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M E M O R A N D U M

To: Kathryn O'Brien
Central Corridor Project Office

From: Hugh Saurenman
Shannon McKenna
ATS Consulting

Date: April 23, 2010

Subject: Vibration and Noise Management and Remediation Plan

INTRODUCTION

An important consideration during construction of the Central Corridor Light Rail Project will be to protect the existing historic properties from vibration induced damage. This Vibration Noise Management and Remediation Plan (VNMRP) presents the preliminary and detailed review of the buildings in Attachment A of the Programmatic Agreement that are within 50 feet of the CCLRT alignment and the proposed approach for minimizing the potential for vibration induced damage. It was prepared to fulfill obligations of the Central Corridor LRT Programmatic Agreement, specifically, Stipulation V, Noise and Vibration Assessment and Mitigation. The review of historic buildings was performed by MacDonald & Mack Architects with staff qualified as historic architects under the Secretary of the Interior's Professional Qualifications Standards. The proposed strategy for minimizing vibration impacts was developed by ATS Consulting.

MINIMIZING ADVERSE EFFECTS FROM VIBRATION

The goal of the vibration section of the VNMRP is to maximize the protection of historic structures using techniques that have proven successful at minimizing damage caused by vibration during construction. The key elements of the plan are a careful review of the historic buildings, assigning vibration limits to each building that are appropriate for the condition of the specific building, and monitoring building condition and the vibration levels during construction. While it is not possible to guarantee that no damage will occur during construction, through a series of reasonable steps most potential for damage can be eliminated.

The specific steps that will be taken to protect buildings from damage during construction are:

A. Pre-Construction Survey: It is relatively standard to perform a pre-construction survey of the structural elements of buildings in the vicinity of major construction projects. Pre-construction surveys typically include inspecting building foundations, exterior, and interior elements and documenting any pre-existing defects such as cracks, settlement, subsidence, corrosion, or water damage. Defects that should be monitored during construction will be noted and, where appropriate, crack monitors installed prior to the start of construction. For historic structures, the pre-construction survey also will include an inspection of the historically significant features of the buildings. Historically significant features found in buildings along the CCLRT alignment include decorative elements such as ornamental terra cotta, stained glass windows, and sheet metal cornices. The historical survey was performed by MacDonald & Mack Architects and the structural survey will be

performed by qualified professional engineers prior to the start of construction. The survey report will assist in the resolution of any damage claims that are made as a result of the construction.

B. Vibration Limits: This report includes recommended vibration limits for each of the identified historic structures. The limits are based on guidelines provided by the Federal Transit Administration (FTA) and on the potential sensitivity of each building as identified by MacDonald & Mack Architects. Background on vibration thresholds used to protect sensitive buildings is provided in Appendix A of this VNMRP. Construction vibration limits are almost always given in terms of the peak particle velocity (PPV) in inches per second (in/sec). The two thresholds are:

1. Historic buildings that have standard vibration sensitivity: **0.5 in/sec (PPV)**
2. Historic buildings with greater potential for damage from vibration: **0.12 in/sec (PPV)**

As discussed in Attachment A, a PPV of 2 in/sec is the most common vibration limit for construction projects and there is research that suggests that many single family residences and other structures can sustain substantially higher vibration levels without damage. Therefore, the use of 0.5 in/sec as the default vibration limit for a historic building is conservative. The limit of 0.12 in/sec for fragile historic structures is among the most restrictive limits used to protect buildings. Again, this is a conservative limit and most historic structures in the CCLRT corridor probably could experience substantially higher vibration levels without experiencing even minor cosmetic damage.

C. Vibration Monitoring: The primary goal of monitoring is to verify that the vibration limits are not exceeded. When construction activities that create high vibration levels will be performed near vibration sensitive buildings, the contractor will be required to continuously monitor vibration to verify that the construction activities do not exceed the vibration limits. In addition, the contractor will be required to perform testing to verify that the vibration levels will be below the applicable limits before starting the actual construction. For example, if vibratory compaction is needed near a historic building, a short test using the compactor should be monitored prior to starting the compaction to ensure that the vibration levels will be below the allowable limits. If vibration from the test approaches or exceeds the limits, the contractor will be required to reduce the intensity of the vibratory compactor until the vibration amplitudes at all sensitive buildings are below the applicable limit. Only then will the actual vibratory compaction commence, with continued monitoring. More information on the equipment, process, and documentation of vibration monitoring is included in Attachment E.

