension system or an isolated slab track would comply with the applicable FTA criteria. The use of high compliance fasteners appears to be inadequate to mitigate the groundborne noise at the Choral Hall.

There would be occasions where two trains are in the tunnels (one westbound and the other eastbound). During these events, the vibration would increase by up to 3 VdB, and the groundborne noise would increase by up to 3 dBA. However, since such dual train passbys would typically occur *at this area* 70 times or fewer per day, higher criteria would apply for the institutional spaces within WDCH. For institutional buildings (office use), the FTA criteria for occasional events are 78 VdB and 43 dBA. Thus, there would be no net change in impact compared to the single train passby. For the Choral Hall, the criteria for occasional events are higher, but with mitigation the groundborne noise would be less than the 38 dBA criterion and there would be no impact for this condition. The Main Auditorium criteria remain unchanged regardless of the frequency of events. As shown in Figure 14 and Table 4, with any of the considered mitigation options, the increased levels from two trains in the tunnel comply with the criterion in the Main Auditorium.

The baseline sound and vibration measurements are noted in Table 2 below along with the FTA criteria[5] for operational groundborne vibration and noise.

Table 2 FTA Criteria and Baseline Conditions

Space	FTA Category	Criteria						Ambient	
		Groundborne Vibration			Groundborne Noise			Vibration	Noise
		Freq.	*Occas.*	*Infreq.*	*Freq.*	*Occas.*	*Infreq.*		
REDCAT	Special Buildings (Theaters)	72 VdB	80 VdB		35 dBA	43 dBA		50 VdB	28 dBA (1) NC 19
WDCH Main Auditorium (Room 2002)	Special Building (Concert Halls and recording Studios)	65 VdB			25 dBA			46 VdB	26 dBA NC 18
WDCH Orchestra Pit (Room 1001)	Separated from performing space by stage floor							45 VdB	**
WDCH Sound Lock, Level 1 (Room 1003)	Apply Calculation to other Level 1 spaces, Category 3	75 VdB	78 VdB	83 VdB	40 dBA	43 dBA	48 dBA	35 VdB	**
WDCH Choral Hall (Room 2154)	Special Building (Auditoriums)	72 VdB	80 VdB		30 dBA	38 dBA		44 VdB	30 dBA (2) NC 26
WDCH/LAPA Conference room 2nd Floor (Room 2145)	3: Institutional	75 VdB	78 VdB	83 VdB	40 dBA	43 dBA	48 dBA	52 VdB	27 dBA NC 18
WDCH/LAPA Conference Room 3rd Floor (Room 3060)	3: Institutional	75 VdB	78 VdB	83 VdB	40 dBA	43 dBA	48 dBA	52 VdB	**
Board of Directors Office (Room 2144)	3: Institutional	75 VdB	78 VdB	83 VdB	40 dBA	43 dBA	48 dBA	**	27 dBA NC 18

Notes:
1. Measured in March 2011
2. HVAC appears to be on.

** not measured

[5] FTA criteria were cited in the Draft EIS/EIR. Concert halls and theaters are generally designed to meet Noise Criteria (NC) curves, and the baseline measured levels are indicated in this memo.

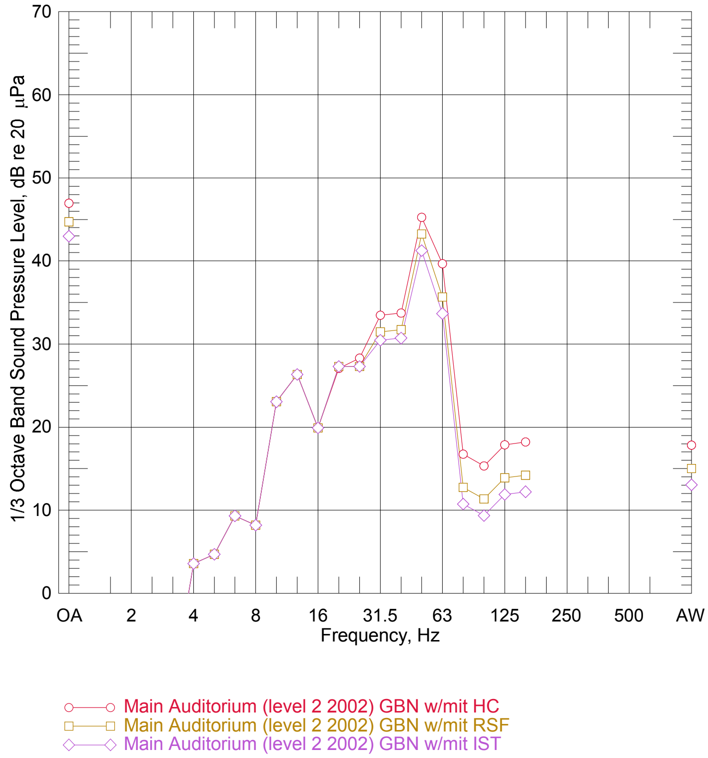


FIGURE 13 Predicted Groundborne Noise at WDCH – Main Auditorium With Mitigation Options

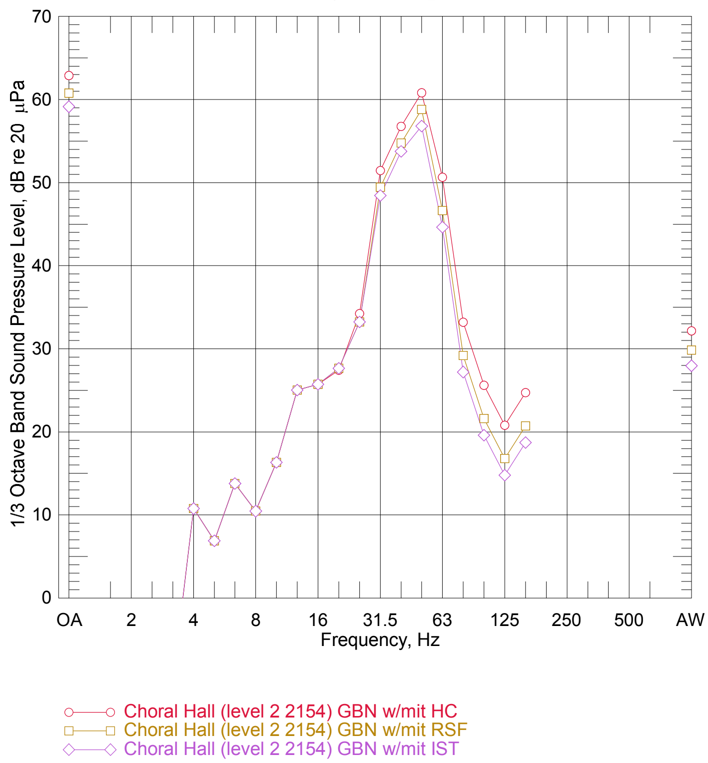


FIGURE 14 Predicted Groundborne Noise at WDCH – Choral Hall with Mitigation Options

Tables 3 and 4 summarize the updated effects from operations and the effectiveness of different measures to mitigate these effects below significance.

Table 3 Operational Effects from LA Metro Regional Connector Project – No Mitigation

Space	Criteria				Single 3-car Train (Frequent)		Two 3-car Trains (Occasional or Infrequent)		Impact?
	Groundborne Vibration		Groundborne Noise						
	Freq.	*Occas./ Infreq.*	*Freq.*	*Occas./ Infreq.*	Vibration	Noise	Vibration	Noise	
REDCAT	72 VdB	80 VdB	35 dBA	43 dBA	39 VdB	22 dBA	42 VdB	25 dBA	No
WDCH Main Auditorium (Room 2002)	65 VdB		25 dBA		45 VdB	23 dBA	48 VdB	**26** dBA	Yes: Two trains
WDCH Orchestra Pit (Room 1001)					43 VdB	21 dBA	46 VdB	24 dBA	No
WDCH Sound Lock, Level 1 (Room 1003)	75 VdB	78/ 83 VdB	40 dBA	43/48 dBA	41 VdB	21 dBA	44 VdB	24 dBA	No
WDCH Choral Hall (Room 2154)	72 VdB	80 VdB	30 dBA	38 dBA	60 VdB	**37** dBA	63 VdB	**40** dBA	Yes: One and Two trains
WDCH/LAPA Conference room 2nd Floor (Room 2145)	75 VdB	78/ 83 VdB	40 dBA	43/48 dBA	57 VdB	37 dBA	60 VdB	40 dBA	No
WDCH/LAPA Conference Room 3rd Floor (Room 3060)	75 VdB	78/ 83 VdB	40 dBA	43/48 dBA	55 VdB	33 dBA	58 VdB	36 dBA	No
Bold entries exceed criteria									

Table 4 Operational Effects from LA Metro Regional Connector Project – Groundborne Noise with Mitigation for Affected Spaces

Space	Groundborne Noise Criteria		Groundborne Noise without Mitigation		Mitigation Options Considered	Groundborne Noise with Mitigation (dBA)		Impact after Mitigation?
	Freq.	*Occas./ Infreq.*	Single Train	Two Trains		Single Train	Two Trains	
WDCH Main Auditorium (Room 2002)	25 dBA		23 dBA	**26** dBA	HC RSF IST	18 15 13	21 18 16	No: all mitigation options would be effective
WDCH Choral Hall (Room 2154)	30 dBA	38 dBA	**37** dBA	**40** dBA	HC RSF IST	**32** 30 28	35 33 31	No: Only RSF and IST options would be effective

Notes:
Bold entries exceed criteria
HC: High Compliance Fasteners (e.g., Cologne Egg or High Attenuation LVT)
RSF: Resiliently Supported Fasteners
IST: Isolated Slab Track

Construction Impacts

Building damage criteria and impacts were previously discussed in the 7 April 2011 memorandum where the potential for building damage impacts from cut and cover activities were indicated.

The FTA also provides criteria for short-term impacts (or annoyance) during construction, with the criteria equivalent to the same criteria provided for operational groundborne vibration and noise discussed above.

For tunneling vibration, the EIS/EIR indicates that tunnel boring machines (TBM) can generate vibration as high as 0.055 in/sec peak particle velocity (PPV) at a distance of 33 feet from the TBM source. Since the alignment refinements have not brought the alignment closer than 40 feet to historic resources, no new construction vibration impacts are expected due to the change in tunnel depth. No new mitigation measures would be required.

Thus, TBM vibration of 0.018 in/sec PPV at 70 ft[6] would result in an RMS vibration level of approximately 73 VdB at the lowest parking level. The corresponding groundborne noise could be on the order of 40 to 53 dBA. Taking into account building isolation and losses through the parking structure, the short-duration noise and vibration from TBM at Walt Disney Concert Hall and at the REDCAT, are indicated in Table 5 and would potentially exceed the criteria for groundborne noise at the Main Auditorium during performances and recording sessions and at the LAPA conference room on the 2nd floor (Room 2145). It is possible that some of the other 2nd floor LAPA office spaces would experience the same effects as Room 2145. The duration of impact would be on the order of 10 days assuming 35 ft per day progress.

Groundborne noise and vibration would also be generated by delivery trains in the tunnel during construction assuming delivery trains are the method selected to move soil from tunnel to surface. These slow moving trains have greater groundborne noise and vibration effects than the trains used for operations due to the presence of wheel flats or jointed construction rails, and even with a correction for the slower tunnel train speed (5 to 10 mph) it is estimated that the vibration would be on the order of 0 to 5 dB greater than that generated by the LA Metro operations. Thus, at WDCH Main Auditorium this would result in groundborne vibration on the order of 50 VdB and groundborne noise of 23 to 28 dBA, potentially exceeding the groundborne noise criterion. At the Choral Hall the tunnel train would generate groundborne noise of 37 to 42 dBA, which potentially exceeds the groundborne noise criterion. Groundborne vibration from the tunnel train would comply with criteria.

Table 5 summarizes the short-term effects from construction, and Table 6 indicates the anticipated effects of mitigation on the potential impacts at the Main Auditorium and the Choral Hall.

The following mitigation measures were considered for construction impacts:

- Tunnel Boring Machine
    - Maintenance and Operation: minimize vibration from jacking or pressing operations (if applicable, perhaps the action could smoothed out to avoid a sharp push), and maintain machinery in good working order.
    - Coordination and Notification: There would be times when the Main Auditorium is vacant or not used for a noise-sensitive activity, thereby eliminating any noise impact from TBM. Similarly, there would be times at the LAPA Conference Room (and offices) when activities are not particularly noise sensitive. Close coordination with the WDCH would ensure that the noise-generating parts of TBM operations would be conducted to avoid noise sensitive periods.

---

[6] Scaled for distance as $PPV(distance) = PPVref(ref\_dist/dist)^{1.5}$, per FTA Guidance Manual

- Tunnel Train
  - Speed: Limiting the speed of the tunnel train to 5 mph in the vicinity of the WDCH would reduce the groundborne noise to the lower range, or 5 dBA from the maximum range.
  - Resilient Mat: A resilient system to support and fasten the tunnel train tracks would reduce the groundborne noise at least 4 dBA. Such as system would include a) resilient mat under the tracks and b) a resilient grommet or bushing under the heads of any track fasteners (assuming some kind of anchor or bolt system). The hardness of the resilient mat should be in the 40 to 50 durometer range, and be about 1 to 2" thick, depending on how heavily loaded the cars would be. The contractor would need to select the mat thickness so that the rail doesn't bottom out during a car passby.
  - Conveyor: The tunnel train could be replaced with a conveyor system to transport materials in the tunnel.
  - Coordination and Notification: There would be times when the Main Auditorium and Choral Hall are vacant or not used for noise-sensitive activities, thereby eliminating any noise impact from the tunnel train. Close coordination with the WDCH would ensure that the tunnel train passbys would be conducted to avoid noise sensitive periods.

Table 5 Construction Short-Term (Annoyance) Effects – No Mitigation

Space	Criteria (Occasional)		TBM		Tunnel Train		Impact?
	Vibration	Noise	Vibration	Noise	Vibration	Noise	
REDCAT	80 VdB	43 dBA	53 VdB	18 to 33 dBA	44 VdB	21 to 26 dBA	No
WDCH Main Auditorium (Room 2002)	65 VdB	25 dBA	53 VdB	18 to **33 dBA**	50 VdB	23 to **28 dBA**	Yes, groundborne noise
WDCH Orchestra Pit (Room 1001)	**	**	53 VdB	18 to 33 dBA	48 VdB	21 to 26 dBA	No
WDCH Sound Lock, Level 1 (Room 1003)	78 VdB	43 dBA	53 VdB	18 to 33 dBA	46 VdB	20 to 25 dBA	No
WDCH Choral Hall (Room 2154)	80 VdB	38 dBA	58 VdB	23 to 38 dBA	65 VdB	37 to **42 dBA**	Yes, tunnel train groundborne noise
WDCH/LAPA Conference room 2nd Floor (Room 2145)	78 VdB	43 dBA	68 VdB	33 to **48** dBA	62 VdB	37 to 42 dBA	Yes, TBM groundborne noise
WDCH/LAPA Conference Room 3rd Floor (Room 3060)	78 VdB	43 dBA	53 VdB	18 to 33 dBA	60 VdB	33 to 38 dBA	No
Bold entries exceed criteria							

Table 6 Construction Short-Term (Annoyance) Effects – Groundborne Noise with Mitigation for Affected Spaces

Space	Groundborne Noise Criteria (Occasional)	Groundborne Noise without Mitigation (dBA)		Mitigation Options Considered	Groundborne Noise with Mitigation (dBA)		Impact after Mitigation?
		TBM	Tunnel Train		TBM	Tunnel Train	
WDCH Main Auditorium (Room 2002)	25 dBA	18 to **33**	23 to **28**	Speed Mat Conveyor Maint Coord	n/a n/a n/a 18 to **33** 18 to **33**	23 19 to 24 <25 n/a 23 to **28**	No, LA Metro will use one or more of the mitigation options to meet FTA criteria
WDCH Choral Hall (Room 2154)	38 dBA	23 to 38	37 to **42**	Speed Mat Conveyor Maint Coord	Not req.	37 33 to 38 <38 n/a 37 to **42**	No, LA Metro will use one or more of the mitigation options to meet FTA criteria
WDCH/LAPA Conference room 2nd Floor (Room 2145)	43 dBA	33 to **48**	37 to 42	Speed Mat Conveyor Maint Coord	n/a n/a n/a 33 to **48** 33 to **48**	Not req.	No, LA Metro will use one or more of the mitigation options to meet FTA criteria

Notes:
Bold entries exceed criteria
Speed: Speed reduction – near 5 mph near WDCH
Mat: Resilient mat – 40 to 50 durometer hardness, 1 to 2" thick with resilient grommet or bushing under the track fastener heads (assuming an anchor or bolt fastening system)
Conveyor: Use conveyor instead of tunnel train to transport materials through the tunnel
Maint: Maintenance and operation of the equipment to minimize vibration. TBM: minimize vibration from jacking or pressing operations, and maintain machinery in good working order.
Coord: Coordination with WDCH to conduct these construction activities around noise sensitive activities in the affected spaces; the groundborne noise level would not be lessened, but there would be no sensitive activity to impact

APPENDICES

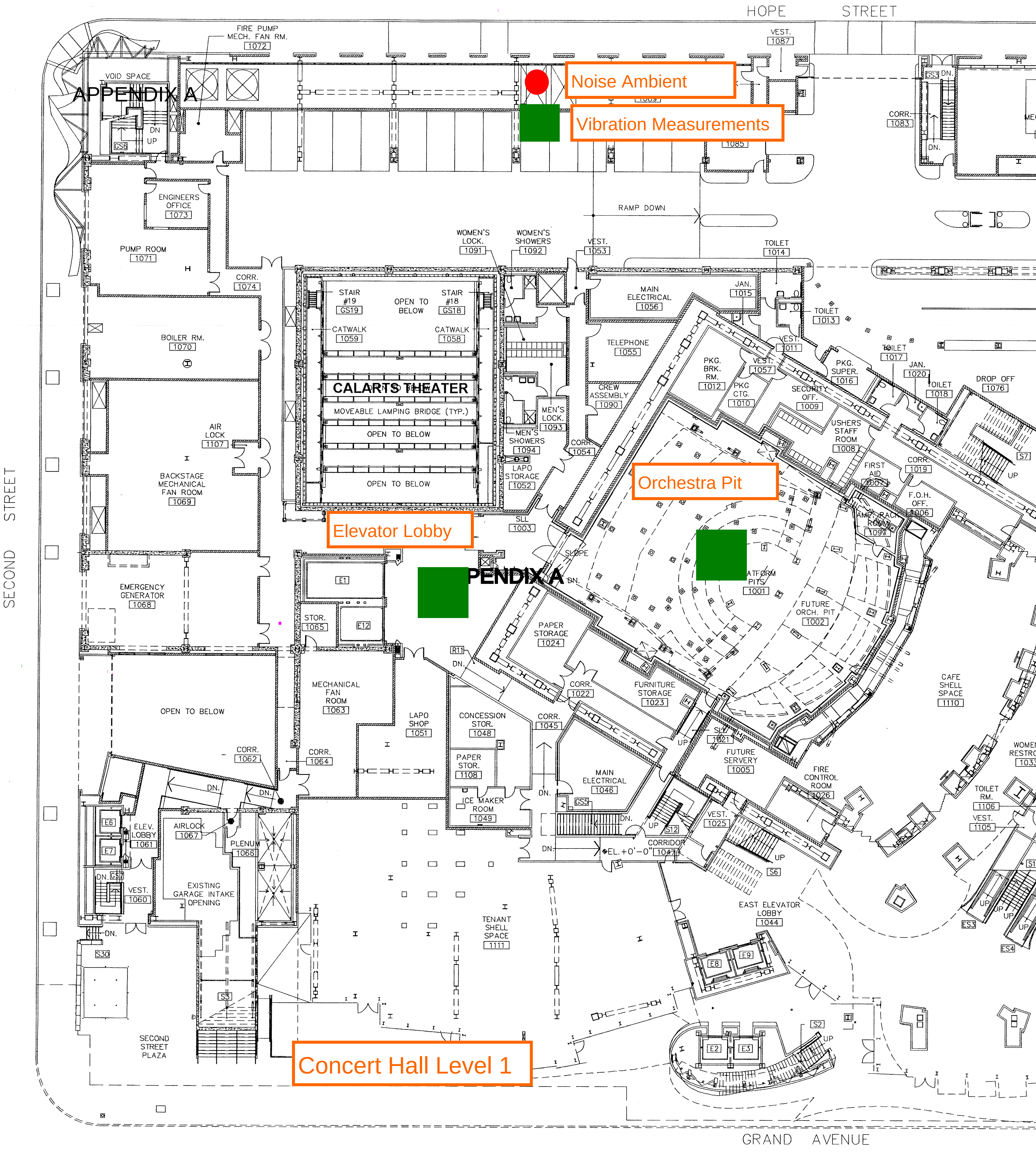
A. Field setup WDCH and parking garage (PDF)

B. Plan and Profile Drawings (marked up from June 29 Draft Submittal, Drawing T104)

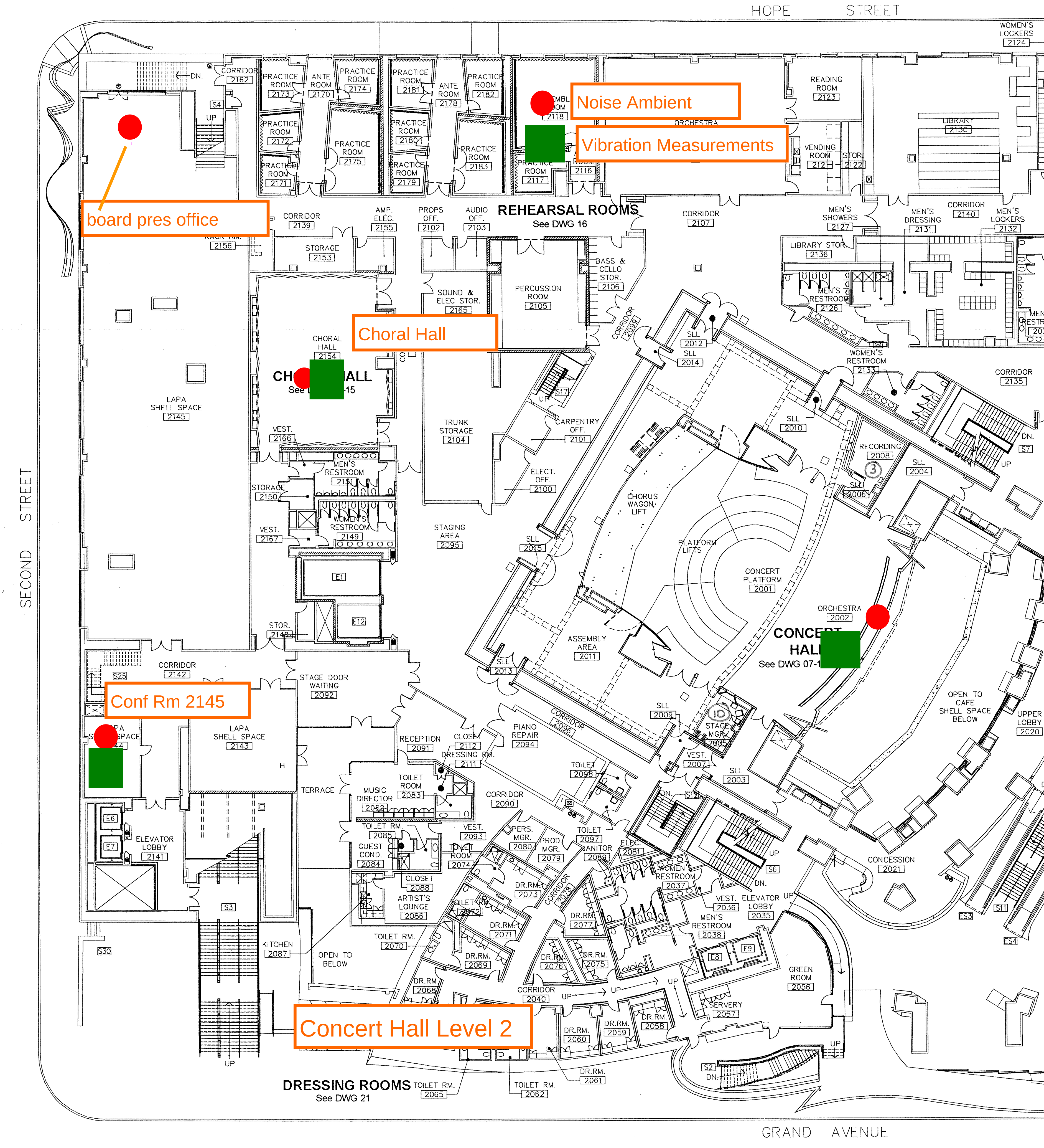
C. Ambient measurement results

D. Building response data ranges

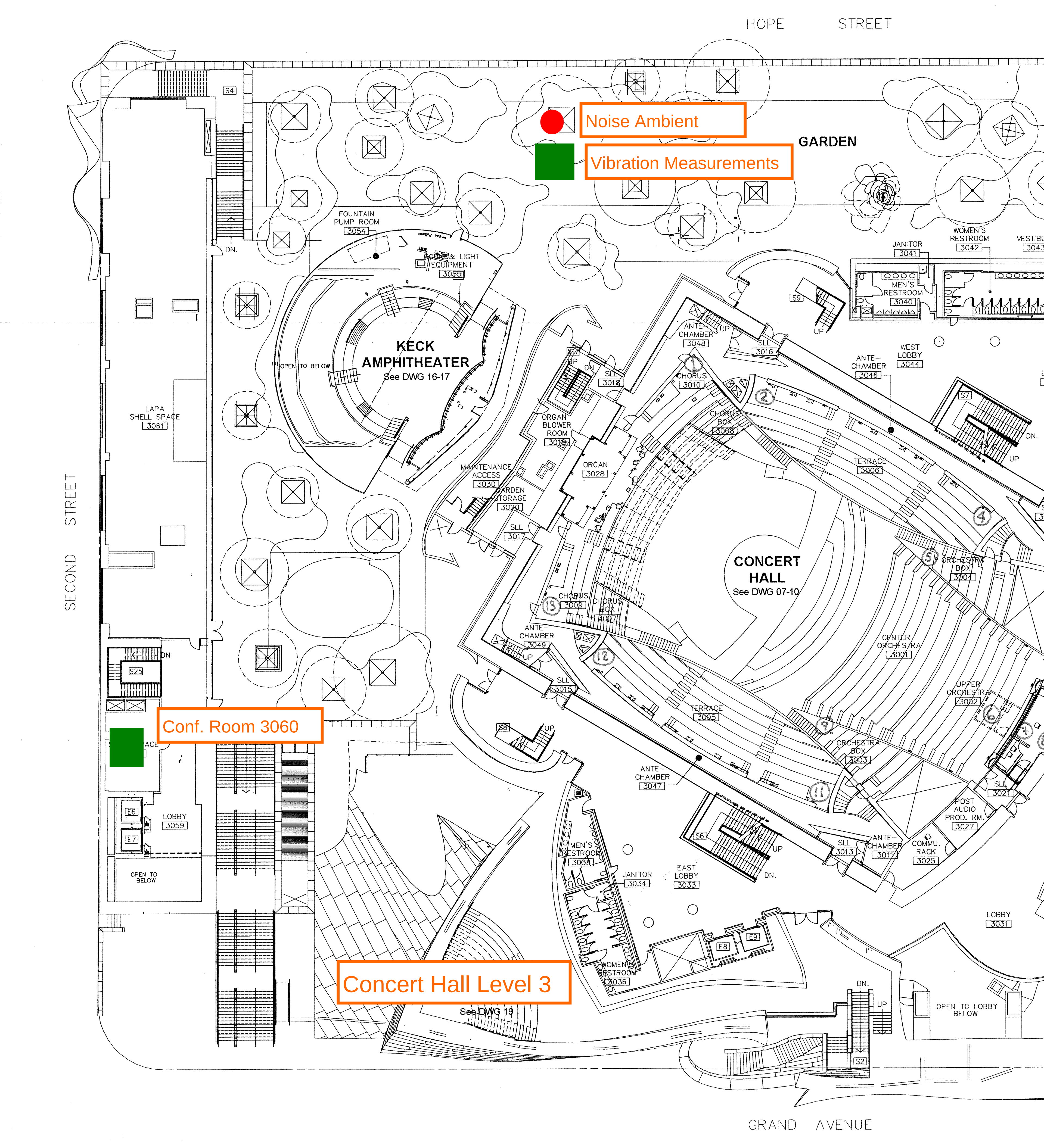
E. Compare TM with previous



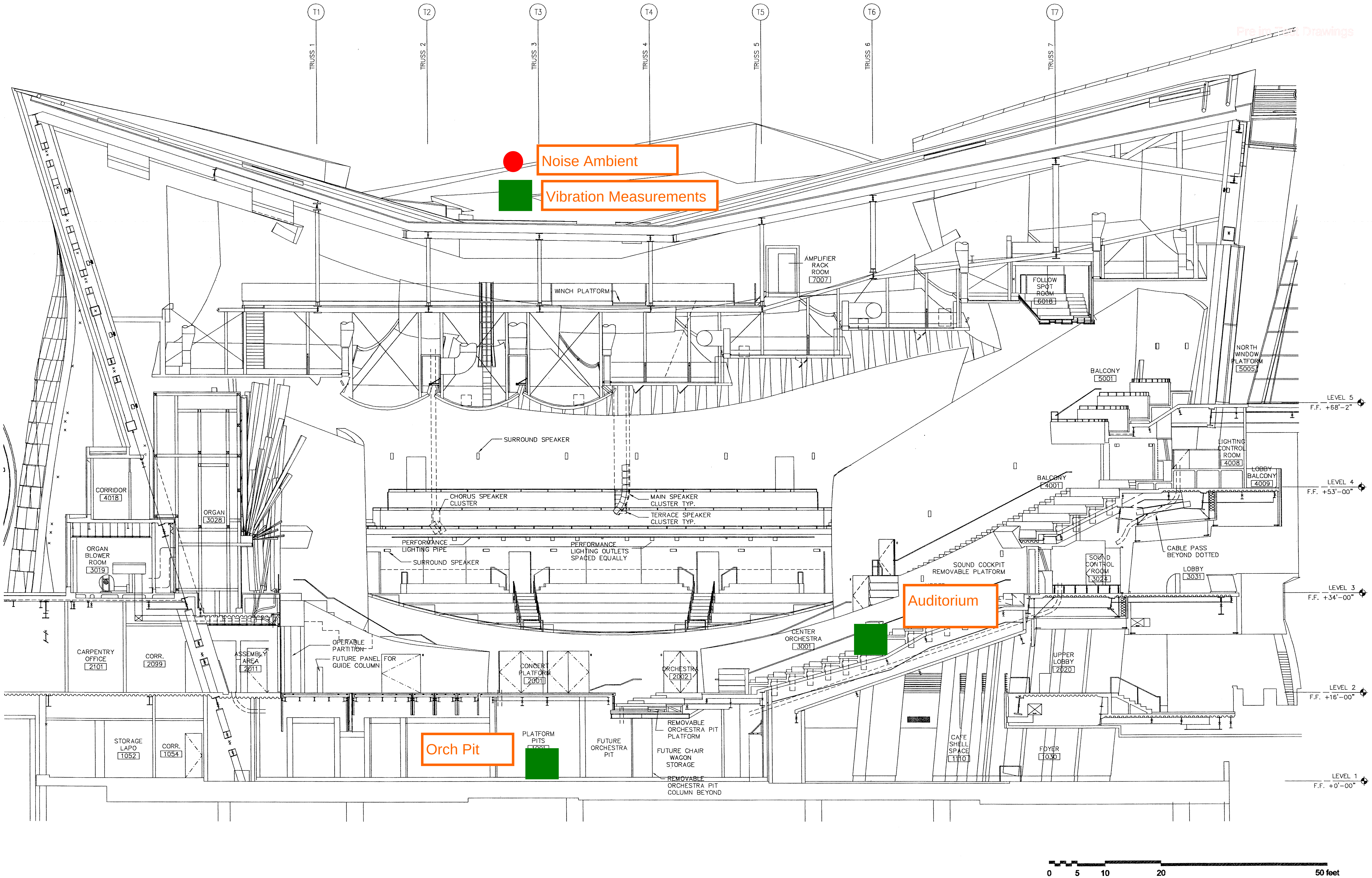
APPENDIX A
Noise Ambient
Vibration Measurements
Orchestra Pit
Elevator Lobby
Concert Hall Level 1
CALARTS THEATER
HOPE STREET
SECOND STREET
GRAND AVENUE
FIRE PUMP MECH. FAN RM. 1072
VOID SPACE
VEST. 1087
CORR. 1083
ENGINEERS OFFICE 1073
PUMP ROOM 1071
CORR. 1074
RAMP DOWN
WOMEN'S LOCK. 1091
WOMEN'S SHOWERS 1092
VEST. 1053
TOILET 1014
STAIR #19 GS19
OPEN TO BELOW
STAIR #18 GS18
CATWALK 1059
CATWALK 1058
MOVEABLE LAMPING BRIDGE (TYP.)
MAIN ELECTRICAL 1056
JAN. 1015
TOILET 1013
BOILER RM. 1070
TELEPHONE 1055
VEST. 1011
TOILET 1017
PKG. BRK. RM. 1012
VEST. 1057
PKG. SUPER. 1016
JAN. 1020
TOILET 1018
DROP OFF 1076
PKG CTG. 1010
SECURITY OFF. 1009
CREW ASSEMBLY 1090
AIR LOCK 1107
MEN'S LOCK. 1093
MEN'S SHOWERS 1094
CORR. 1054
USHERS STAFF ROOM 1008
FIRST AID 1007
CORR. 1019
BACKSTAGE MECHANICAL FAN ROOM 1069
LAPO STORAGE 1052
F.O.H. OFF. 1006
AMP. RACK ROOM 1109
SLL 1003
SLOPE
PLATFORM PITS 1001
EMERGENCY GENERATOR 1068
E1
STOR. 1065
E12
FUTURE ORCH. PIT 1002
PAPER STORAGE 1024
R11
DN.
OPEN TO BELOW
MECHANICAL FAN ROOM 1063
LAPO SHOP 1051
CONCESSION STOR. 1048
CORR. 1022
FURNITURE STORAGE 1023
CORR. 1045
CAFE SHELL SPACE 1110
CORR. 1062
CORR. 1064
PAPER STOR. 1108
SLL 1021
FUTURE SERVERY 1005
MAIN ELECTRICAL 1046
FIRE CONTROL ROOM 1026
TOILET RM. 1106
VEST. 1105
ICE MAKER ROOM 1049
ELEV. LOBBY 1061
AIRLOCK 1067
PLENUM 1066
GS5
VEST. 1025
S12
CORRIDOR 1047
EL. +0'-0"
S6
VEST. 1060
EXISTING GARAGE INTAKE OPENING
EAST ELEVATOR LOBBY 1044
TENANT SHELL SPACE 1111
S30
S3
E8
E9
ES3
ES4
S2
E2
E3
SECOND STREET PLAZA



HOPE STREET
GRAND AVENUE
SECOND STREET
Noise Ambient
Vibration Measurements
board pres office
Choral Hall
Conf Rm 2145
Concert Hall Level 2
REHEARSAL ROOMS
See DWG 16
CHORAL HALL
2154
LAPA SHELL SPACE
2145
PERCUSSION ROOM
2105
TRUNK STORAGE
2104
STAGING AREA
2095
CONCERT PLATFORM
2001
ORCHESTRA
2002
ASSEMBLY AREA
2011
CHORUS WAGON LIFT
PLATFORM LIFTS
RECORDING
2008
LIBRARY
2130
READING ROOM
2123
STAGE DOOR WAITING
2092
LAPA SHELL SPACE
2143
ELEVATOR LOBBY
2141
TERRACE
KITCHEN
2087
OPEN TO BELOW
GREEN ROOM
2056
CONCESSION
2021
OPEN TO CAFE SHELL SPACE BELOW
UPPER LOBBY
2020
DRESSING ROOMS
See DWG 21



HOPE STREET
SECOND STREET
GRAND AVENUE
Noise Ambient
Vibration Measurements
GARDEN
Conf. Room 3060
Concert Hall Level 3
KECK AMPHITHEATER
See DWG 16-17
CONCERT HALL
See DWG 07-10
See DWG 19
LAPA SHELL SPACE 3061
FOUNTAIN PUMP ROOM 3054
SOUND & LIGHT EQUIPMENT 3055
OPEN TO BELOW
MAINTENANCE ACCESS 3030
GARDEN STORAGE 3029
SLL 3017
ORGAN BLOWER ROOM 3019
ORGAN 3028
SLL 3018
ANTE-CHAMBER 3048
SLL 3016
CHORUS 3010
CHORUS BOX 3008
CHORUS 3009
CHORUS BOX 3007
ANTE-CHAMBER 3049
SLL 3015
TERRACE 3005
TERRACE 3006
ANTE-CHAMBER 3046
WEST LOBBY 3044
JANITOR 3041
WOMEN'S RESTROOM 3042
VESTIBU 3043
MEN'S RESTROOM 3040
ORCHESTRA BOX 3004
CENTER ORCHESTRA 3001
UPPER ORCHESTRA 3002
ORCHESTRA BOX 3003
ANTE-CHAMBER 3047
MEN'S RESTROOM 3038
JANITOR 3034
EAST LOBBY 3033
WOMEN'S RESTROOM 3036
SLL 3013
ANTE-CHAMBER 3011
COMMU. RACK 3025
POST AUDIO PROD. RM. 3027
SLL 3021
LOBBY 3031
LOBBY 3059
OPEN TO BELOW
OPEN TO LOBBY BELOW
S2
S4
S6
S7
S8
S9
S17
S25
E6
E7
E8
E9
UP
DN.

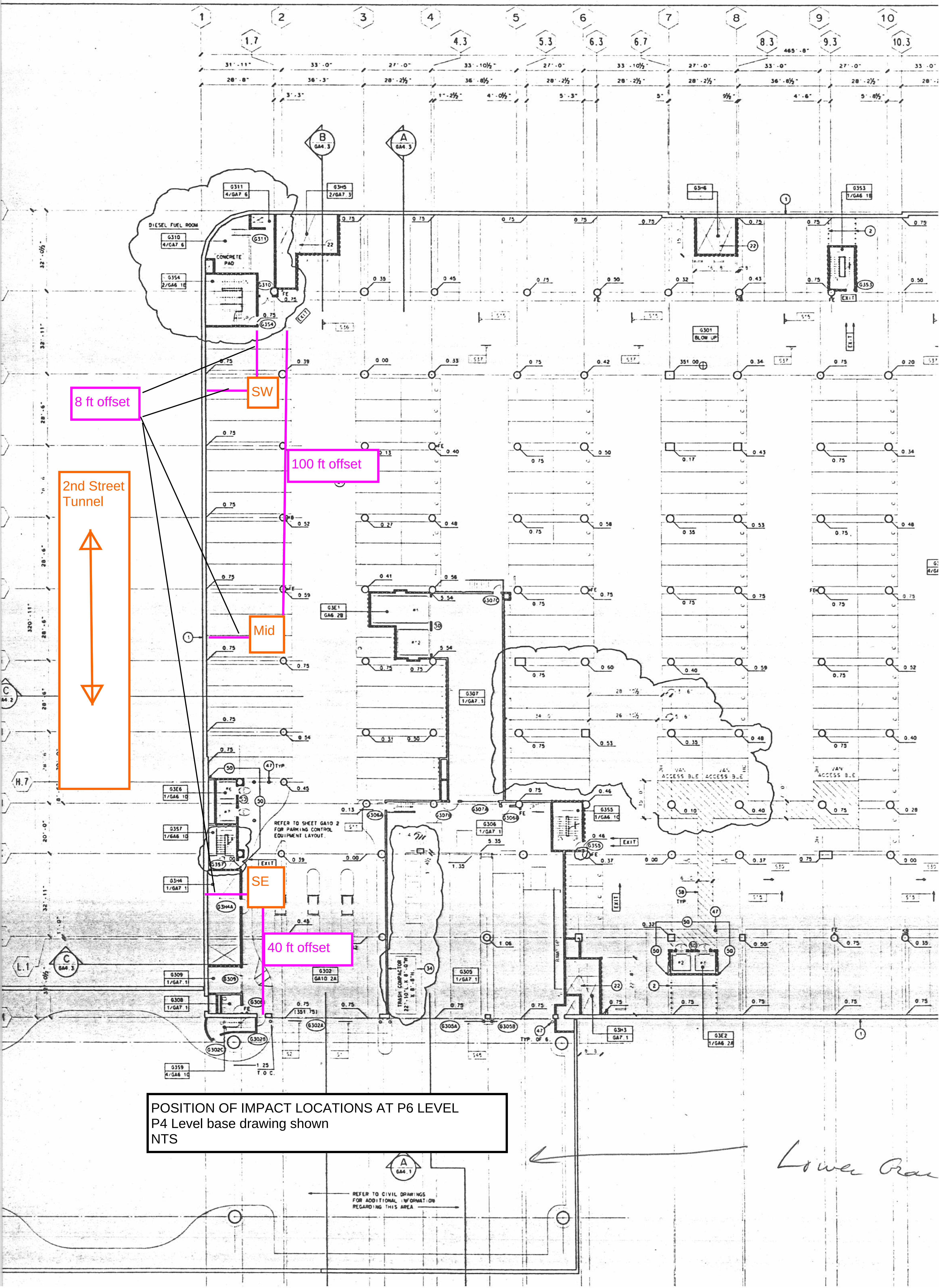


Page: DWG 09

Scale: 1/16" = 1'-0"

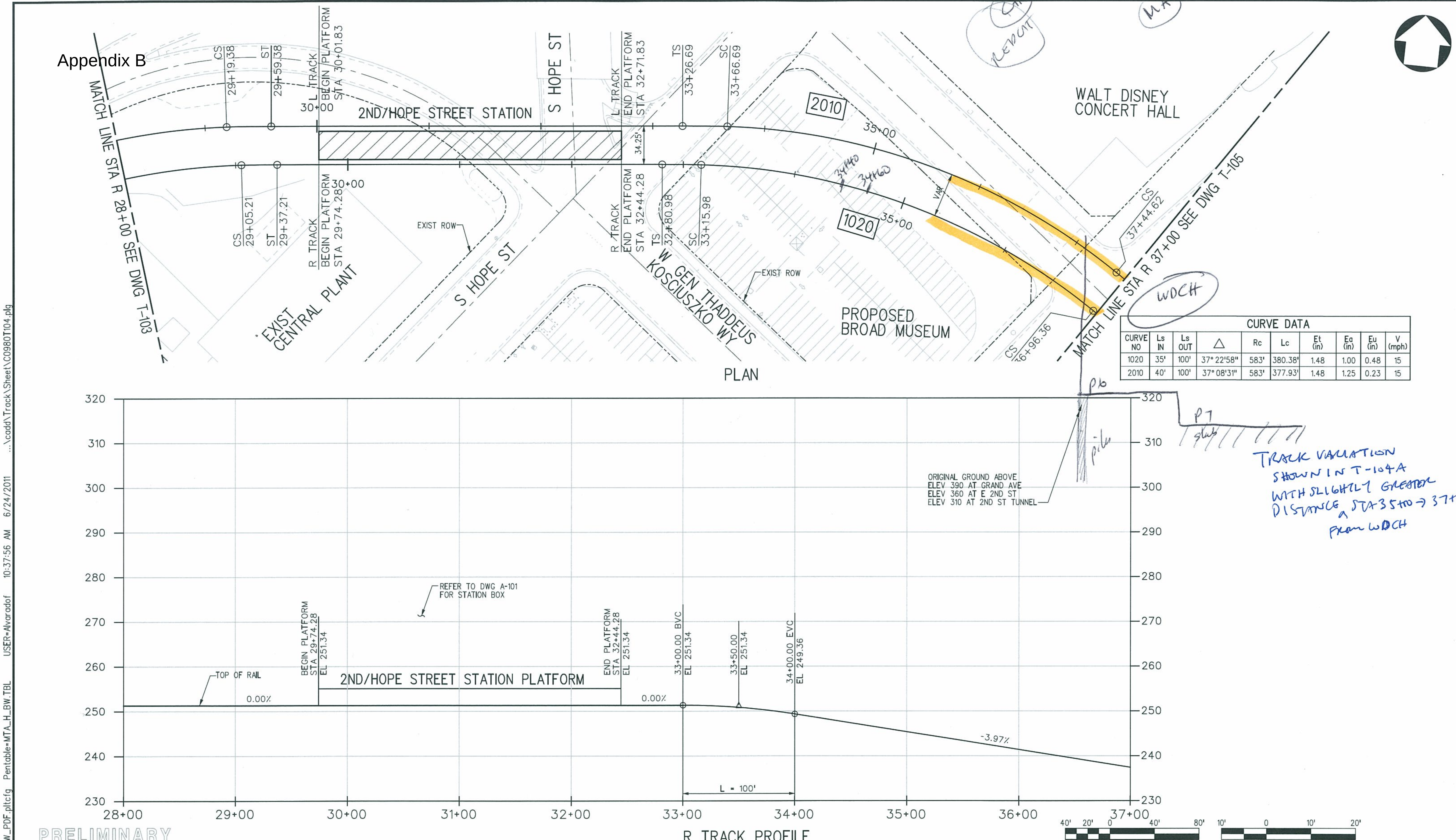
Concert Hall ▪ CL Section

WALT DISNEY CONCERT HALL



POSITION OF IMPACT LOCATIONS AT P6 LEVEL
P4 Level base drawing shown
NTS

Appendix B



CURVE DATA									
CURVE NO	Ls IN	Ls OUT	△	Rc	Lc	Et (in)	Ea (in)	Eu (in)	V (mph)
1020	35'	100'	37° 22'58"	583'	380.38'	1.48	1.00	0.48	15
2010	40'	100'	37° 08'31"	583'	377.93'	1.48	1.25	0.23	15

PRELIMINARY

THE PREPARATION OF THIS DRAWING HAS BEEN FINANCED BY THE TAXES OF THE CITIZENS OF LOS ANGELES COUNTY AND OF THE STATE OF CALIFORNIA.