D. Visual Inspection During Construction: Follow-up visual inspection of particularly sensitive building features will be performed during and after high-vibration construction activities near sensitive buildings. For example, the visual inspections of stained glass windows at several churches will be performed periodically to verify that no problems are developing.

E. Remove or Secure Fragile Elements: Before construction begins, some of the fragile elements in a building, such as chandeliers or wall decorations, can be removed for the duration of the construction, or they can be more safely secured to the wall to ensure that they are not damaged or displaced due to high vibration activities. The historic architects for the project will be available to consult with the building owners to identify any fragile elements that should be secured prior to the start of construction. The securing of the fragile elements will be the responsibility of the building owners.

F. Secure or Repair Loose Elements: Any elements identified on a building as loose or in danger of damage due to a pre-existing condition can be repaired prior to construction to ensure that high vibration activities will not exacerbate the problem. If it is not feasible to repair the element (which would be the building owner's responsibility), temporary means of securing the element should be

used. Again, the historic architects for the project will be available to consult with the building owners on any repairs that are recommended.

G. Alternative Construction Procedures: For some construction processes, it may not be feasible to meet the vibration limits. In these cases, alternative construction processes may be required. Examples include the use of vibratory compaction near several of the historic churches and operating large tracked vehicles such as bulldozers next to sensitive buildings. Alternative procedures include use of non-vibratory compaction in limited areas and using a bobcat in place of large bulldozers within 25 ft of buildings.

REVIEW OF HISTORIC BUILDINGS

MacDonald & Mack conducted a review of all the buildings in Attachment A of the Programmatic Agreement that are within 50 ft of the proposed LRT route. The report detailing their findings is included as Attachment B of this VNMRP. Photographs of some of the architectural elements of concern are found in Attachment C and maps showing the general location of the buildings are given in Appendix D.

Table 1 summarizes the information and recommended mitigation measures for each of the buildings listed in Attachment A of the Programmatic Agreement. The first column gives the building name, the second column identifies the buildings that have structural elements that required a more detailed review by MacDonald & Mack to determine necessary vibration mitigation measures. They are numbered corresponding with labels on the maps in Attachment D showing their locations.

An 'X' in the third column indicates that the building requires a pre-construction survey. All buildings identified in the Programmatic Agreement require the survey. Information regarding the methodology for the survey can be found in Attachment E.

The vibration monitoring columns specify the appropriate vibration limit for each building that the contractor must comply with and that will be verified by vibration monitoring. The vibration limit of 0.5 in/sec PPV is applicable to all of the buildings and structures listed in Table 1 and the 11 properties identified in the review by MacDonald and Mack as having architectural concerns will require monitoring. Of those 11 properties, the three buildings that are identified as requiring the vibration limit of 0.12 PPV for fragile historic buildings are the St. Louis, King of France Catholic Church, the Central Presbyterian Church, and St. Agatha's Conservatory of Music and Fine Arts. Attachment E is draft specifications on the vibration limits and monitoring that will be incorporated into the construction documents.

An 'X' in the ground-borne noise mitigation or airborne noise mitigation column indicates those buildings that were identified in the FEIS as requiring mitigation. Ground-borne and airborne noise mitigation refers to reducing noise and vibration from operation of the CCLRT. A discussion of the appropriate ground-borne noise mitigation for operation is found in the following section. None of the historic properties listed in the Programmatic Agreement were identified in the FEIS as requiring mitigation of airborne noise generated by light rail operations.

The special provisions column indicates those buildings that were identified by MacDonald & Mack in their detailed review of historic buildings to warrant special consideration in the development of vibration limits and mitigations during construction. Those special provisions are discussed in detail in the Special Provisions section below.

The comments column notes the elements of each building that were investigated by MacDonald & Mack during their detailed review. Please refer to Attachment B, the MacDonald & Mack memorandum, for more details on their review of the historic structures.