REV | DATE | BY | APP | REG NO | EXPIRES | SEAL HOLDER | DESCRIPTION

DESIGNED BY J. SUSILO
DRAWN BY M. AL-MASHAT
CHECKED BY
IN CHARGE
DATE 06/29/2011

LOS ANGELES COUNTY METROPOLITAN TRANSPORTATION AUTHORITY

The Connector Partnership
777 S. FIGUEROA STREET 10TH FLOOR LOS ANGELES, CA 90017 T 213-312-3100 F 213-312-3114

SUBMITTED
APPROVED

REGIONAL CONNECTOR TRANSIT CORRIDOR
PRELIMINARY ENGINEERING
TRACK ALIGNMENT
PLAN AND PROFILE
STA R 28+00 TO STA R 37+00

CONTRACT NO C0980
DRAWING NO T-104
REV
SCALE HORZ: 1" = 40' VERT: 1" = 10'
SHEET NO

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APPENDIX C Ambient measurements

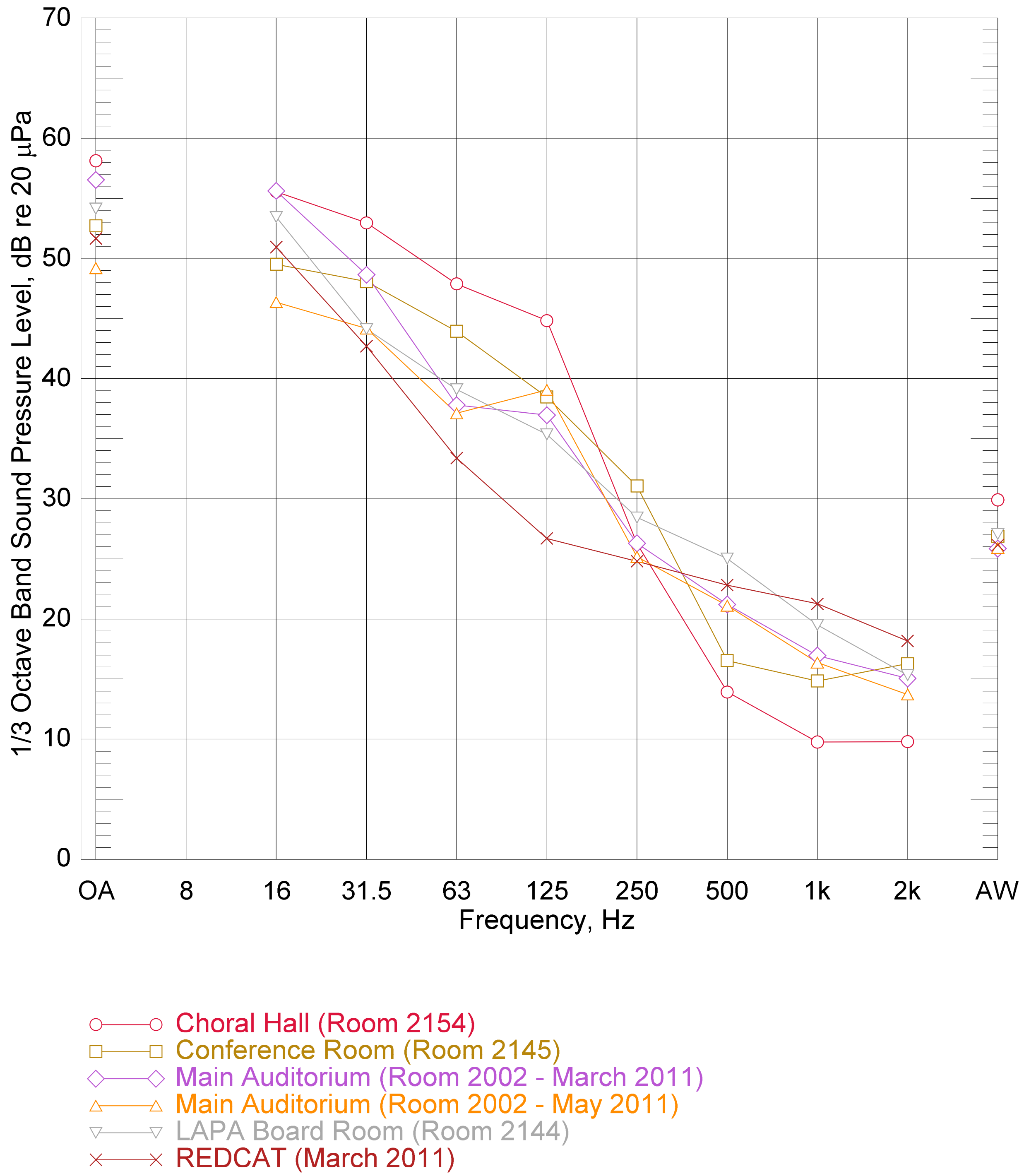


Figure C1 Ambient Noise Measurements – Octave Bands

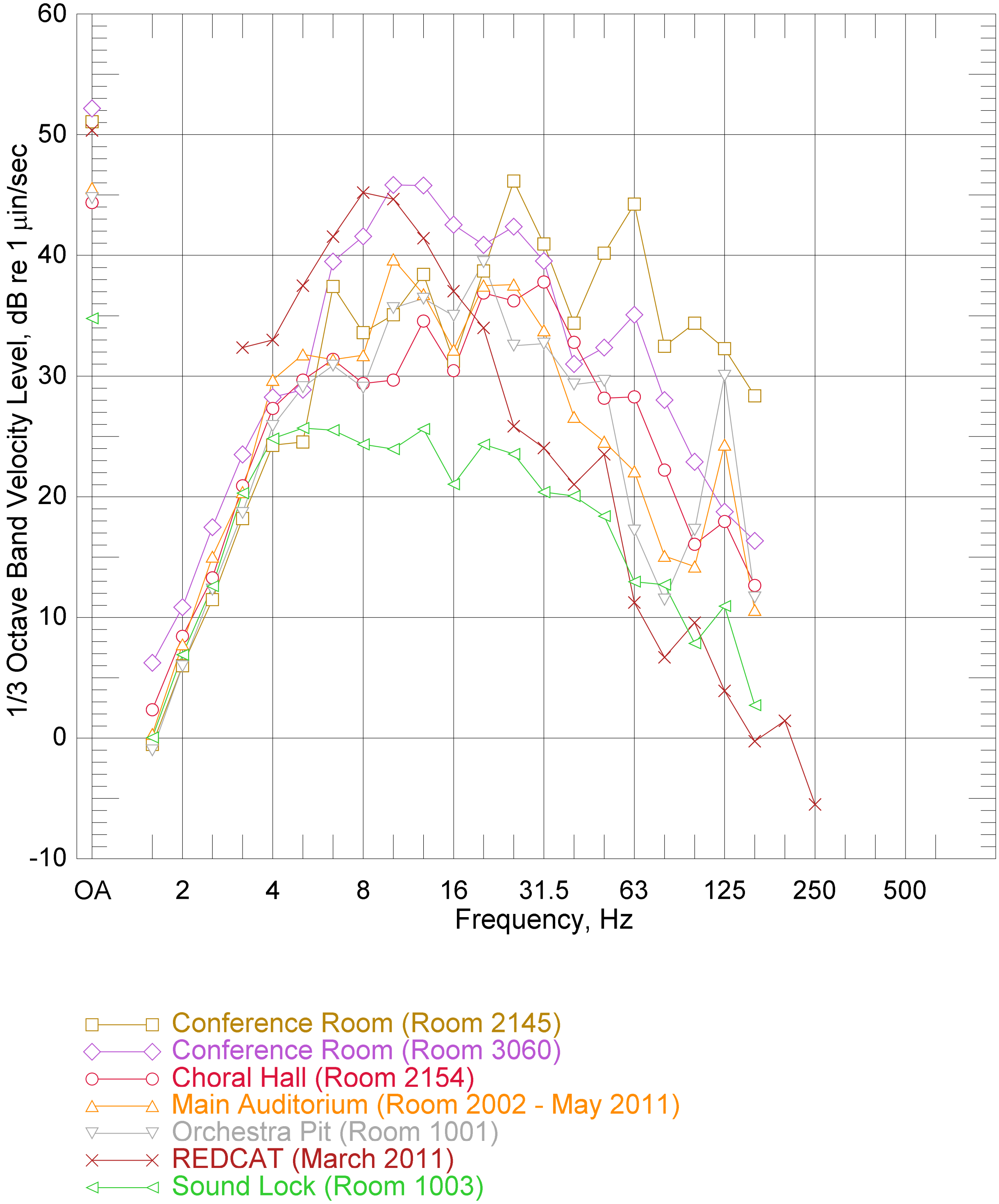
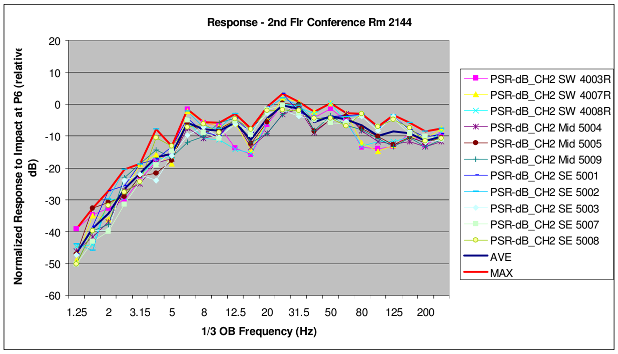
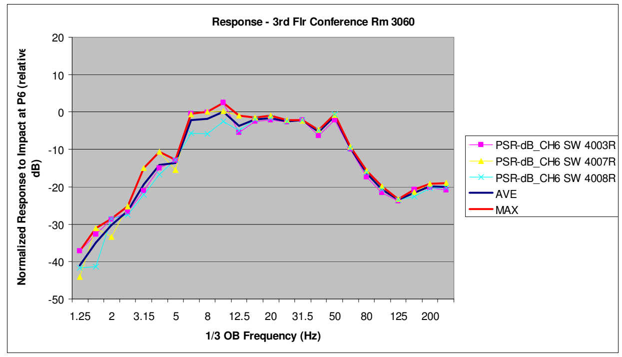
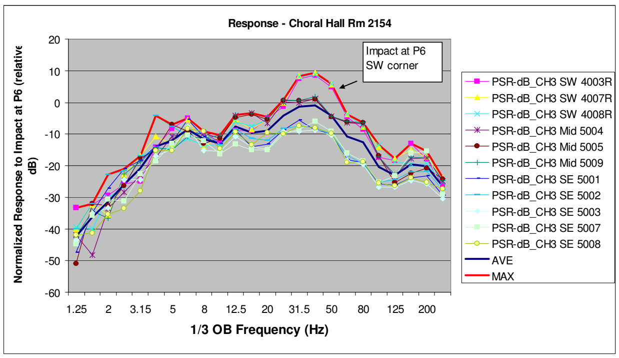


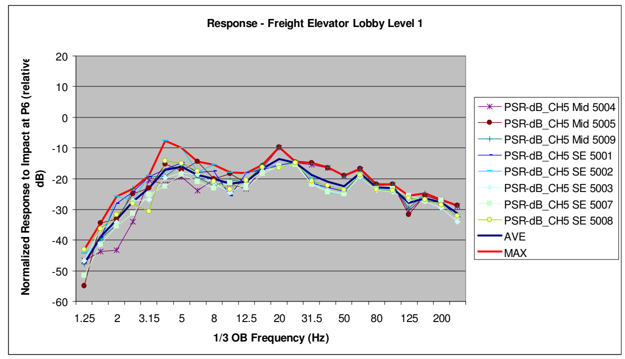
Figure C2 Ambient Vibration Measurements

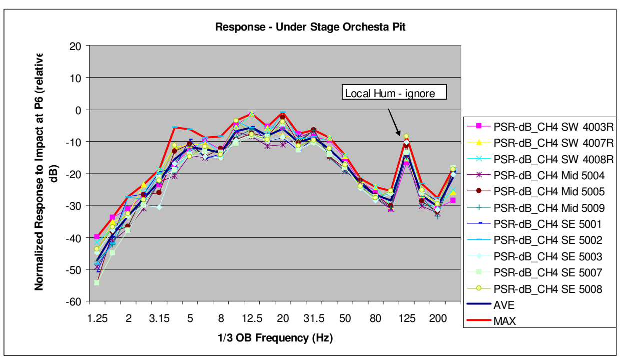
APPENDIX D Building Response Data











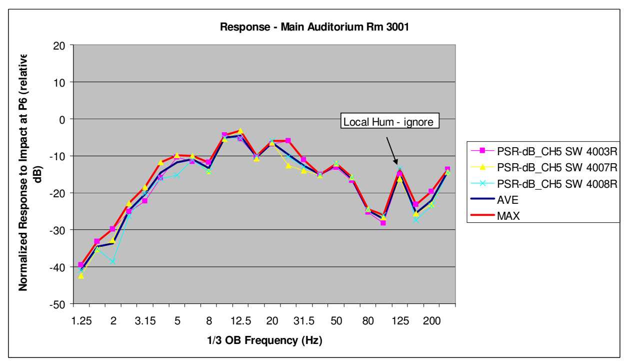
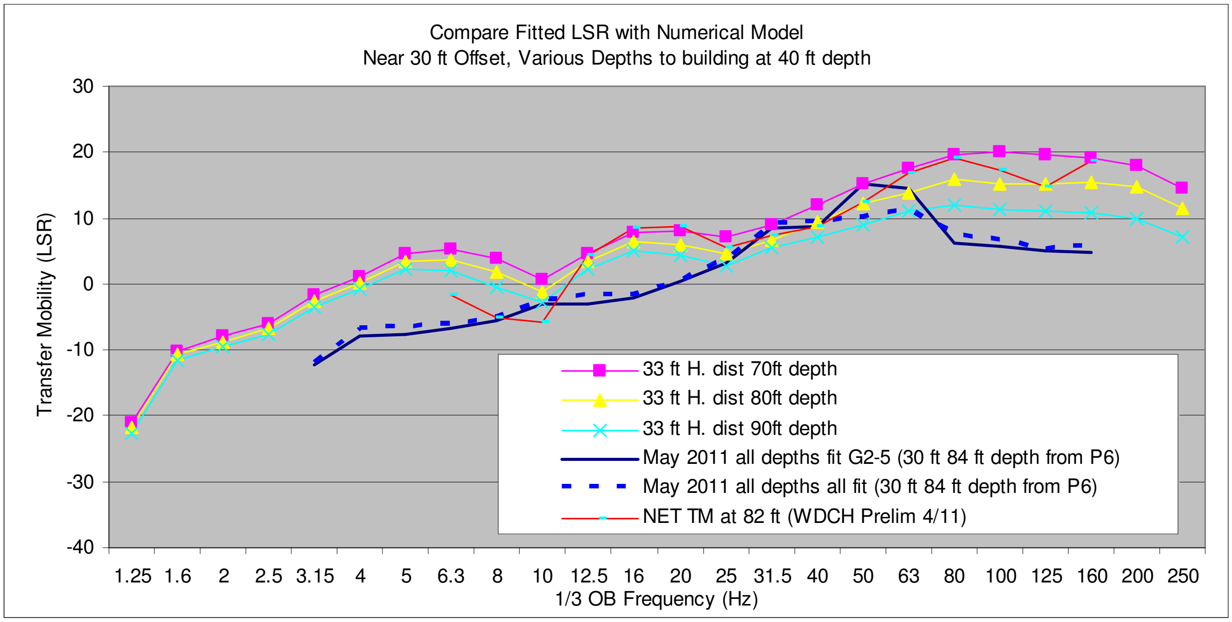
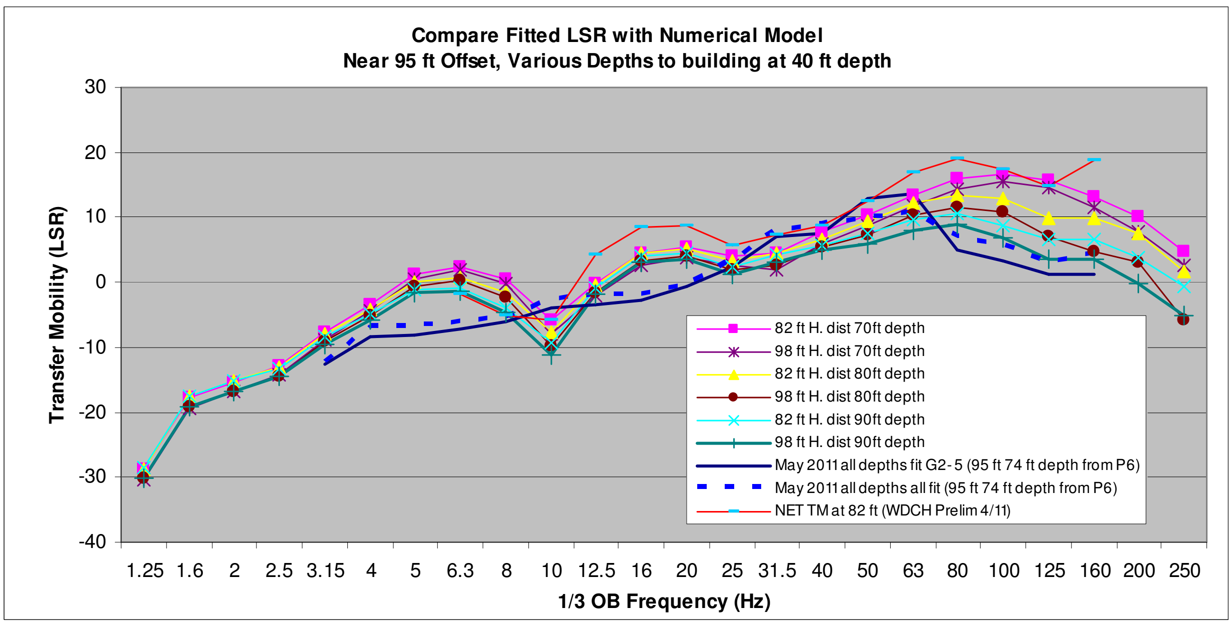


Figure D1 Building Response Data

APPENDIX E Compare TM with Previous





Compare TM (line source – LSR)

- Numerical Model at different horizontal offsets and depths. Numerical Model does not include effect of building coupling at P6.
- May 2011 field data
- NET adjusted TM used for previous WDCH analysis (FEIS April 2011)

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MEMORANDUM

DATE: 9 March 2011 revised 7 April 2011

TO: John Prizner, Connector Partnership

FROM: Deborah Jue, Richard Carman

SUBJECT: Noise and Vibration - Task 6.1.4.4 – Historic Resources
Construction and Operational Vibration Impact – Preliminary Results
WIA#10-088

This memorandum addresses our preliminary analysis for impacts on Historic Resources at areas where the current Advanced Conceptual Engineering (ACE) alignment differs from the Fully Underground LRT (FULRT) alignment evaluated for the Draft EIS/EIR. This revision clarifies the discussion regarding impacts.

Executive Summary

The ACE alignment has been refined in response to comments from the public and as a result of engineering studies to improve the FULRT alignment from an operational perspective. Only the refinement of the alignment between Broadway and 3rd Street has a potential effect on nearby affected historic resources. All other parts of the alignment have either not been refined or have been refined but there are no nearby historic resources. This memo summarizes the potential noise and vibration effect of raising the alignment between the Broadway Station and approximately 3rd Street (bored tunnel) on the nearby affected historic resources. This preliminary analysis includes results from recent sound and vibration measurements conducted at Walt Disney Concert Hall, and it indicates that analysis modifications in the areas of the proposed refinements would result in some new operational or construction impacts for one historic structure identified as:

- Walt Disney Concert Hall: Potential groundborne noise effects during operations and potential short-term groundborne vibration and noise impacts during construction.

The estimated building damage impacts are unchanged from the Draft EIS/EIR analysis.

Recommendations

In addition to the measures previously identified in the Draft EIS/EIR to reduce or eliminate the effect of impacts, the Final EIS/EIR should include the following mitigations to reduce the adverse impacts:

- Further evaluation during preliminary engineering to verify appropriate criteria for recording activities at Walt Disney Concert Hall
- Evaluation during preliminary engineering to verify prediction estimates

- If necessary, use high compliance resilient fasteners, floating slab trackbed or appropriate measures to reduce operational groundborne noise impact
- Provide advance notification for Walt Disney Concert Hall and the Roy and Edna Disney/CalArts Theater (REDCAT) regarding tunneling construction schedules.
- Monitor groundborne noise inside during construction.

Introduction

The ACE alignment has been refined in response to comments from the public and as a result of engineering studies to improve the FULRT alignment from an operational perspective.

The refinement with potential impacts to historic/cultural resources includes a change in depth of structures. The change in depth of structures between the Draft EIS/EIR plan (dated December 2009) and the current Final EIS/EIR plan and profile (dated February 28, 2011) is primarily due to raising of the alignment between the Broadway Station and approximately 3rd Street (bored tunnel). Below is a list of historic/cultural resources along the alignment and whether they are in close proximity to a refinement.

Building	FEIS/EIR compared to DEIS/DEIR	Location Relative to Tunnel
APE 2-1 Barker Brothers	No change	Adjacent to existing Blue Line tunnel
APE 2-7 Roosevelt Building	No change	Adjacent to existing Blue Line tunnel
APE 2-12 General Petroleum, Mobil Oil Building	No Change	Adjacent to existing Blue Line Tunnel
APE 2-13 Superior Oil Company Building	No Change	Adjacent to existing Blue Line Tunnel
APE 3-1 The California Club	No Change	Adjacent to new Regional Connector Tunnel
APE 3-2 Los Angeles Central Library	No Change	Adjacent to new Regional Connector Tunnel
APE 3-4 Belmont Tunnel, Hollywood-Glendale-Burbank-San Fernando Valley Tunnel	No Change	Removed during construction
APE 4-3 2nd Street Vehicle Tunnel	12.32 feet higher	Below running tunnel
APE 4-4 Walt Disney Concert Hall	12.32 feet higher	Adjacent to running tunnel
APE 7-19 Former Nishi Hongwanji Buddhist Temple	No change	Adjacent to portal
APE 7-30 S. Kamada Restaurant, Atomic Café, Señor Fish, and Coast Imports	No change	Above proposed station box to be removed during construction
APE 8-2 Los Angeles Times Building	0.4 feet higher	>100 feet from 2nd Street to North
APE 8-3 Mirror Building	0.4 feet higher	Adjacent to 2nd/Broadway Station
APE 8-11 Higgins Building	3.1 feet lower	Adjacent to running tunnel
APE 8-12 Cathedral of St. Vibiana	0.4 feet lower	Offset from 2nd Street, adjacent to running tunnel
APE 8-13 Cathedral of St. Vibiana, Rectory	0.6 feet higher	Adjacent to running tunnel

Thus, with the exception of the Walt Disney Concert Hall and the 2nd Street tunnel, qualitative analysis indicates no change in noise and vibration impact for the Final EIS/EIR compared to the Draft EIS/EIR because the tunnel structure would be slightly deeper (no change or less impact), or would be less than one foot above that in the Draft EIS/EIR (not significant at the typical structure depths).

Therefore the affected historic resources that are addressed in the remainder of this memo are:

- APE 4-3 2nd Street Vehicle Tunnel (Belmont Tunnel, Hollywood-Glendale-Burbank-San Fernando Valley Tunnel)
- APE 4-4 Walt Disney Concert Hall

Operational Impacts

No impacts would occur at the 2nd Street Tunnel due to project operations. Groundborne noise and vibration could effect Walt Disney Concert Hall and would be potentially adverse because either

a) any changes that could occur as a result of groundborne vibration or noise generated by the Project would alter a characteristic of a historic property in a manner that would diminish the integrity of the property's location, design, setting, materials, workmanship, feeling, or association, or
b) the potential changes generated by groundborne vibration and noise for this alternative would constitute a substantial adverse change that would impair the significance of this historical resource.

The baseline sound measurements conducted on 4 March 2011 are noted below along with the FTA criteria[1] for operational groundborne vibration and noise:

- Walt Disney Concert Hall – special building (concert halls and recording studios):
  - 65 VdB for groundborne vibration
  - 25 dBA for groundborne noise
  - Baseline sound levels of 24 to 28 dBA and NC 15 to 21 (with ventilation system on) – this condition is assumed to be acceptable for performances at the Concert Hall.
  - Baseline noise for conditions used during recording (i.e., ventilation system turned off) was not measured
- Roy and Edna Disney/CalArts Theater (REDCAT) – special building (theaters):
  - 72 VdB for groundborne vibration
  - 35 dBA for groundborne noise
  - Baseline sound levels of 26 dBA and NC 19 (with ventilation system on)

Using the FTA approved prediction model with project-specific parameters developed during the ACE analysis for the proposed Broad Museum (final ref. date TBD) and preliminary information regarding the building isolation provided at REDCAT, the groundborne vibration and noise estimates have been updated. To date, no vibration isolation measures have been identified for the Concert Hall, although several measures to isolate audible noise from the Hall have been installed based on anecdotal evidence such as resilient hangers to decouple the wall panels from the structure.

As shown in Table 1, the groundborne noise would potentially exceed the FTA criterion and the baseline conditions at the Concert Hall. The use of high compliance resilient fasteners, floating slab trackbed or other appropriate measures should be sufficient to mitigate this impact. More study should be done during preliminary engineering (PE) design to:

[1] FTA criteria were cited in the Draft EIS/EIR. Concert halls and theaters are generally designed to meet Noise Criteria (NC) curves, and the baseline measured levels are indicated in this memo.

- establish the groundborne noise criterion appropriate for when the Concert Hall is used to make professional recordings,
- determine vibration transmission characteristics from tunnel location and through the soil into Concert Hall
- measure the attenuation of vibration (i.e., losses) through the Concert Hall parking structure, and
- determine more accurately the level of groundborne noise impact.

Table 1 summarizes the updated effects and recommended measures to mitigate these effects below significance. Appendix A contains a comparative matrix of the prediction parameters, impacts and mitigation options.

Table 1 Operational Noise and Vibration Effects at Historic Resources

Resource	Refinement Predicted Levels	DEIS/DEIR Impact	DEIS/DEIR Mitigation	FEIS/FEIR Impacts	FEIS/FEIR Mitigation
APE 4-3 2nd Street Vehicle Tunnel	Not applicable	None	None	None	None
APE 4-4 Walt Disney Concert Hall	Concert Hall: 55 to 64 VdB 31 to 45 dBA NC26 to 45 REDCAT: 37 to 45 VdB 11 to 26 dBA ≤NC19	None	None	Potential vibration (Groundborne Noise)	• Engineering studies during PE to verify criteria and improve predictions. • High compliance resilient fasteners, floating slab trackbed or other appropriate measures to reduce groundborne noise should be implemented. • MOA
MOA: Memorandum of Agreement					

Construction Impacts

The FTA provides construction damage criteria applicable to four building categories:

I. Reinforced-concrete, steel or timber (no plaster)	0.5 in/sec PPV
II. Engineered concrete and masonry (no plaster)	0.3 in/sec PPV
III. Non-engineered timber and masonry buildings	0.2 in/sec PPV
IV. Buildings extremely susceptible to vibration damage	0.12 in/sec PPV

Thus, buildings with plaster finishes, unreinforced masonry, non-engineered reinforced concrete or timber framing would typically fall under Category III. Buildings with existing damage to plaster finishes or buildings in poor structural condition would typically fall under Category IV. Table 2 summarizes potential building damage effects.

The Draft EIS/EIR analysis has categorized all of these historic buildings and structures as Category IV buildings, for which any building within 21 feet of heavy construction activities (non-tunneling) would be potentially impacted by construction vibration. This screening distance would apply to cut and cover construction.

- Since construction vibration impact has already been determined for the Walt Disney Hall, close to the 2nd and Hope Station and cut and cover work, no new impacts would be generated by these refinements to the Project. Previously identified measures in the Draft EIS/EIR would still be sufficient to mitigate these impacts.

Table 2 Construction Building Damage Effects

Resource	DEIS/DEIR Impact	DEIS/DEIR Mitigation	FEIS/FEIR Impacts	FEIS/FEIR Mitigation
APE 4-3 2nd Street Vehicle Tunnel	None	None	None	none
APE 4-4 Walt Disney Concert Hall and REDCAT	Vibration Impact from cut and cover work (Construction)	PBS, BPM, MOA	Same as DEIS	Same as DEIS
PBS: Pre-construction Baseline Survey and Geotechnical Investigations BPM: Building Protection Measures, Geotechnical and Vibration Monitoring, and Post-Construction Survey MOA: Memorandum of Agreement				

The FTA also provides criteria for short-term impacts (or annoyance) during construction, with the criteria equivalent to the same criteria provided for operational groundborne vibration and noise[2].

For tunneling vibration, the Draft EIS/EIR indicates that tunnel boring machines (TBM) can generate vibration as high as 0.055 in/sec peak particle velocity (PPV) at a distance of 33 feet from the TBM source. Since the alignment refinements have not brought the alignment closer than 40 feet to historic resources, no new construction vibration impacts are expected due to the change in tunnel depth. No new mitigation measures would be required.

Thus, TBM vibration of 0.018 in/sec PPV at 70 ft[3] would result in an RMS vibration level of 73 VdB. The corresponding groundborne noise could be on the order of 40 to 53 dBA. Taking into account building isolation and losses through the parking structure, the short-duration noise and vibration from TBM at Walt Disney Concert Hall and at the REDCAT, are indicated in Table 3 and would exceed the criteria for groundborne vibration at the Concert Hall. The duration of impact would be on the order of a few weeks, unless further studies establish different TBM groundborne vibration and noise levels based on proposed field measurements such as the vibration transmission losses through the parking structure.

Groundborne noise and vibration would also be generated by delivery trains in the tunnel during construction. These slow moving trains would possibly have wheel flats or operate on jointed construction rails, and it is estimated that the vibration would be on the order of 5 to 10 dB less than that generated by the LA Metro operations[4]. Thus, at Walt Disney Concert Hall this would result in groundborne vibration on the order of 45 to 59 VdB and groundborne noise of up to 40 dBA or NC40. Thus, the delivery trains would potentially cause a short-term groundborne noise impact at the Concert Hall. It is not projected that the REDCAT would be impacted by delivery trains.

As mentioned above, this analysis includes preliminary information regarding the effect of building isolation currently implemented into the design of the REDCAT and Walt Disney Concert Hall. More study should be done during engineering design to verify the local vibration characteristics of the intervening soil between tunnel and affected structures, the vibration

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[2] FTA criteria for short-term impacts (or annoyance) during construction, with the criteria equivalent to the same criteria provided for operational groundborne vibration and noise of 75 VdB and 40 dBA, respectively, for frequent events (70 events/day). For less frequent events, the criteria would be 78 VdB and 43 dBA for occasional (30 to 70 events/day) events and 83 VdB and 48 dBA for infrequent (fewer than 30 events/day) activities. These annoyance criteria would apply to environments where occupants use these historic resources.

[3] Scaled for distance as $PPV(distance) = PPVref(ref\_dist/dist)^{1.5}$, per FTA Guidance Manual

[4] See Table 4.7-18 in the Draft EIS/EIR

transmission losses through the parking structure and to verify appropriate criteria for recording in the Concert Hall. Table 3 summarizes the short-term effects from construction. Measures previously identified for operational impacts (above) and construction vibration impacts (DEIS) should be sufficient to mitigate this impact.

Table 3 Construction Short-Term (Annoyance) Effects

Resource	Refinement Predicted Levels	DEIS/DEIR Impact	DEIS/DEIR Mitigation	FEIS/FEIR Impacts	FEIS/FEIR Mitigation
APE 4-3 2nd Street Vehicle Tunnel	Not applicable	None	None	None	None
APE 4-4 Walt Disney Concert Hall and REDCAT[1]	TBM: 68 VdB 35 to 48 dBA Delivery train: Concert Hall 45 to 59 VdB 21 to 40 dBA NC 21 to 40 REDCAT: 27 to 40 VdB ≤21 dBA; ≤NC14	None	None	Potential vibration (groundborne vibration and noise) at the Concert Hall	• Engineering studies during PE to verify criteria and prediction estimates. • Construction GBN Monitoring • BPM, MOA

Note 1: includes the expected effect of building isolation at the REDCAT and the greater distance of the Concert Hall
BPM: Building Protection Measures, Geotechnical and Vibration Monitoring, and Post-Construction Survey
MOA: Memorandum of Agreement

APPENDIX A

The following matrix indicates the effect of input assumptions and expected mitigation effects on the groundborne noise impact for the Walt Disney Concert Hall. Existing baseline conditions indicate that the Concert Hall is exposed to sound on the order of NC 15 to 21 and 24 to 28 dBA. The baseline conditions for recording sessions (e.g., no ventilation system, late evening hours, etc.) should be confirmed.

	Mitigation		
Assumptions	**None**	**High Compliance Resilient Fasteners**	**Floating Slab Trackbed**
No Coupling Loss Low Absorption in Concert Hall (A/Srad<0.15) Low vibration loss through parking structure.	**Impact: 46 dBA NC 45**	**Impact: 40 dBA NC 39**	No Impact: 26 dBA NC 20
Moderate Coupling Loss and Floor Amplification Average Absorption (A/Srad=0.5) Low vibration loss through parking structure.	**Impact: 37 dBA NC 34**	**Impact: 30 dBA NC 26**	No Impact: 18 dBA <NC 15
Moderate Coupling Loss and Floor Amplification Average Absorption Moderate vibration loss through parking structure.	**Impact (estimate)**	No Impact (estimate)	No impact (estimate)
Moderate Coupling Loss and Low Floor Amplification High Absorption (A/Srad=0.8) Low vibration loss through parking structure.	**Impact: 31 dBA NC 26**	No Impact : 25 dBA NC 19	No Impact: 12 dBA <NC 15
Substantial vibration loss through parking structure	No Impact (estimate)	No impact (estimate)	No impact (estimate)

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MEMORANDUM

DATE: 15 March 2011 revised 12 July 2011

TO: John Prizner, Connector Partnership

FROM: Deborah Jue, Richard Carman

SUBJECT: Noise and Vibration - Task 6.1.4.4 –Impacts at Little Tokyo
Preliminary Results
WIA#10-088

This memorandum addresses our preliminary analysis for impacts at the Little Tokyo district at areas where the current Advanced Conceptual Engineering (ACE) alignment differs from the Fully Underground LRT (FULRT) alignment evaluated for the Draft EIS/EIR. This revision clarifies the discussion regarding impacts. This revision adds discussion for the potential impact from two simultaneous trains and clarifies the discussion on construction impacts and mitigation.

Executive Summary

The ACE alignment has been refined in response to comments from the public and as a result of engineering studies to improve the FULRT alignment from an operational perspective. This memo summarizes the potential noise and vibration effect of re-routing the alignment in Little Tokyo on nearby buildings. This preliminary analysis indicates that the proposed refinements would result in some new operational and construction impacts for nearby buildings. These new impacts include:

- Hikari Lofts: Potential groundborne noise and vibration effects during operations and potential short-term groundborne vibration and noise impacts during construction.
- Nakamura Tetsujiro Building: Potential groundborne noise effects during operation and potential short-term groundborne vibration and noise impacts during construction.
- Japanese Village Plaza (JVP interior designer office): Potential groundborne noise effects during operation and potential short-term groundborne vibration and noise impacts during construction.

The impacts for potential building damage are unchanged from the Draft EIS/EIR analysis.

Recommendations

In addition to the measures previously identified in the Draft EIS/EIR to reduce or eliminate the effect of impacts, the Final EIS/EIR should include the following mitigations to reduce the adverse impacts:

- Evaluation during preliminary engineering to verify groundborne noise and vibration predictions
- If necessary, use high compliance resilient fasteners, floating slab or other appropriate measures to reduce operational groundborne noise impacts

- Provide advance notification for Hikari Loft residents and Nakamura Tetsujiro Building occupants regarding tunneling construction schedules.
- Provide interior monitoring of the groundborne noise and vibration during construction.

Introduction

The ACE alignment has been refined in response to comments from the public and as a result of engineering studies to improve the FULRT alignment from an operational perspective.

The refinement with potential impacts to buildings in the Little Tokyo district includes routing the tunnel directly below or near several buildings. The change in the alignment between the Draft EIS/EIR plan (dated December 2009) and the current Final EIS/EIR plan and profile (dated February 28, 2011) as they affect these buildings are as follows:

Building	FEIS/EIR compared to DEIS/DEIR	Location Relative to Subway
Japanese Village Plaza (retail and office)	Construction changed from cut and cover on 2nd street to tunnel under building	Directly over tunnel
Hikari Lofts (4s residential over retail)	Construction changed from cut and cover on 2nd street to tunnel near building	5 to 10 ft from near edge of tunnel structure (in plan view)
Japanese Village Plaza Parking Garage	Construction changed from cut and cover on 2nd street to tunnel under building	Directly over tunnel
Nakamura Tetsujiro Building (office)	Construction changed from cut and cover on 2nd street to tunnel under building	Directly over tunnel
Commercial Building (San Pedro at 2nd)	Construction changed from cut and cover on 2nd street to tunnel near building	32 ft from near edge of tunnel structure (in plan view)

Thus, the potential noise and vibration impact on these buildings is addressed in this memorandum.

Operational Impacts

Groundborne noise could exceed the FTA criteria and affect the Hikari Lofts and offices in the Japanese Village Plaza and the Nakamura Tetsujiro Building.

As discussed in the Draft EIS/EIR the FTA criteria for operational groundborne vibration and noise are as follows:

- Residential buildings (Category 2)
  - 72 VdB for groundborne vibration
  - 35 dBA for groundborne noise
- Quiet Office or Institutional buildings (Category 3)
  - 75 VdB for groundborne vibration
  - 40 dBA for groundborne noise.

Further, there would be times when there are two trains passing by this area; however, since such dual train passbys would typically occur *at this area* 70 times or fewer per day, higher criteria would be applied for occasional events (30 to 70 events per day):

- Residential buildings (Category 2)
  - 75 VdB and 38 dBA
- Quiet Office (Category 3)
  - 78 VdB and 43 dBA

Table 1 summarizes the updated effects and recommended measures to mitigate these effects below significance.

Table 1 Operational Noise and Vibration Effects at Historic Resources

Building	Refinement Predicted Levels		DEIS/ DEIR Impact	DEIS/ DEIR Mit.	FEIS/ FEIR Impacts	Grndbne Noise Levels with Mitigation	FEIS/FEIR Mitigation
	One Train	Two Trains					
Japanese Village Plaza (acupuncture office)	53 – 66 VdB 24 – 41 dBA	56 – 69 VdB 27 – **44 dBA**	None	None	Potential Groundborne Noise	No impact One train: 19 – 36 dBA Two trains: 22 – 39 dBA	• Engineering studies during PE to verify prediction estimates. • High compliance resilient fasteners or other appropriate measures as needed to eliminate impact.
Japanese Village Plaza (interior designer office)	Similar to Hikari Lofts	Similar to Hikari Lofts	None	None	Potential Groundborne Noise	Similar to Hikari Lofts	• Engineering studies during PE to verify prediction estimates. • High compliance resilient fasteners or other appropriate measures as needed to eliminate impact.
Japanese Village Plaza Parking Structure	N/A	N/A	None	None	None	N/A	None
Hikari Lofts (4-story residential over retail)	64 – 69 VdB **40 – 47 dBA**	67 – 72 VdB **43 – 50 dBA**	None	None	Groundborne Noise	No Impact One train: 25 - 32 dBA Two trains: 28 – 35 dBA	• Engineering studies during PE to verify prediction estimates. • High compliance resilient fasteners, floating slab trackbed or other appropriate measures as needed to eliminate impact.
Nakamura Tetsujiro Building (office)	Similar to Hikari Lofts	Similar to Hikari Lofts	None	None	Groundborne Noise	Similar to Hikari Lofts	• Engineering studies during PE to verify prediction estimates. • High compliance resilient fasteners, floating slab trackbed or other appropriate measures as needed to eliminate impact.
Commercial Building (San Pedro at 2nd)	N/A	N/A	None	None	None	N/A	None

N/A: Not Applicable
Bolded entries exceed criteria

Construction Impacts

The FTA provides construction damage criteria applicable to four building categories:

I. Reinforced-concrete, steel or timber (no plaster)	0.5 in/sec PPV
II. Engineered concrete and masonry (no plaster)	0.3 in/sec PPV
III. Non-engineered timber and masonry buildings	0.2 in/sec PPV
IV. Buildings extremely susceptible to vibration damage	0.12 in/sec PPV

Thus, recently constructed buildings in this area would likely be Category I or II and buildings with plaster finishes, unreinforced masonry, non-engineered reinforced concrete or timber framing would typically fall under Category III. Most of the buildings listed in this memorandum are assumed to be Category II or Category I, with the exception that some of the smaller buildings in the Japanese Village Plaza have plaster finishes (Category III). These FTA criteria are “threshold damage” criteria which are meant to indicate the level at which architectural or minor damage could occur (e. g., aesthetic cracks in plaster or stucco). Table 2 summarizes potential building damage effects.

The Draft EIS/EIR analysis has provided a screening distance of 15 feet for Category I buildings, 20 feet for Category II buildings and 26 feet for Category III building, for which any building within the screening distance of non-tunneling heavy construction activities (e.g., large vibratory roller or similar) would be potentially impacted by construction vibration. No vibratory or impact pile driving work would be done for the Project. This screening distance would apply to cut and cover construction. The plaster finished buildings in the Japanese Village Plaza lie beyond the 26 ft screening distance for Category III buildings, and the parking garage is expected to lie beyond the 15 ft screening distance for Category I buildings. Thus, none of the buildings fall within the applicable screening distances for cut and cover construction, and thus there would no vibration impacts from cut and cover construction.

For tunneling vibration, the Draft EIS/EIR indicates that tunnel boring machines (TBM) can generate vibration as high as 0.055 in/sec peak particle velocity (PPV) at a distance of 33 feet from the TBM source. Thus, the TBM vibration at any of these buildings would be well below any applicable criterion for building damage.

Table 2 Construction Building Damage Effects

Resource	DEIS/DEIR Impact	DEIS/DEIR Mitigation	FEIS/FEIR Impacts	FEIS/FEIR Mitigation
Japanese Village Plaza (office and retail)	None	None	None	None
Japanese Village Plaza Parking Structure	None	None	None	None
Hikari Lofts (4s residential over retail)	None	None	None	None
Nakamura Tetsujiro Building (office)	None	None	None	None
Commercial Building (San Pedro at 2nd)	None	None	None	None
BPM: Building Protection Measures, Geotechnical and Vibration Monitoring, and Post-Construction Survey				

The FTA also provides criteria for short-term impacts (or annoyance) during construction, with the criteria equivalent to the same criteria provided for operational groundborne vibration and noise. In the case of residential and institutional (quiet office) buildings, the annoyance criteria would be as follows:

- Frequent Events (70 events/day)
  - Residential: 72 VdB for vibration and 35 dBA for groundborne noise
  - Quiet office: 75 VdB and 40 dBA
- Occasional Events (30 to 70 events/day)
  - Residential: 75 VdB and 38 dBA
  - Quiet office: 78 VdB and 43 dBA
- Infrequent Events (fewer than 30 events/day)
  - Residential: 80 VdB and 43 dBA
  - Quiet office: 83 VdB and 48 dBA

Thus, scaling for distance a TBM at 25 ft distance would potentially generate vibration of 0.0834 in/sec PPV[1] which would result in an RMS vibration level of 86 VdB. The corresponding groundborne noise could be on the order of 51 dBA, and the Hikari Lofts would potentially be exposed to these levels of TBM groundborne vibration and noise. Even though this maximum vibration and noise from TBM operations would be occasional or infrequent, the TBM activities would potentially exceed the annoyance criteria listed above of occasional or frequent events for the Hikari Lofts and impact would be on the order of a few days. Similar impacts would be expected at the interior designer office located in Japanese Village Plaza (JVP) and at Nakamura Tetsujiro Building

Groundborne noise and vibration would also be generated by delivery trains[2] in the tunnel during construction. These slow moving trains would possibly have wheel flats or operate on jointed construction rails, and it is estimated that the vibration would be on the order of 5 to 10 dB less than that generated by the LA Metro operations. Thus, at Hikari Lofts this would result in groundborne vibration on the order of 64 VdB and groundborne noise of up to 42 dBA. These levels would be less than the criteria for infrequent events and thus no impact would occur from delivery trains. Similarly, no impact would be expected at any of the other receptors.

Table 3 summarizes the short-term effects and recommended mitigation measures. As indicated by the FTA criteria, events which occur less often warrant a higher criterion, since people are less likely to be affected by these irregular events and so a higher level of vibration or noise would be acceptable. Further, the criteria are geared towards sleep sensitivity or activities requiring concentration. Thus, in determining the significance of short-term (annoyance) groundborne noise impacts, it is also important to understand that these short term annoyance impacts are comparable in level to other common household appliances like a refrigerator (45 dBA), air conditioner (55 dBA) or fish tanks (45 to 55 dBA). Metro will mitigate the potential short-term (or annoyance) groundborne vibration and noise impacts during TBM operation. Metro will provide advanced notification and coordination by doing the following:

- Metro will establish a Construction Community Relation program to inform and coordinate construction activities including notification of all occupants at Hikari Lofts, the interior designer office at the JVP and the Nakamura Tetsujiro Building about the schedule of tunneling activities at least one month prior to the start of the activities.
- Metro will monitor groundborne noise and vibration levels in buildings adjacent to TBM activity during its operation in that area.
- During the few days the TBM will be operating in this area, should noise measurements exceed FTA criteria for short term (or annoyance) impacts during construction Metro will meet immediately with the business or resident who has determined the impact as noticeable and mitigate appropriately.

[1] Scaled for distance as PPV(distance) = PPVref(ref_dist/dist)$^{1.5}$, per FTA Guidance Manual
[2] Draft EIS/EIR description of construction indicates portal deliveries of 8 to 20 trucks per day. Of these, 6 to 10 deliveries would be pre-cast concrete tunnel liners which will need to be delivered to the tunnel excavation site. Additional trains could be required to transport excavated material from the tunnel. The total number of tunnel train passbys would be less than 30 trains per day (infrequent events).

Table 3 Construction Short-Term (Annoyance) Effects

Resource	Refinement Predicted Levels	DEIS/ DEIR Impact	DEIS/ DEIR Mitigation	FEIS/FEIR Impacts	Refinement Levels with Mitigation	FEIS/FEIR Mitigation
Japanese Village Plaza (acupuncture office)	TBM: <70 VdB, <35 dBA Delivery Train: <61 VdB, <36 dBA	None	None	None	N/A	None
Japanese Village Plaza (interior designer office)	TBM: 86 VdB, 51 dBA Delivery Train: 64 VdB, 42 dBA	None	None	Groundborne Noise and Vibration from TBM	TBM: 86 VdB, 51 dBA	• Advance notice and coordination • Construction GBNV Monitoring • BPM • Maint.
Japanese Village Plaza Parking Structure	N/A	None	None	None	N/A	None
Hikari Lofts (4-story residential over retail)	TBM: 86 VdB, 51 dBA Delivery Train: 64 VdB, 42 dBA	None	None	Groundborne Noise and Vibration from TBM	TBM: 86 VdB, 51 dBA	• Advance notice and coordination • Construction GBNV Monitoring • BPM
Nakamura Tetsujiro Building (office)	TBM: 84 VdB, 49 dBA Delivery Train: 64 VdB, 42 dBA	None	None	Groundborne Noise and Vibration from TBM	TBM: 84 VdB, 49 dBA	• Advance notice and coordination • Construction GBNV Monitoring • BPM • Maint.
Commercial Building (San Pedro at 2nd)	N/A	None	None	None	N/A	None

N/A: Not applicable
BPM: Building Protection Measures, Geotechnical and Vibration Monitoring, and Post-Construction Survey
Maint: minimize vibration from jacking or pressing operations (if applicable, perhaps the action could smoothed out to avoid a sharp push), and maintain machinery in good working order

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DATE: 30 March 2011

TO: John Prizner, Connector Partnership

FROM: Deborah Jue, Richard Carman

SUBJECT: Noise and Vibration - Task 6.1.4.4 - Broad Museum WIA#10-088
Preliminary Results

Executive Summary

This memorandum summarizes the results of preliminary noise and vibration analysis for the proposed Broad Museum. The Broad Museum and the supporting garage structure are located on the property identified as Parcel L which is bounded by 2nd Street, Hope Street, Grand Avenue and General Thaddeus Kosciuszko Way. This is a recently developed project and therefore was not previously included in the scope of the Draft EIS/EIR. Further, the current Advanced Conceptual Engineering (ACE) alignment includes some refinements from the Draft EIS/EIR alignment including routing the tunnel under the property where the proposed Broad Museum will be constructed. The proposed building would include three (3) garage levels extending the entire site with the museum supported by a portion of the garage structure. A second development yet to be determined will occupy the remaining space above the parking structure. This analysis does not specifically address that development as it is unknown what uses would be planned.

This preliminary analysis utilizes available information regarding subsurface conditions to provide an estimate of the groundborne vibration that would be transmitted to the proposed Broad Museum and the corresponding groundborne noise that could be radiated into the building. Since this analysis extrapolates from available data, the range of predicted values is necessarily wide. This analysis indicates that for a single train passby the groundborne vibration at the Broad Museum would be less than the FTA criterion of 75 VdB for institutional buildings and that groundborne noise within the Museum could range from 36 dBA to 51 dBA, with the expected value to be approximately 42 dBA. During Preliminary Engineering, field tests will be conducted to measure the transfer mobility for the site specific soil conditions, and this additional information will improve the accuracy of the prediction substantially, and the range of predictions will be much more narrow. The FTA criterion for institutional buildings is 40 dBA. Other recent LA Metro projects have applied the institutional criteria to museum buildings; however, it may be appropriate to apply more restrictive criteria as discussed further in this memo. Thus, it is expected that control measures such as high compliance resilient fasteners would be required to reduce the impact of groundborne noise at the Museum.

There will be occasions where two trains are in the tunnels (one westbound and the other eastbound). During these events, the vibration would increase by up to 3 VdB, and the groundborne noise would increase by up to 3 dBA. However, since such dual train passbys would typically occur *at this area* 70 times or fewer per day, higher criteria would apply. For institutional buildings, the FTA criteria for occasional events are 78 VdB and 43 dBA, thereby resulting in no net change in level of impact.

During construction, vibration from the tunnel boring machine is expected to be well below the structural damage criterion of 0.5 in/sec peak particle velocity, but the groundborne noise from the tunnel boring machine could be on the order of 42 to 57 dBA at the parking garage level, and the groundborne noise from delivery trains could reach 46 dBA within the Museum building. The criterion for temporary groundborne noise annoyance impacts is 40, 43 or 48 dBA depending on frequency of occurrence. Thus, the project could potentially generate temporary groundborne noise impacts at the Museum.

Recommendations
WIA recommends the inclusion of high compliance resilient fasteners in the vicinity of the Broad Museum. More studies and analysis should be conducted during preliminary engineering to narrow down the prediction estimates and identify the technical requirements and extent of the fasteners.

For annoyance impacts caused by groundborne noise during the construction phase, WIA recommends that LA Metro implement administrative controls to reduce or eliminate these impacts.

Introduction
This memorandum addresses our preliminary analysis of LA Metro noise and vibration at the proposed Broad Museum, which would be located above the current Advanced Conceptual Engineering (ACE) alignment. The project alignment drawings used for this preliminary memorandum were received in January and February 2011. (Track Plans dated 1/27/11 and profile received on 2/4/11). Broad Museum drawings were received on 1/17/11. The relevant drawings used for this analysis are included in Appendix A.

This preliminary analysis indicates that the Project will possibly require some form of vibration control to maintain operational groundborne noise levels below criteria in the Broad Museum.

The proposed ACE alignment would cross the property line at approximately Station 33+00, but the proposed Broad Museum would be constructed on the eastern two-thirds of the property, and the proposed Museum would lie directly above the ACE alignment from approximately Station 34+40 to 36+00.

Operational Noise and Vibration

The preliminary analysis follows the Federal Transit Administration (FTA) methodology for "Detailed Analysis"[1] which uses the following equation for vibration:

(1) $L_V(\text{distance}) = L_F(\text{speed}) + TM_{Line}(\text{distance}) + C_{Tunnel} + C_{Build}$

Where

L_V = Vibration at a specific horizontal distance from the alignment in decibels re 1 micro-inch/second

L_F = Force density or system input spectrum of the LRV on the track structure. This is a function of parameters such as

- Speed
- Wheel/Rail condition (corrugation, wear, etc.)
- Rail configuration (joints, special trackwork, tangent, curved, etc.)
- Track structure (direct fixation on invert, ballasted track, resilient fasteners, floating slab, etc.)

TM_{Line} = Transfer mobility of the intervening ground or subsurface layers for a line input of a specified length (typically the length of a train consist) as measured at the receiver.

C_{Tunnel} = This factor is not explicitly called out in the FTA methodology, but can be used to account for coupling loss between the tunnel structure and the surrounding soil.

C_{Build} = Corrections to account for ground-building coupling losses, floor to floor attenuation and building response to vibration

Groundborne noise is determined by the groundborne vibration level, and it is calculated as follows:

(2) $L_A = L_V + K_{rad} + K_{A\text{-}wt}$

Where

L_A = A-weighted noise level in dB re 20 micro-inch/second

K_{rad} = Adjustment for conversion of vibration velocity to sound pressure, taking into account the acoustical absorption in the room and the sound radiating characteristics of the room surfaces

$K_{A\text{-}wt}$ = A-weighting adjustment curve

The following parameters were used for this analysis:

- LRV
    - 3-car train
    - 35 mph maximum speed (since trains will be entering/leaving the nearby station, it is possible that the train speed could be less)
    - Direct fixation (medium compliance fasteners on the order of 140,000 lb/in dynamic stiffness)
    - L_F in this case is taken from an energy-average of various similar LRV operating on direct fixation fasteners including LA Metro Blue Line (Nippon-Sharyo P865), LA Metro Goldline (Siemens P2000 or Breda P2550) and Sound Transit (Kinki-Sharyo). The assumed L_F spectrum is shown in Figure 1.

[1] Originally developed in 1986 by WIA, this method has been incorporated into the FTA Guidance Manual.

- Tunnel
    - 90 to 110 ft depth from surface
    - Bored tunnel – no coupling loss with the Fernando Formation assumed
- Subsurface conditions
    - The geotechnical studies indicate that the alignment tunnel will be founded in Fernando Formation in this area[2]
    - Fernando Formation exposed at ground surface of Broad building
    - Shear and p-wave velocities as documented by seismic surveys conducted in 1981 between Grand and Olive Streets at nearby properties[3] (See Appendix B)
    - Transfer mobility derived from combination of numerical model results using shear wave velocities and vibration tests conducted by WIA in Fernando Formation in 1984 at a site in the area (Oxford Properties[4])
        - A family of curves from the 1984 tests is presented in Figure 2. Due to some anomalies with the analysis in 1984, the results for close-in distances are not realistic and a distance of 147 ft (45 m) was selected as a reference distance for that data.
        - A numerical model based on layered soils and shear wave data was used to model the transfer mobility. The model is sensitive to a Q factor which determines the damping effect of shallow layers, and which is undetermined at this time. This analysis makes use of the relative differences for parameters such as receptor depth and distance in the numerical model and applies those differences to the field data obtained in 1984 for the Fernando Formation. Since there can be local conditions that effect the transfer mobility even within the same soil conditions, these derived adjustments are necessarily conservative.
        - See Figure 3 for a comparison of selected numerical model results. Shown in the figure are three conditions. An average adjustment was derived from the numerical modeled results to account for horizontal distance, receptor depth and source depth.
        - The test results from 1984 have been adjusted for depth of source, receiver and horizontal distance to the alignment by using average differences in the numerical model. Figure 4 illustrates the final range of TM estimated between the tunnel and the Broad Museum. See that the adjusted FERNL2 curve is much higher than the other curves; the remaining analysis was conducted using an energy average of the remaining three curves.
        - Further testing during the Preliminary Engineering phase will be conducted to test the specific soil vibration propagation characteristics at or very close to this site. This additional information will improve the accuracy of the prediction substantially.
        -

[2] Preliminary geologic profiles prepared by MACTEC Engineering and Consulting. Date TBD
[3] Three seismic surveys conducted by LeRoy Crandall & Associates within 3 blocks of the proposed museum. The other two surveys were conducted in 1977 and 1978.
[4] "Ground-borne Vibration Propagation Investigation – Fernando Formation Bedrock," prepared by WIA for Metro Rail Transit Consultants, April 1984. Additional site tests were conducted at Jewelers Mall and 643 Olive to verify prediction results for those buildings, but the Fernando transfer mobility was not updated to reflect those results.

- Broad Museum
    - "Barrette" supports to transfer load from garage foundation along 2nd Street
    - Barrettes will be installed under the building foundation along, extending from near the existing grade to 30 or 40 ft depth below surface to be even with the bottom of the 2nd Street Tunnel
    - Spread footing foundation will rest on the barrettes along 2nd Street, and otherwise will be founded in the Fernando Formation
    - Other than the fact that we assume that the vibration transmission from the light rail train will occur at the depth of the barrettes, we have assumed no effect or coupling loss between the barrettes and the soil.
    - 3 levels of garage supported by spread footing foundation at about 8 to 11 ft below grade
    - Museum will be supported by garage structure
    - Correction Factors included in C_{Build}:
        - No coupling loss between the Fernando Formation and the barrettes
        - Little or no coupling loss between the Fernando Formation and the garage foundation
        - Little or no floor to floor loss as vibration travels up the structure
        - Average floor amplification factor
        - Room response factor to account for average, little or no acoustical absorption in the Museum's galleries
    - See Figure 5
- Criteria (FTA)
    - Frequent Events (greater than 70 events per day)
        - Default: FTA Category 3 (Institutional)
            - 75 VdB for groundborne vibration
            - 40 dBA for groundborne
            - Other nearby LA Metro projects have recently used this criteria for museums (Westside extension)
        - WIA recommendation: Museum can be similar to Theater
            - FTA Special Buildings (Theater):
                - 72 VdB for groundborne vibration
                - 35 dBA for groundborne noise
            - These recommended criteria are at the threshold of intrusiveness in this type of space, since these are the levels at which one can feel and hear a train passby without special instrumentation or attention.
            - Mechanical ventilation systems for public spaces such as a library are often designed to a criterion for steady state noise of NC 30 - 40, which is approximately 35 to 48 dBA. At 35 dBA the transient noise from a Metro train passby would be difficult to detect in such an environment.
            - A museum is an active space, in that people are walking around and talking occasionally. The ambient sounds of this activity would exceed 35 dBA, which is another reason we consider 35

dBA an appropriate criteria for groundborne noise from transit operation.

        - Conservative option: Assume same FTA Criteria for Auditoriums
            - 72 VdB for groundborne vibration
            - 30 dBA for groundborne noise
    - Occasional Events (from 30 to 70 event per day)
        - FTA Category 3: 78 VdB and 43 dBA
        - FTA Special Building (Theater): 80 VdB and 43 dBA
        - FTA Special Building (Auditorium): 80 VdB and 38 dBA
- Miscellaneous
    - Engineering design factor is shown in Figure 6. This curve is based on the estimated net uncertainty in derivation of L_F ,TM and other factors used in calculating groundborne noise and vibration
        - Based on our experience, the typical variability in the L_F for a given fleet of vehicles is small for reasonably well-maintained rails and wheels.
        - Since the L_F in this analysis is based on measured data for both the Gold Line and Blue Line vehicles, we expect the actual L_F value to be within 1 or 3 dB of the curve shown in Figure 1 to account for differences in speeds, track conditions and fasteners.
        - The typical variability in the field measured TM and coupling loss parameters also adds another 2 to 4 dB uncertainty for data between 12 and 160 Hz.
        - Further, some additional conservatism has been included:
            - in the adjusted TM by using a conservative approach to applying the adjustments.
            - in the coupling loss factor by calculating the range without coupling loss.
            - in the groundborne noise calculation by calculating the range with very low room absorption.
        - The validity of using this design factor and the accuracy of the FTA prediction model has been examined in a paper presented by WIA to the American Public Transit Association in 1995[5].
    - This model assumes reasonably well-maintained rails and wheels, and thus does not include the effects of occasional moderate flat wheels or poorly maintained rail.
    - This model assumes that the potentially high variability in high frequency vibration will be controlled through regular rail grinding.
    - As noted above, during Preliminary Engineering, field tests will be conducted to determine the TM, and this information will reduce the range of predicted values considerably. Further, once the foundation design has been finalized for the Broad Museum, it can be modeled to determine a likely range of coupling loss response for the garage supported on barrettes (if any).

---

[5] Carman, Richard, "Rail Transit – Groundborne Noise and Prediction Models, A Comparison of Predicted and Measured Data," June 1995.

The range of predicted results for groundborne vibration for a single train passby is shown in Figure 7, and the corresponding range for groundborne noise is shown in Figure 8.

The highest curve in Figure 7 represents the prediction with no building coupling factors. It is likely that coupling loss will occur, thus this curve represents the high range. The middle curve in Figure 7 is a prediction for a building with typical spread footing coupling loss and an average to high floor amplification. The bottom curve in Figure 7 indicates the prediction with spread footing coupling loss and moderate to low floor amplification. As shown in the left axis of the figure, all groundborne vibration is expected to be less than 70 VdB.

For groundborne noise, the results in Figure 7 were converted to groundborne noise (Figure 8), applying the highest conversion factor to the highest vibration estimate, the middle conversion factor to the middle vibration estimate, and the lowest conversion factor to the lowest vibration estimate. As shown in the right axis, the groundborne noise range is expected to be 36 to 51 dBA. The highest value shown is probably unlikely. Figure 9 presents the estimated results with high compliance resilient fasteners, and the expected result would range from 30 to 46 dBA. Again, the highest value shown is probably unlikely. Thus, for groundborne noise, the predicted result with high resilient fasteners is likely to be less than 40 dBA, though these calculations indicate that the high end of the prediction could approach 45 dBA.

There will be occasions where two trains are in the tunnels (one westbound and the other eastbound). During these events, the vibration would increase by up to 3 VdB, and the groundborne noise would increase by up to 3 dBA. However, since such dual train passbys would typically occur *at this area* 70 times or fewer per day, higher criteria would apply. For institutional buildings, the FTA criteria for occasional events are 78 VdB and 43 dBA, and for the other criteria considered, the criteria difference would be even greater. Thus, there would be no net change in impact compared to the single train passby.

Construction Noise and Vibration

The FTA provides construction damage criteria applicable to four building categories:

I. Reinforced-concrete, steel or timber (no plaster)	0.5 in/sec PPV
II. Engineered concrete and masonry (no plaster)	0.3 in/sec PPV
III. Non-engineered timber and masonry buildings	0.2 in/sec PPV
IV. Buildings extremely susceptible to vibration damage	0.12 in/sec PPV

As a new building, the Broad Museum would fall under the Category I, with a vibration criterion of 0.5 in/sec PPV.

The FTA also provides criteria for short-term impacts (or annoyance) during construction, with the criteria equivalent to the same criteria provided for operational groundborne vibration and noise of 75 VdB and 40 dBA, respectively, for frequent events (70 events/day). For less frequent events, the criteria would be 78 VdB and 43 dBA for occasional (30 to 70 events/day) events and 83 VdB and 48 dBA for infrequent (fewer than 30 events/day) activities.

The Draft EIS/EIR indicates that tunnel boring machines could generate peak particle velocities (PPV) of up to 0.0551 in/sec at a distance of 33 feet from the vibration source. The corresponding RMS vibration level would be approximately 83 VdB at that distance. The bottom of the Broad Museum's barrettes would be at least 50 feet from the top of the tunnel which would result in a corresponding TBM vibration of 0.0295 in/sec PPV[6] which would result in an RMS vibration level on the order of 77 VdB. The groundborne noise could be on the order of 42 to 57 dBA. Within the occupied Museum building, the groundborne noise and vibration would be even less. Thus, while TBM vibration would not exceed the threshold for short-term construction vibration annoyance, it is possible that the groundborne noise could be audible and could generate short-term noise annoyance.

Groundborne noise and vibration would also be generated by delivery trains in the tunnel during construction. These slow moving trains would possibly have wheel flats or operate on jointed construction rails which would introduce as much as 5 to 10 dB over a system with smooth rails and trued wheels. However the slow speed (approximately 5 mph) would dramatically reduce the vibration on the order of 15 dB from a system operating at 35 mph. Thus, if we use the predicted levels of noise and vibration from LA Metro operations as a reference value, the tunnel train is expected to generate groundborne noise and vibration 5 to 10 dB less, which would result in groundborne vibration levels on the order of 63 VdB or less, and groundborne noise levels 46 dBA or less. Thus, while delivery train vibration would not exceed the threshold for short-term construction vibration annoyance, it is possible that the groundborne noise could be audible and could generate short-term noise annoyance.

For annoyance impacts caused by groundborne noise during the construction phase, WIA recommends that LA Metro implement administrative controls to reduce or eliminate such impacts. For instance, LA Metro and its contractor could coordinate with the Broad Museum to schedule construction activities to minimize annoyance impacts where reasonable and feasible to do so.

[6] Scaled for distance as PPV(distance) = PPVref(ref_dist/dist)$^{1.5}$, per FTA Guidance Manual

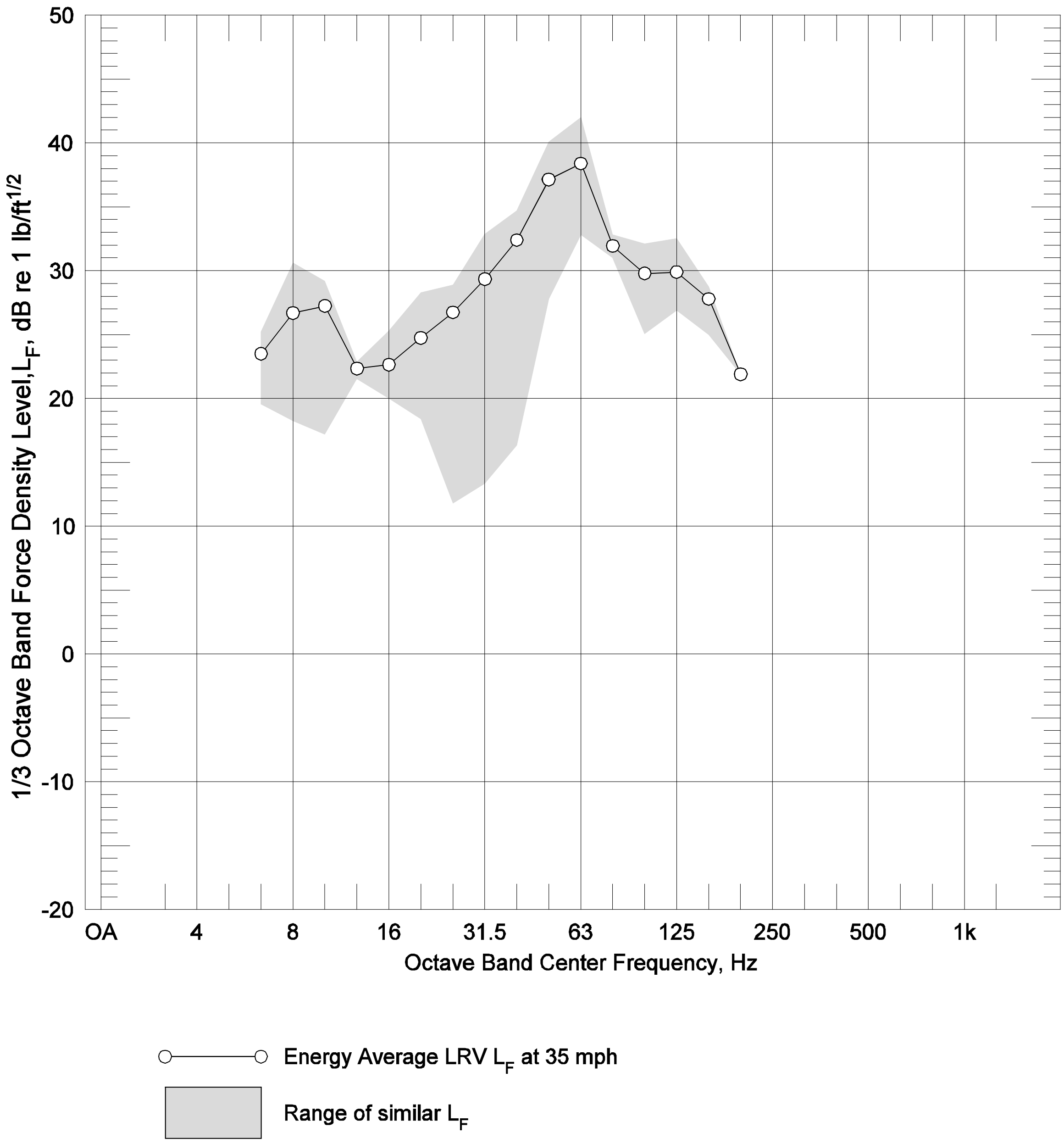


Figure 1 Range of Applicable Force Density (L_F) Spectra
35 mph DF Fasteners

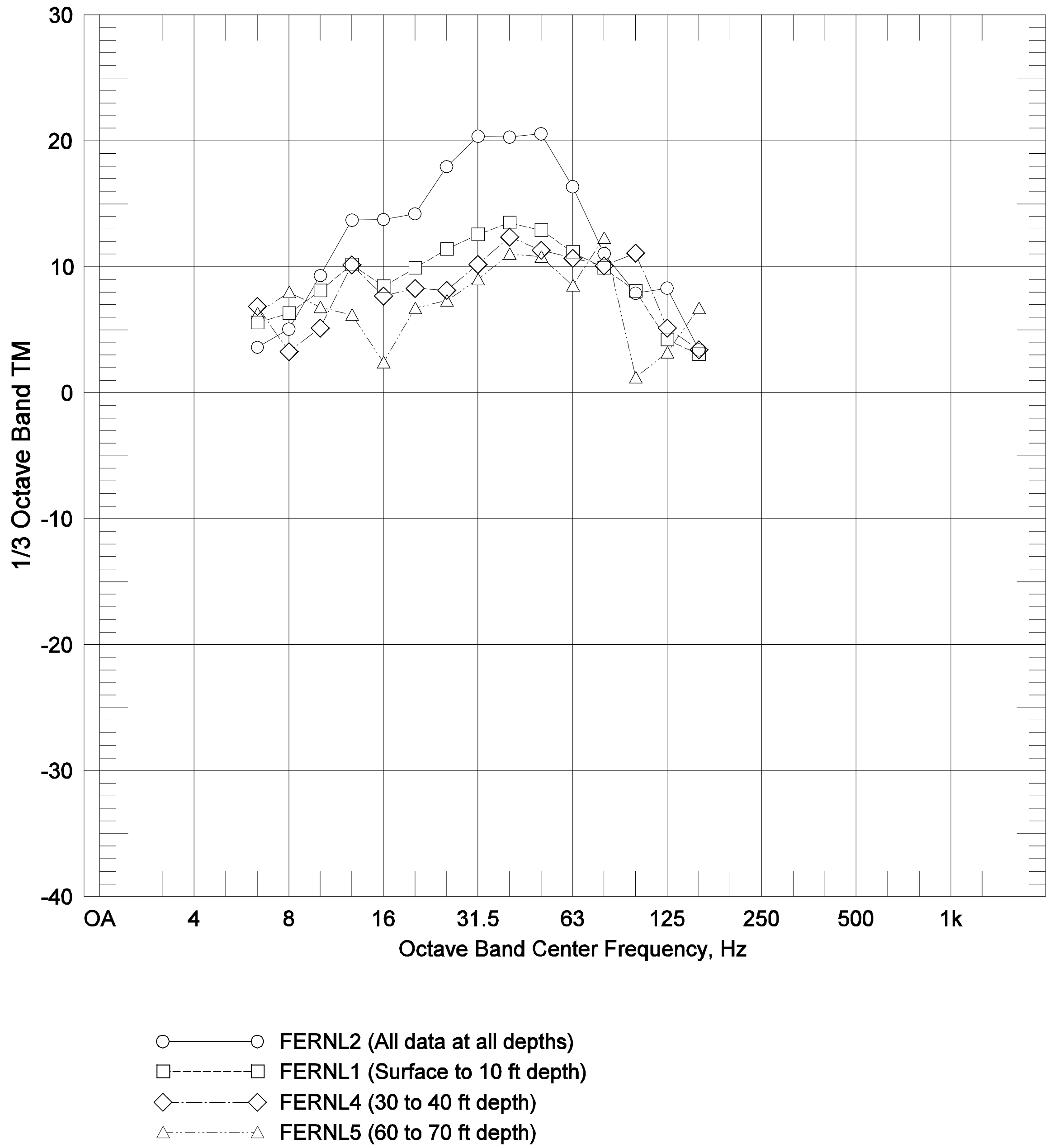


Figure 2 Transfer Mobility for Line Source - Fernando Formation
Family of Curves at 147 ft , Receptor at Ground Surface
Originally Developed for Redline 8-car train (400 ft length)

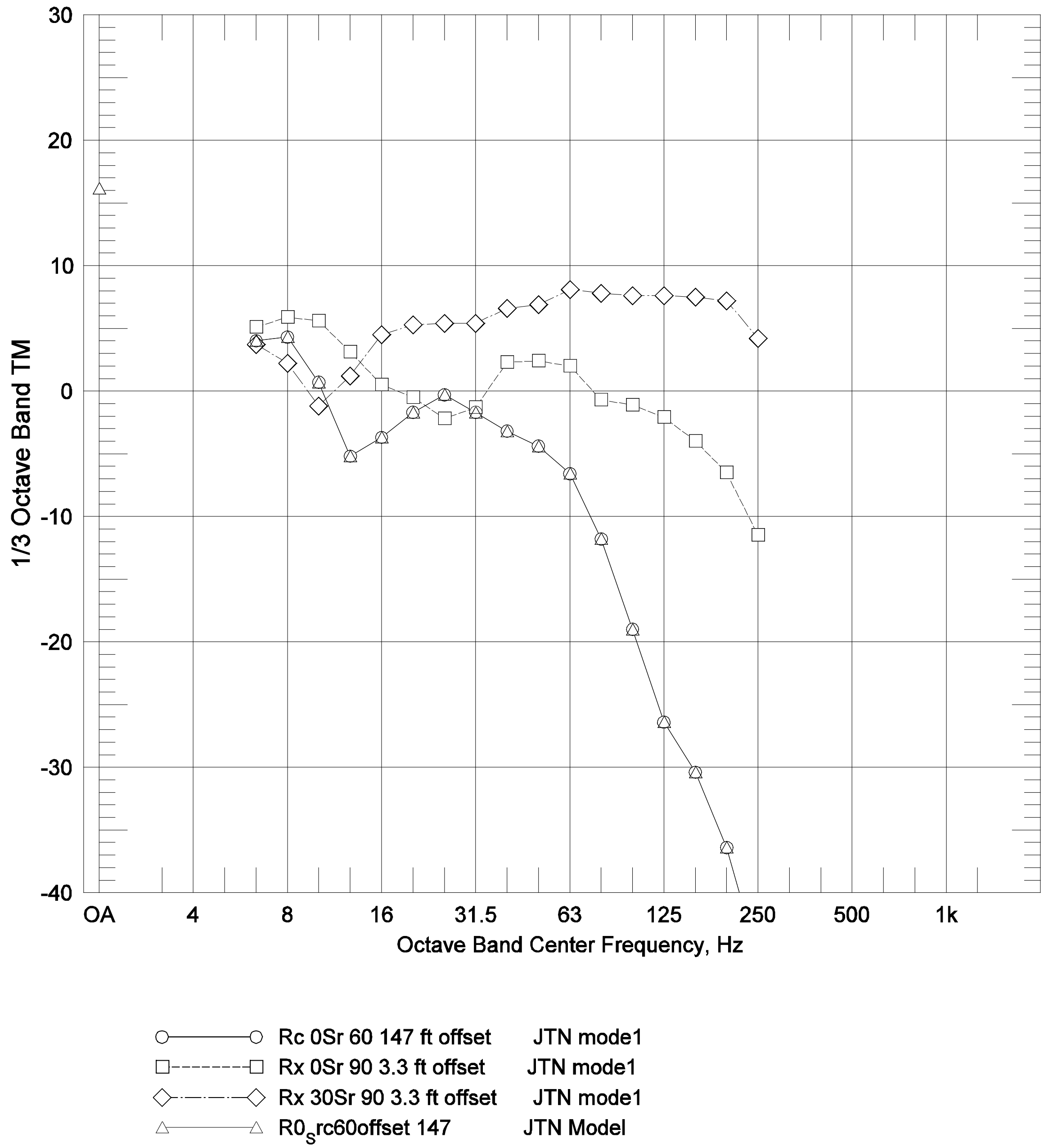


Figure 3 Numerical Model Transfer Mobility - Fernando Formation
Selected Results

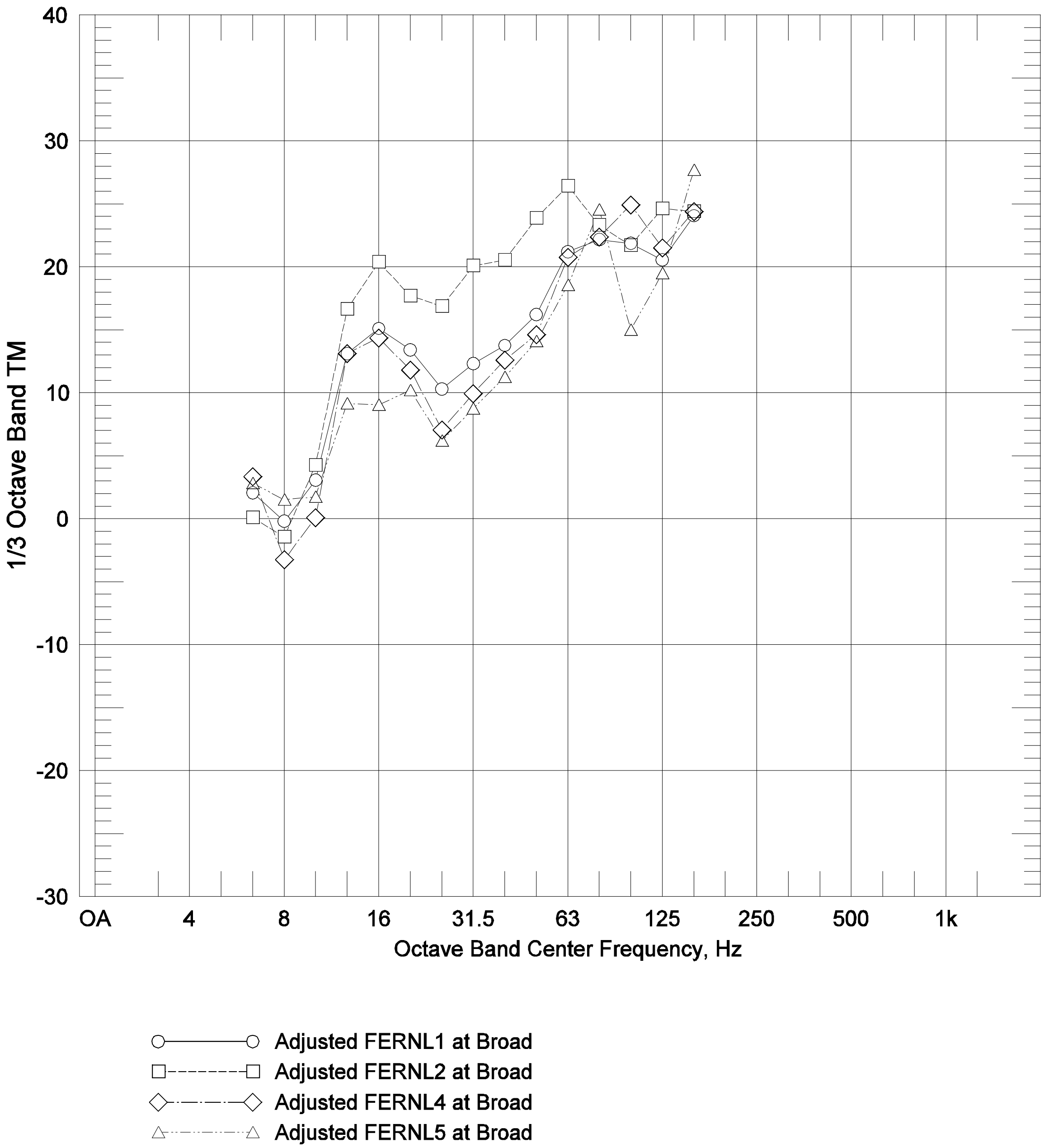


Figure 4 Transfer Mobility - Fernando Formation
FERNL family modified based on numerical model differences
for Receptor at 30 ft depth, Source at 90 ft, 3.3 ft offset

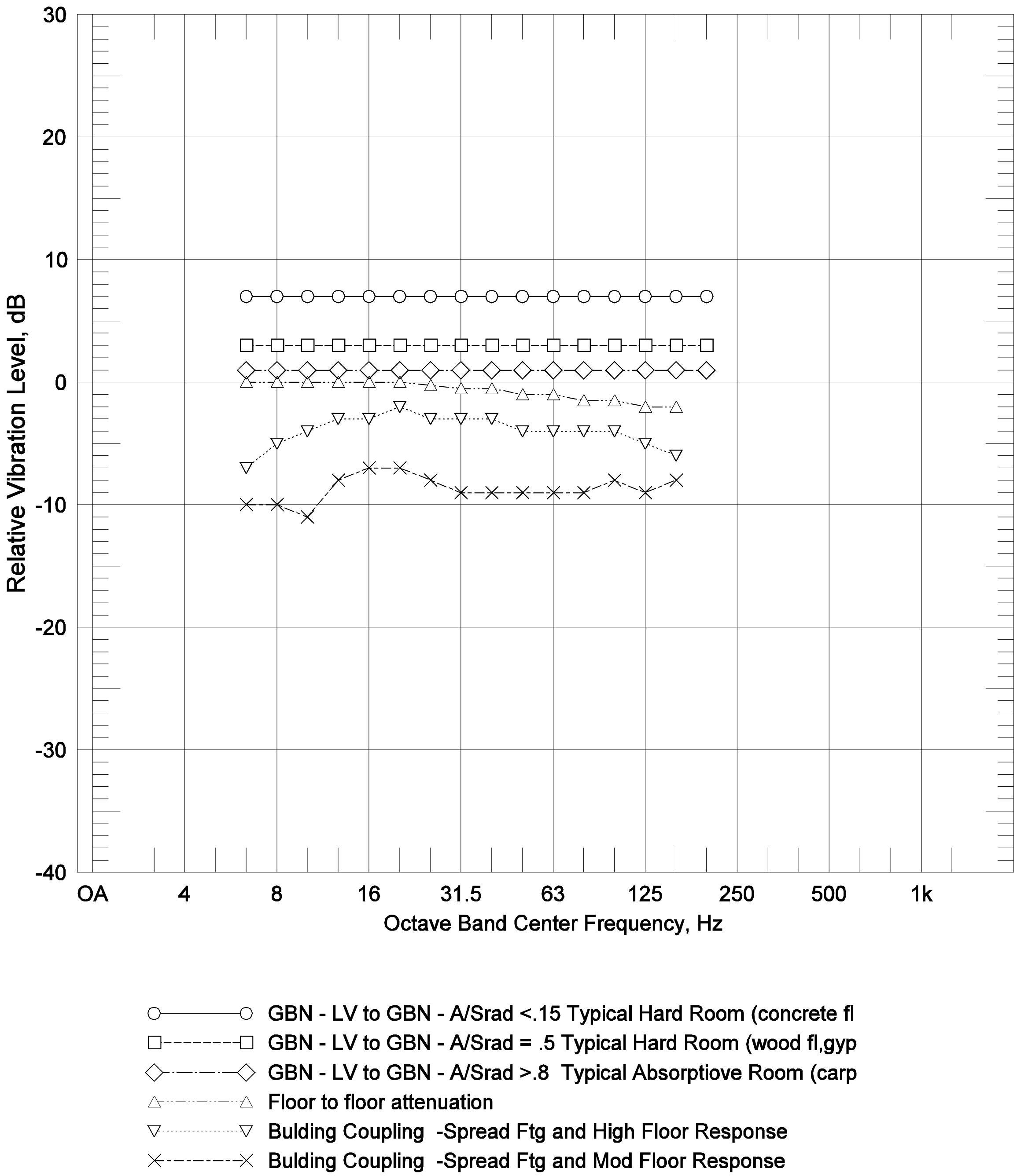


Figure 5 Building Adjustment Factors

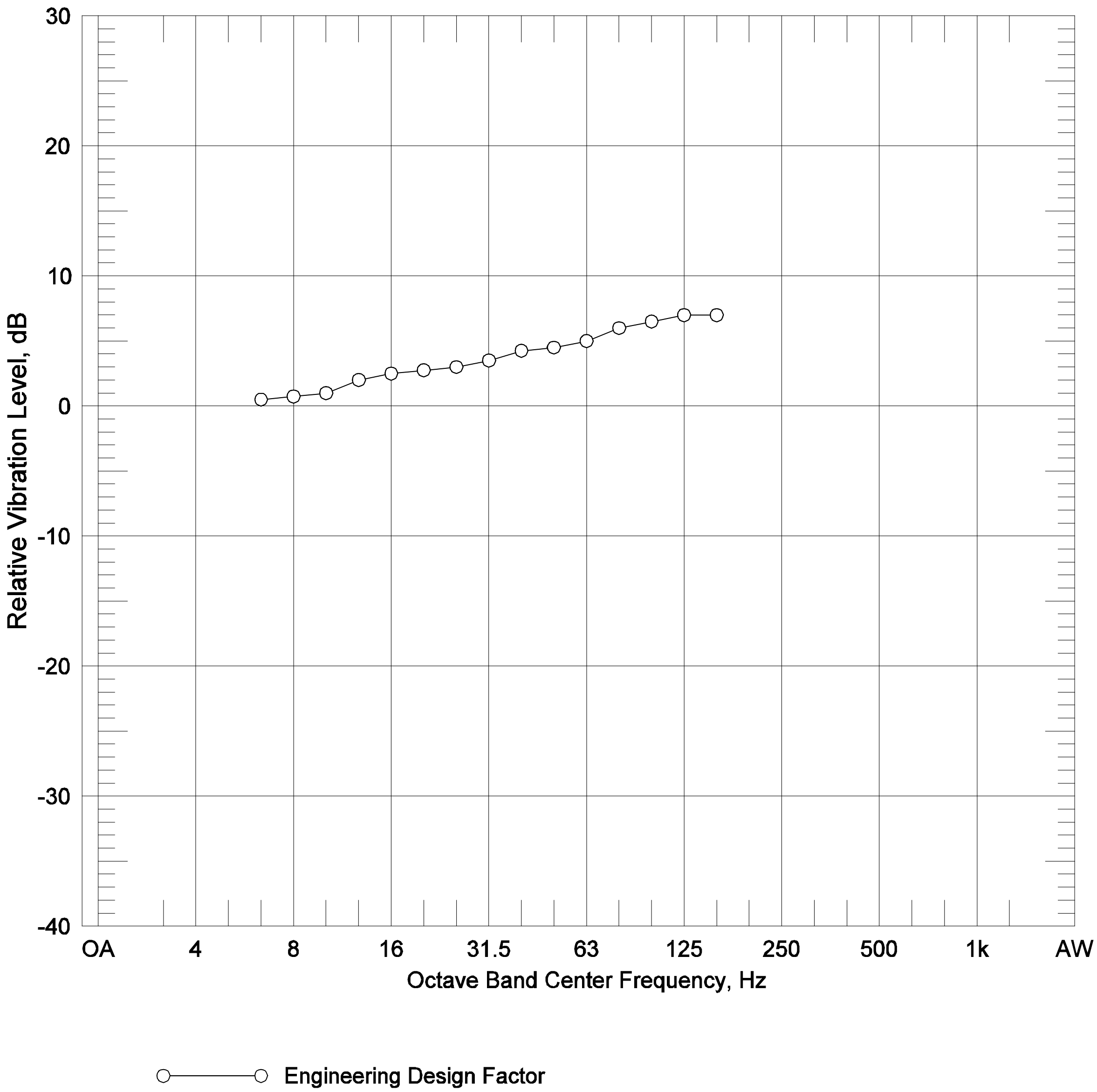


Figure 6 Engineering Design Factor
Groundborne Vibration Calculation

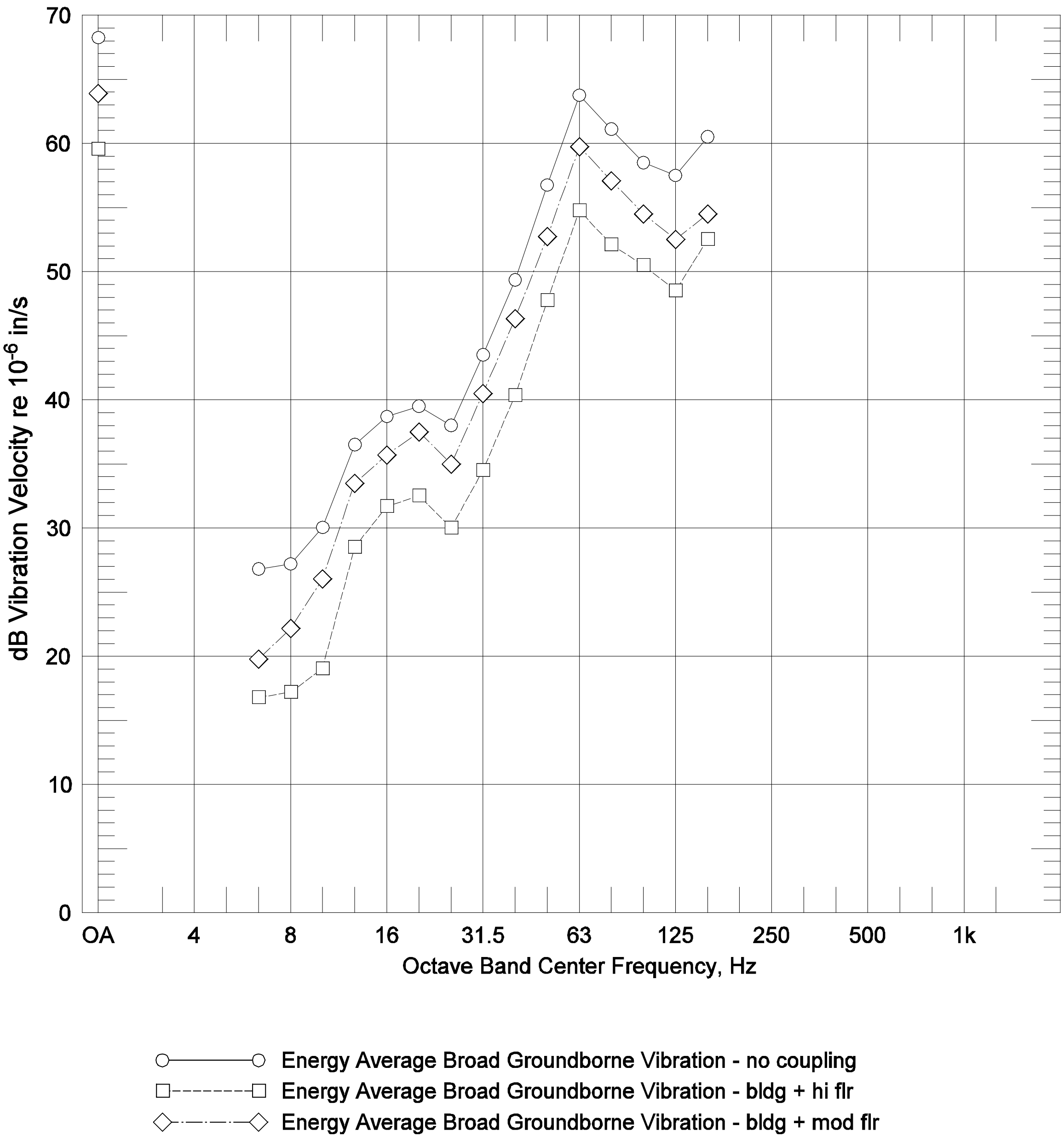


Figure 7 Predicted Range of Groundborne Vibration at Broad
Only using adjusted FERNL1, FERNL3 and FERNL4 TM
With Building Adjustment Factors as noted

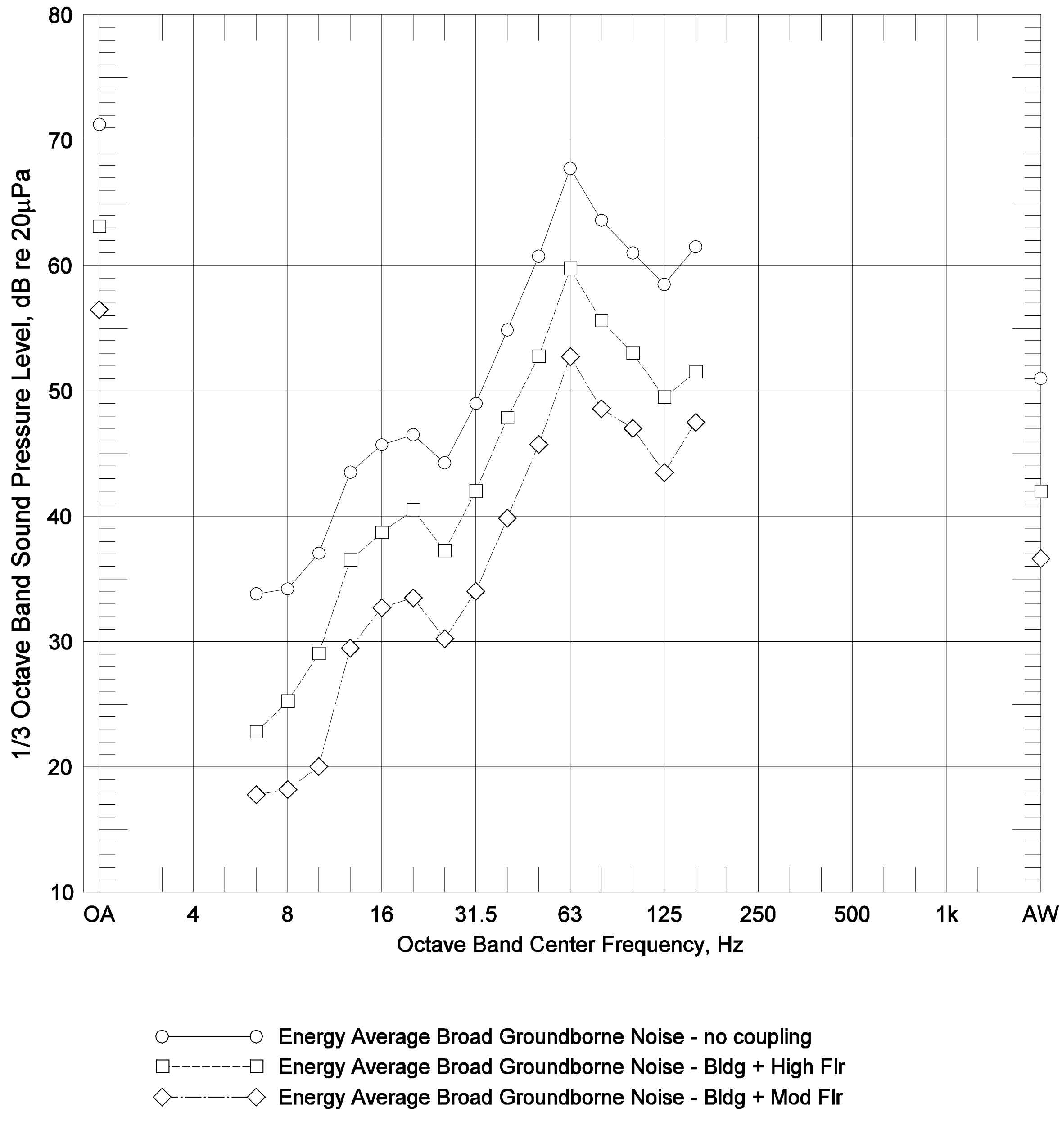


Figure 8 Predicted Range of Groundborne Noise at the Broad Museum
Only using adjusted FERNL1, FERNL3 and FERNL4 TM
With Building Adjustment Factors as noted

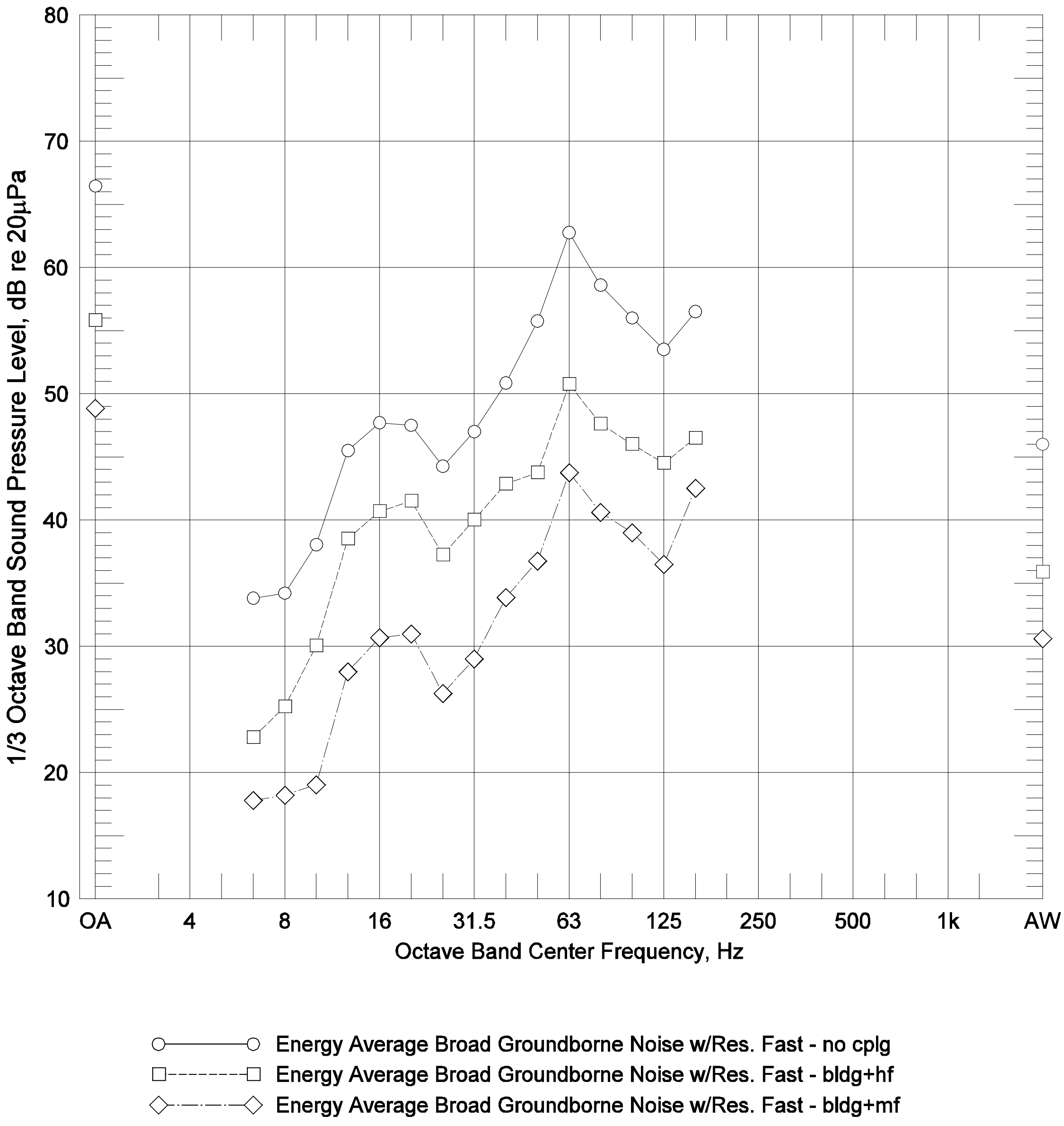
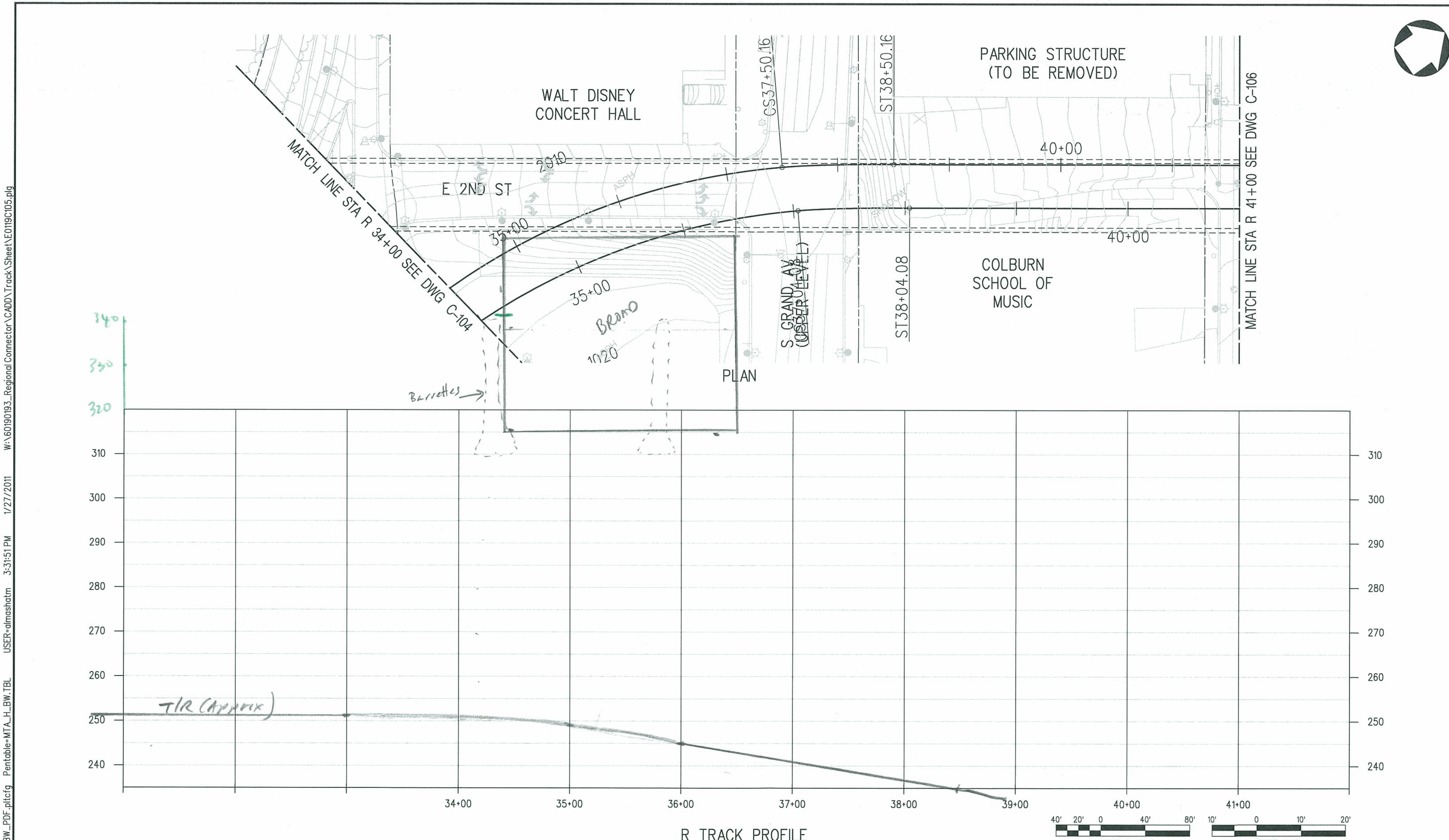
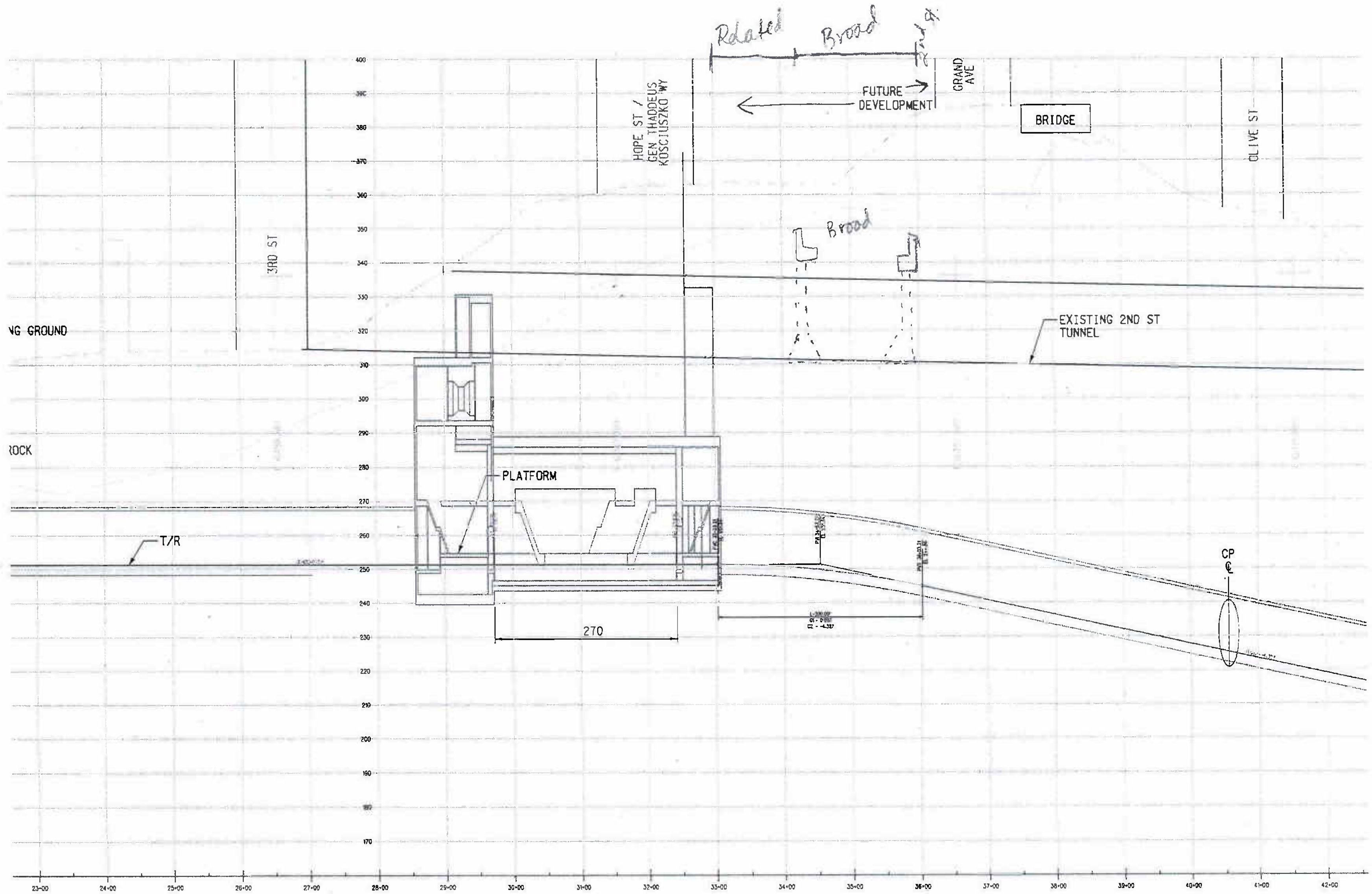


Figure 9 Predicted Range of Groundborne Noise at the Broad Museum
With Resilient Fasteners

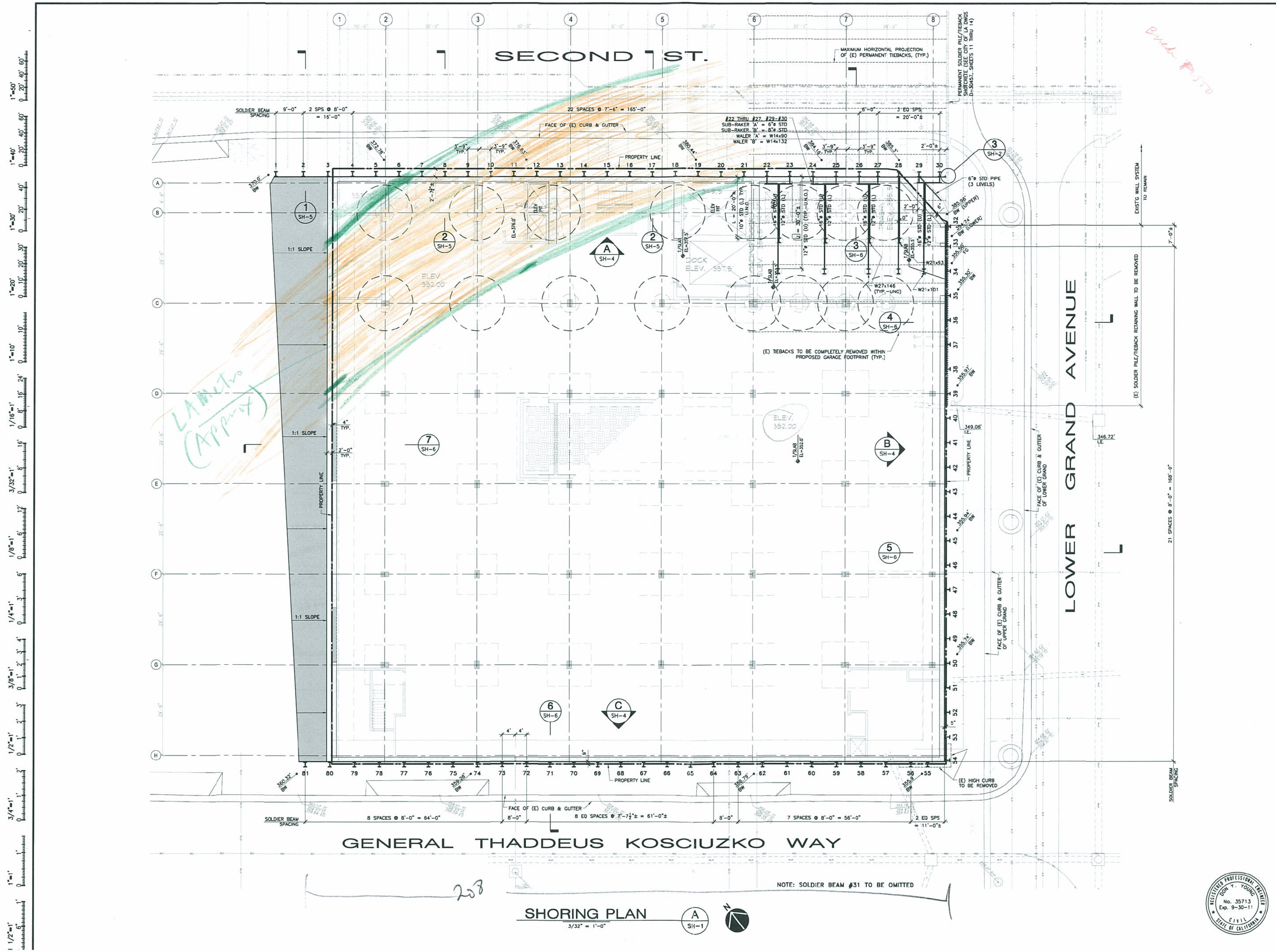
APPENDIX A
Drawings used for this analysis



WALT DISNEY CONCERT HALL
PARKING STRUCTURE (TO BE REMOVED)
E 2ND ST
COLBURN SCHOOL OF MUSIC
S GRAND AV (UPPER LEVEL)
CS37+50.16
ST38+50.16
ST38+04.08
40+00
35+00
MATCH LINE STA R 34+00 SEE DWG C-104
MATCH LINE STA R 41+00 SEE DWG C-106
Bravo
Barrettes
PLAN
T/R (APPROX)
340
330
320
310
300
290
280
270
260
250
240
34+00
35+00
36+00
37+00
38+00
39+00
40+00
41+00
HORIZ: 1"=40'
VERT: 1"=10'
R TRACK PROFILE



Related
Broad
2nd St
FUTURE DEVELOPMENT
GRAND AVE
BRIDGE
HOPE ST / GEN THADDEUS KOSCIUSZKO WY
OLIVE ST
3RD ST
Broad
NG GROUND
EXISTING 2ND ST TUNNEL
ROCK
PLATFORM
T/R
270
CP



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BROAD MUSEUM PARKING FACILITY

TEMPORARY EARTH EMBANKMENT SHORING

620 W. 2ND STREET

LOS ANGELES, CA.

SHORING PLAN

Date	08-25-10
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Sheet	SH-1

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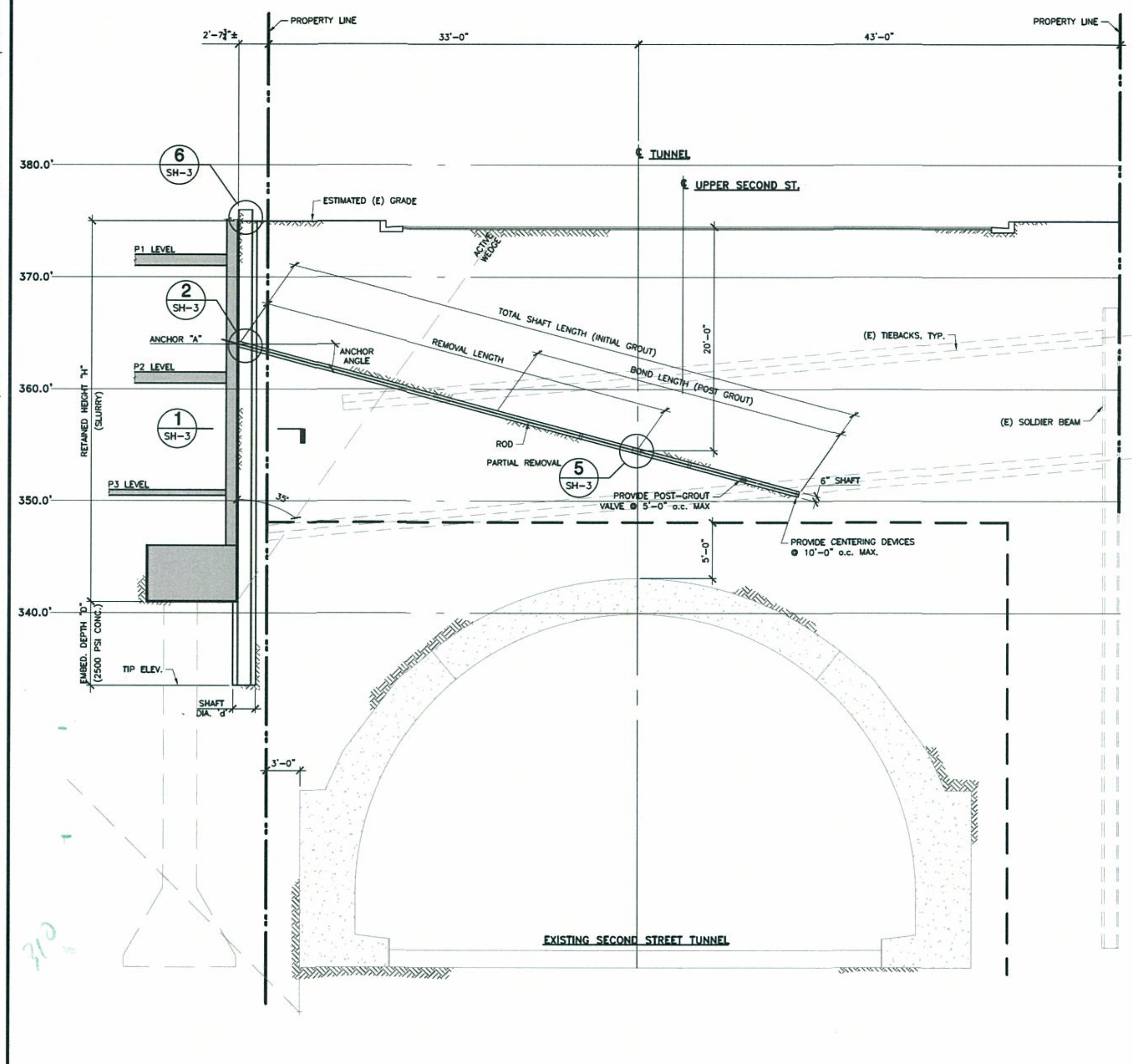

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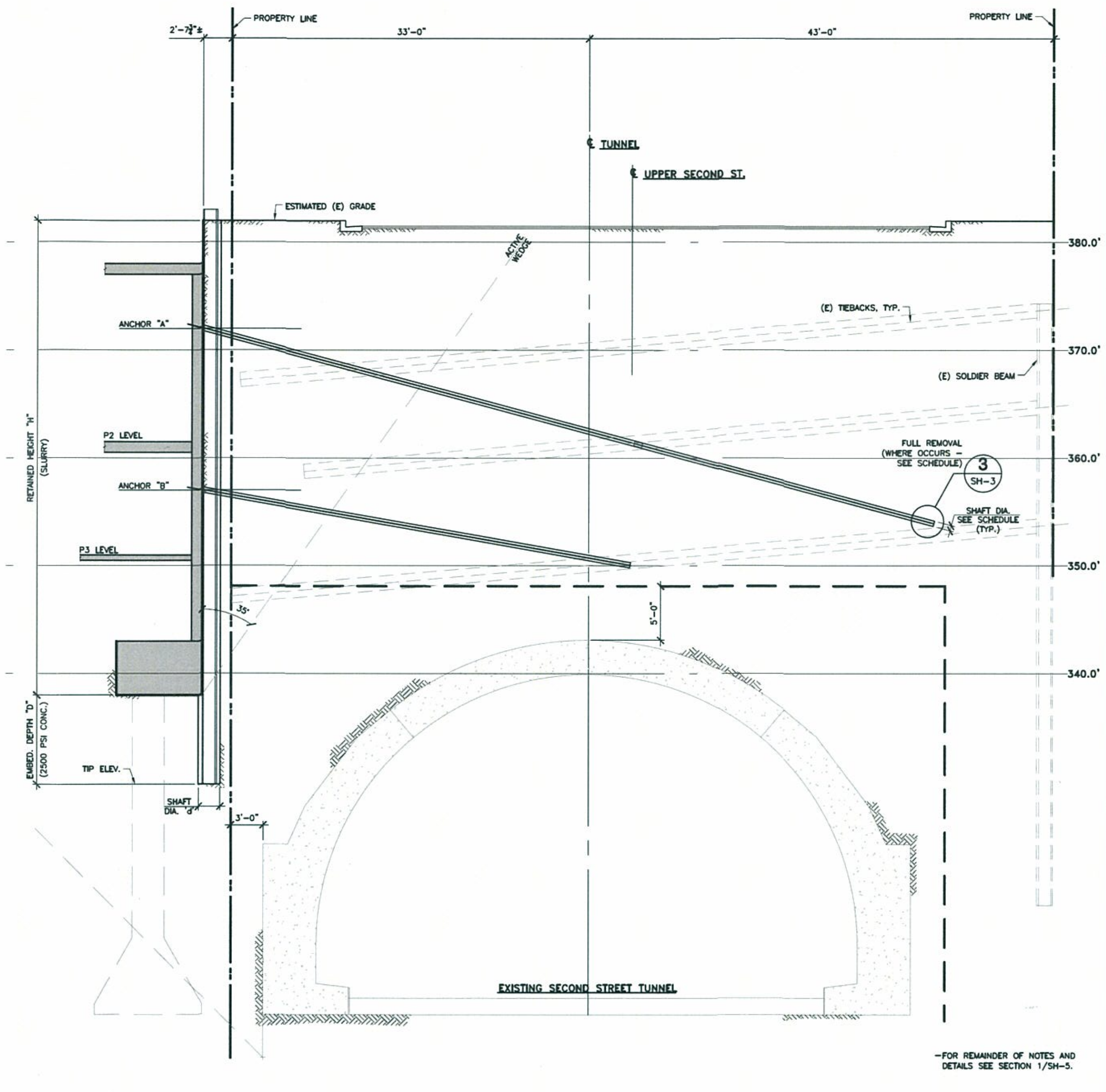

SECTION 2 SH-5
3/16" = 1'-0"

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△ 10-20-10	DYY

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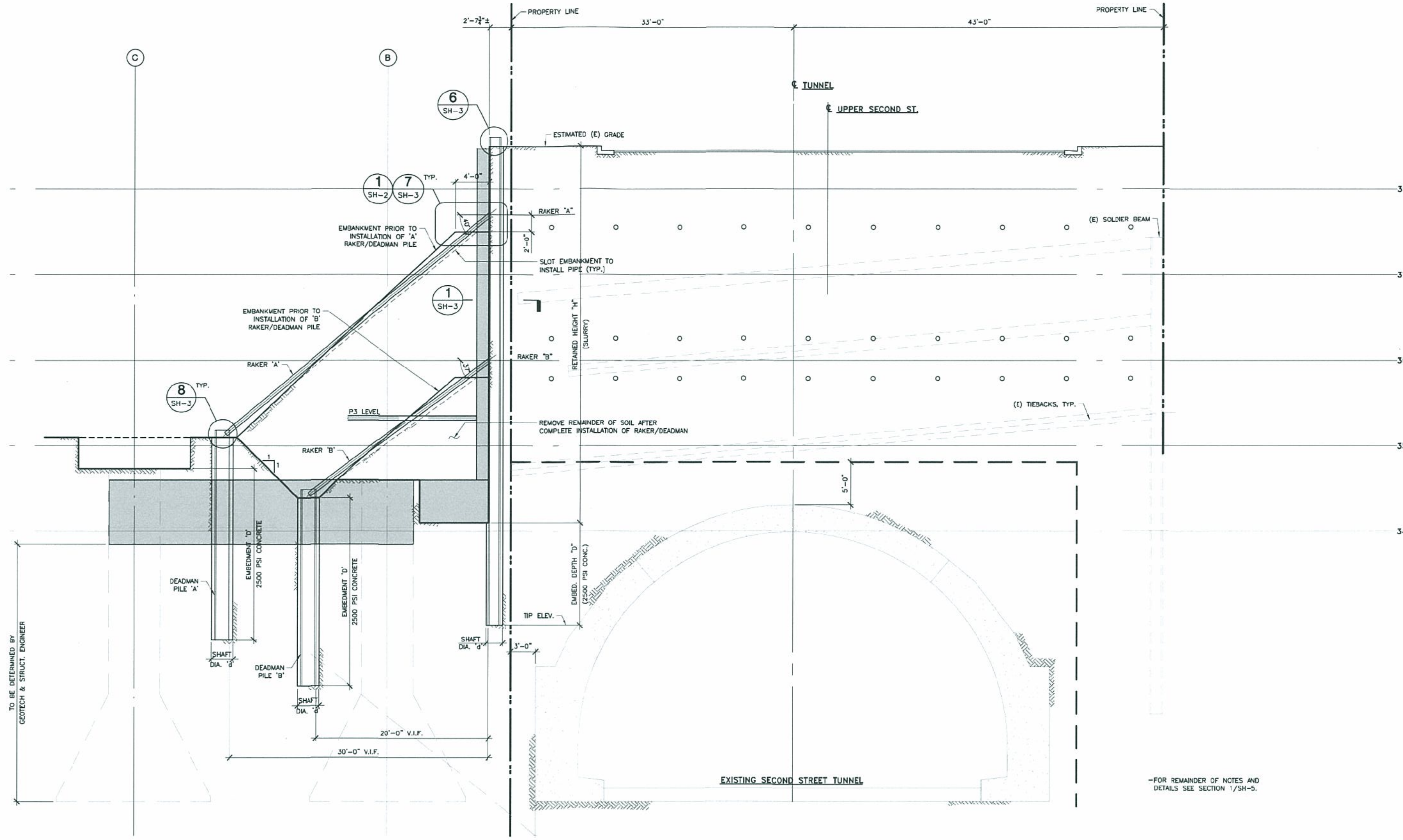

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#22–#23 #24–#25, #26–#27	W27x146	30'	36"	W27x146	35'	36"
#28	W21x101	25'	30"	W21x93	30'	30"
#29–#30	W27x146	30'	36"	W27x146	35'	36"

SECTION 3 / SH-6
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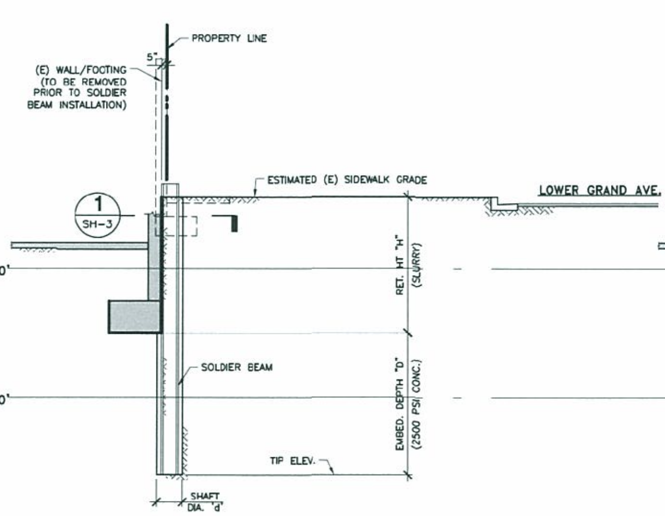

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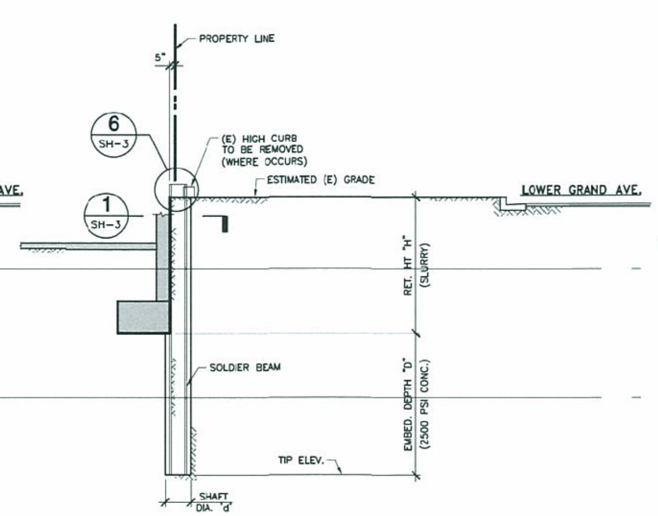

SECTION 5 / SH-6
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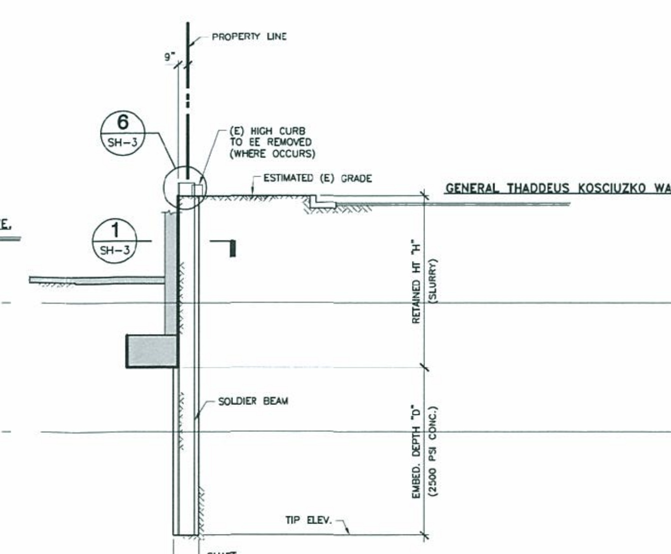

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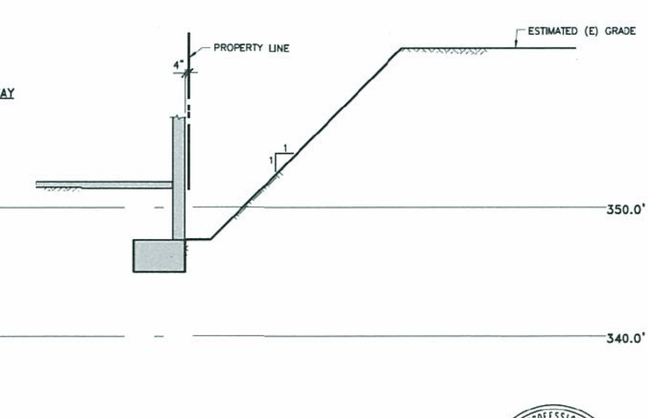

SECTION 7 / SH-6
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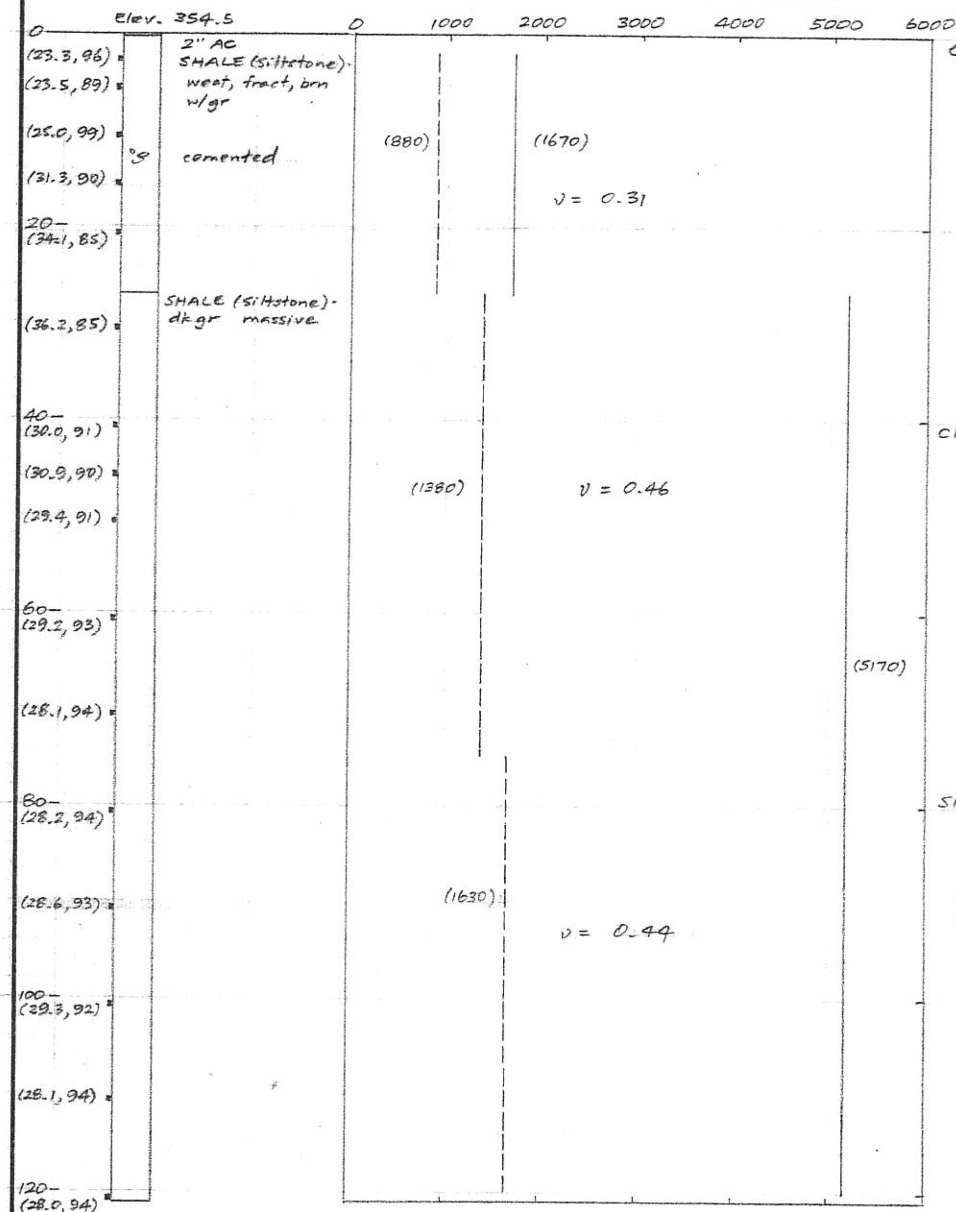
APPENDIX B
Data from soil studies

JOB NO: ADE-81361   CLIENT: BUNKER HILL ASSOCIATES

LOCATION: BETWEEN GRAND AVE. & OLIVE ST. AND 2nd & 3rd PL., LA   [LA 44D2,3]

DATE PERFORMED: 12/18/81   DM + HW   5" ROTARY WASH BORING

BORING 2   PROPAGATION VELOCITY (FT/SEC)



Water level not established

GEOLOGY:

Fernando Formation (Repetto)

CHARACTERISTIC SITE PERIOD:

"A"	0-27'	880 ft/sec
	27-75	1380
	75-120	1630
	>120	2500*
"B"	0-27'	880
	27-75	1380
	75-120	1630
	120-150	2000*
	>150	2500*

$0.5 < T_S < 0.6$ sec

SITE CLASSIFICATION:

Trifunac	1	Intermediate Rock
Mohraz	1	Rock
Seed	2	Stiff

LOG OF DOWNHOLE SEISMIC SURVEY

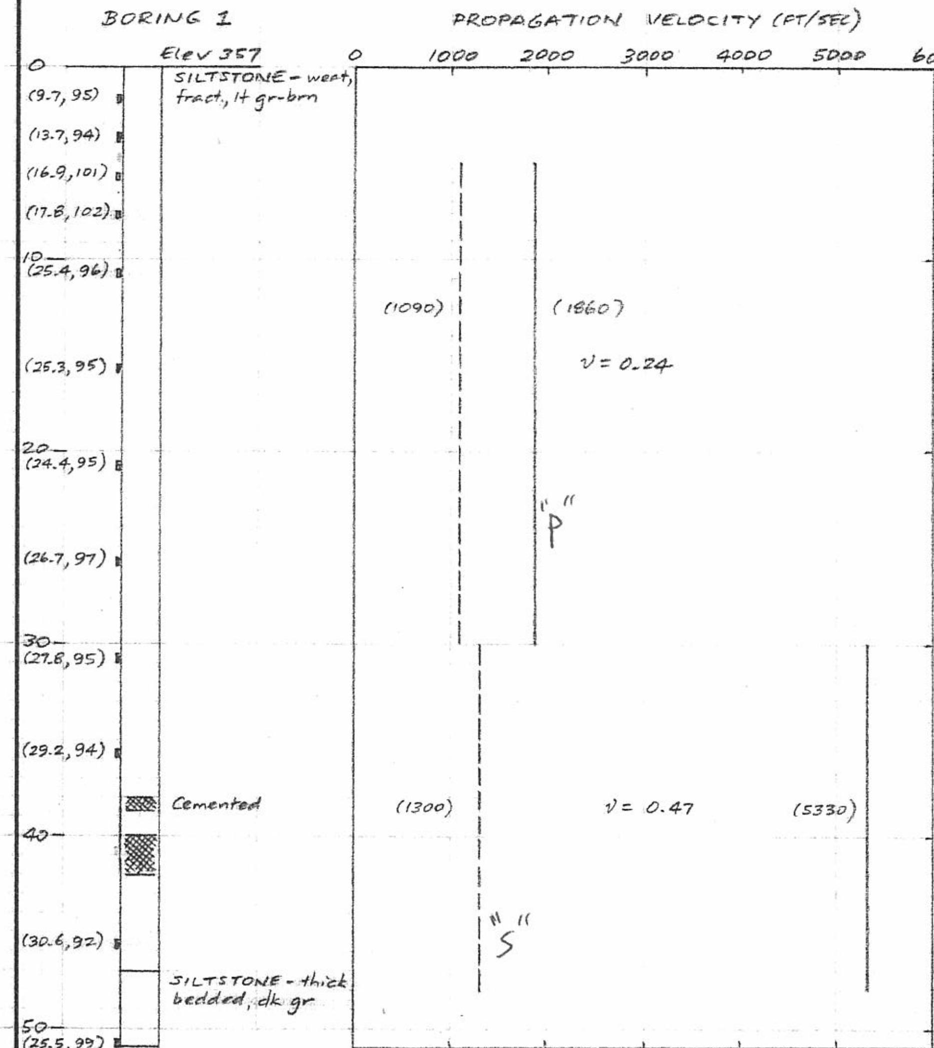
LeROY CRANDALL & ASSOCIATES

PLATE

JOB NO: ADE-77245 CLIENT: RETIREMENT HOUSING FOUNDATION

LOCATION: BETWEEN OLIVE & HILL STS., SOUTH OF SECOND ST., L.A. [44D3]

DATE PERFORMED: 9/77 5" ROTARY WASH BORING



Estimates based on averages.

GEOLOGY:

Repetto formation (Tertiary age) (Fernando)

SITE PERIOD:

"A"	0-30'	1090 ft/sec
	30-50	1300
	50-100	2000*
	>100	2500*
"B"	0-30'	1090
	30-50	1300
	50-150	2000*
	>150	2500*
"C"	0-30'	1090
	30-50	1300
	50-75	1300*
	75-150	2000*
	>150	2500*

$\frac{1}{3} < T_s \leq \frac{1}{2}$ sec

✓ 12/80

SITE CLASSIFICATION

Trifunac	1	Intermediate Rock
Mohraz	1	Rock
Seed	2	Stiff

LOG OF DOWNHOLE SEISMIC SURVEY

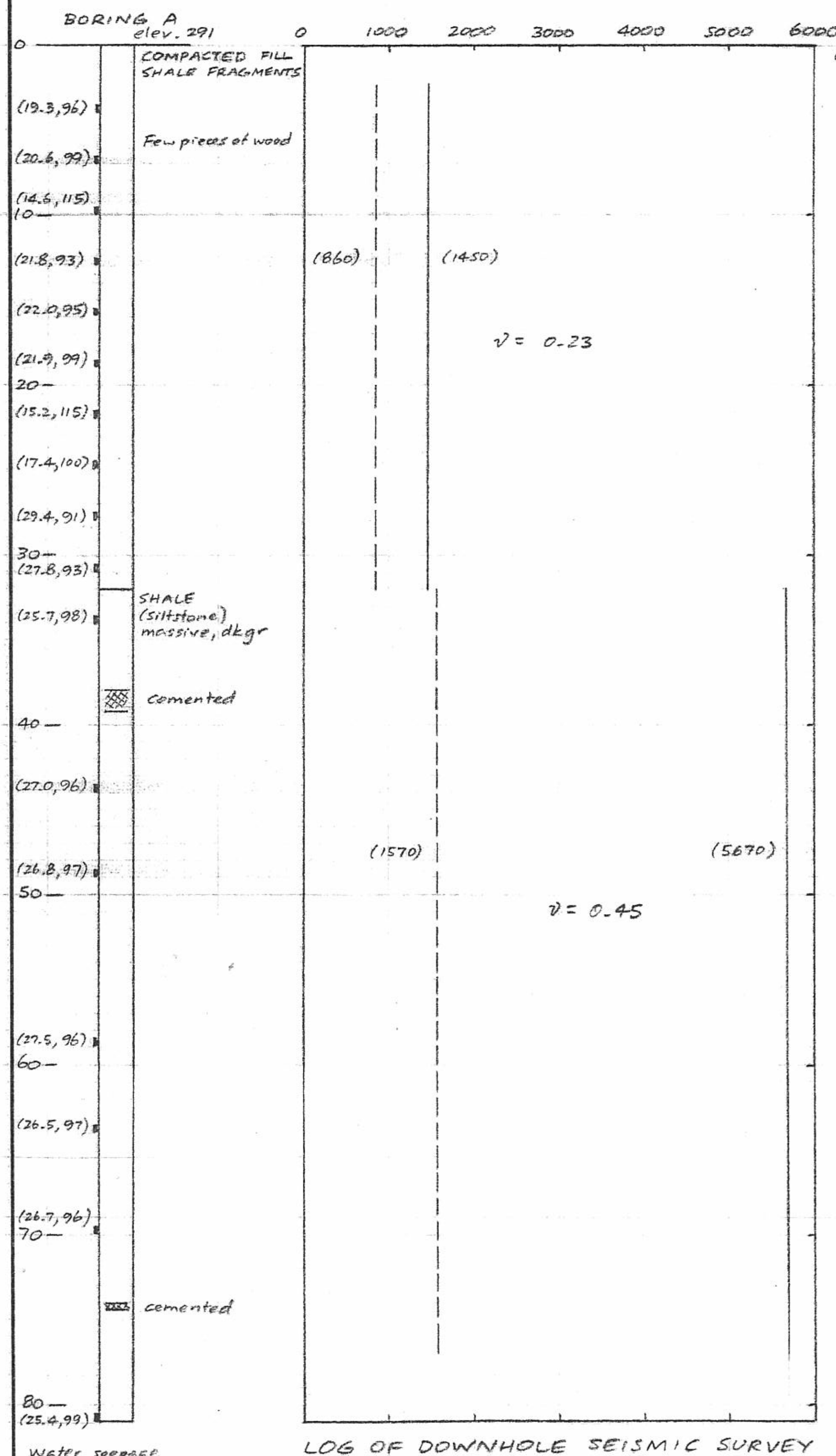
LEROY CRANDALL & ASSOCIATES

JOB ______ DATE ______ BY ______

JOB NO: ADE-78256 CLIENT: ROCKEFELLER REALTY CORP.

LOCATION: NEC FLOWER & FIFTH ST., L.A. [44C3]

DATE PERFORMED: 8/ /78 8" DIAMETER ROTARY WASH BORING



LOG OF DOWNHOLE SEISMIC SURVEY

GEOLOGY:

Compacted Fill
Pliocene Repetto Formation
(Fernando)

SITE PERIOD:

"A"	0-32'	860 ft/sec
	32-78	1570
	78-100	1570*
	100-150	2000*
	>150	2500*
"B"	0-32	860
	32-78	1570
	78-125	2000*
	>125	2500*

$0.4 < T_S < 0.6$ sec

✓ reviewed 10/80

SITE CLASSIFICATION:

Trifunac	1	Intermediate Rock
Mohraz	1	Rock
Seed	2	stiff soil

LeRoy Crandall & Associates

PLATE

JOB DATE BY

WILSON IHRIG & ASSOCIATES
ACOUSTICAL AND VIBRATION CONSULTANTS
CALIFORNIA NEW YORK WASHINGTON

6001 SHELLMOUND STREET
SUITE 400
EMERYVILLE, CA 94608
Tel: 510-658-6719
Fax: 510-652-4441
www.wiai.com

DATE: 7 October 2011

TO: John Prizner, Connector Partnership

FROM: Deborah Jue, Richard Carman

SUBJECT: Noise and Vibration - Task 7.1.1.4 – Revised Tunnel Depth WIA#10-088

We understand that a value engineering exercise for the Regional Connector Project has resulted in a shallower tunnel in the vicinity of the proposed Broad Museum and the Walt Disney Concert Hall compared to the June 29 2011 Draft Submittal Preliminary Engineering alignment. The earlier analyses (Broad, dated 30 March 2011) had used a top-of-rail depth below Lower Grand Avenue on the order of 100 ft based on alignment drawings and available drawings for the proposed Broad Museum garage. Based on the June 2011 alignment a depth of about 115 ft was used for the most recent analysis at WDCH (dated 11 July 2011). We understand that the VE alignment is approximately 14 ft shallower than the June 2011 alignment. Thus, the Broad Museum analysis conducted on March 30, 2011 was at a depth 1 ft higher than the depth currently proposed (14 higher than the June 2011 alignment). Therefore the Broad Museum analysis is still correct in that the mitigations identified are still sufficient and that no new analysis is necessary for the Broad Museum.

In addition, the conclusions from the noise and vibration analyses done to date are sufficient to account for the potential shallower depth of the tunnel, because a) field studies conducted for WDCH indicate that such a difference would typically account for 0-3 dB difference and b) the expected impacts would be eliminated through the mitigation options already identified. More specifically, the studies to date have assumed that lower-performing technology would be sufficient to mitigate the impacts of the June 2011 alignment. Thus, the anticipated effects of a 14-ft-shallower tunnel on those impacts can still be mitigated, if not with the original lower-performing technology (e.g., high compliance resilient fasteners or rail suspension fasteners, etc.), then with one of the higher-performing technologies (e.g., various forms of floating slab track).

Thus, we suggest that a revised analysis is not required at this time, because there would be no new impacts and the analysis to date is sufficient to determine that impacts from the 14-ft-shallower tunnel can be mitigated with available technologies already identified in the FEIS.