Table 1: Summary of Susceptible Buildings and Mitigations

Property:	Historic Building Survey	Pre-construction Survey	Vibration monitoring*		Ground-borne noise mitigation	Airborne noise mitigation	Special provisions	Comments
			Limit (PPV in/sec)					
			0.12	0.50				
Fire Station G, Engine House 5 (Mixed Blood Theatre)		X						
Washington Avenue Bridge		X						
University of Minnesota Campus Mall Historic District		X				X		
Prospect Park Residential Historic District		X						
KSTP Production Studios & Transmission Tower		X			X			
University-Raymond Commercial Historic District :		X						
Mack Building	1	X		X				Ornamental terra-cotta
Conditioned Air Equipment Co.		X						
Johnson Wax Company		X						
Brown-Jaspers		X						
New Wine Church		X						
Security Building		X						
Borchert-Ingersoll Mach. Corp.		X						
Redwing Stoneware Company		X						
2295 Building		X						
Midway Commerce Building		X						
Wright Building		X						
Louis F. Dow Company		X						
Midtown Commons		X						
Specialty Building	2	X		X				Applied art-deco veneer
Twin Cities Bank		X						
GM Truck Garage		X						
Chittenden & Eastman Building		X						
Irving Hudson Commercial		X						
Frigidaire Building		X						
Midway Commercial Building		X						
Fire Station No. 20		X						
Great Lakes Coal and Dock Company Office Building		X						
Minnesota Transfer Railway Company including Main Line		X						
Minnesota Transfer Railway Company University Avenue Bridge		X						
Krank Building (Iris Park Place)	4	X		X				Ornamental terra-cotta
Porky's Drive-In Restaurant	3	X		X				Sign and metal panels
Griggs, Cooper & Company Sanitary Food Manufacturing Plant		X						

Property:	Historic Building Survey	Pre-construction Survey	Vibration monitoring*		Ground-borne noise mitigation	Airborne noise mitigation	Special provisions	Comments
			Limit (PPV in/sec)					
			0.12	0.50				
Quality Park Investment Company Building		X						
St. Paul Casket Company Factory		X						
Brioschi-Minuiti Company Building		X						
Raths, Mills & Bell Company Building		X						
Fire Station No. 18		X						
Owens Motor Company Building		X						
Minnesota Milk Company Building		X						
Ford Motor Company Building		X						
Norwegian Evangelical Lutheran Church (Christ Lutheran Church)	5	X		X				Stained-glass windows, towers
State Capitol Mall Historic District		X						
Minnesota State Capitol	6	X		X				Marble venner, chandeliers, art-glass elements
Minnesota Historical Society Building (Judicial Center)		X						
State Capitol Power Plant		X						
Central Presbyterian Church	8	X	X		X	X	X	Stained glass windows
St. Louis, King of France Church and Rectory	7	X	X		X	X	X	Chandeliers, wall sconces, stained-glass windows, bells
St. Agatha's Conservatory of Music and Fine Arts	9	X	X			X	X	Loose sheet metal cornice
St. Paul Athletic Club	10	X		X				Ornamental terra-cotta
Minnesota Building		X						
St. Paul Urban Renewal Historic District		X						
Pioneer Press Building		X						
First National Bank Building		X						
Endicott Building	11	X		X				Interior leaded-glass arcade
Lowertown Historic District		X						
St. Paul Union Depot (Including elevated railroad track deck)		X						
* An X in the vibration monitoring column indicates the buildings where monitoring will be performed and what the vibration limit is. The limit of 0.5 in/sec PPV is applicable to all of the other buildings. Monitoring will be performed at these buildings if potential vibration problems arise.								

GROUNDBORNE NOISE MITIGATION AND CONTROL

The three historic properties identified in the FEIS as requiring ground-borne noise mitigation are the KSTP Studios, the St. Louis, King of France Catholic Church and the Central Presbyterian Church:

- **KSTP Studios**: The predicted ground-borne noise levels exceed the FTA impact threshold for ground-borne noise in the studios closest to University Avenue. The main broadcast studios are substantially farther from University Avenue and predicted ground-borne noise levels are well below the impact threshold. Sufficient mitigation of the ground-borne noise levels in the smaller studios closest to University Avenue can be achieved through the use of resilient fasteners.
- **St. Louis, King of France Catholic Church and Central Presbyterian Church**: The predicted ground-borne noise levels exceed the FTA impact threshold for ground-borne noise at both churches. The impact can be eliminated through the use of a floating slab track system or an equivalent vibration mitigation measure.

An important step in controlling levels of ground-borne vibration and noise during operation is to maintain the wheels and rails in good condition. The smoother the interaction of the wheels and rails, the lower the vibration forces are. All indications are that Metro Transit's maintenance policies have been successful at maintaining the wheels and rails on the Hiawatha LRT in good condition. Metro Transit's policy with respect to identifying wheels with flats and truing the wheels is:

- When an operator notices that a vehicle has a flatted wheel, the maintenance department is notified and the vehicle is scheduled for maintenance at the next opportunity.
- The wheel tires are inspected and hand measured every 5,000 miles. Any wheels with profiles that do not meet the specifications or that have flats are scheduled for maintenance.
- A laser system is used to measure the wheels every 25,000 miles. If the wheel profile or the wheel out-of-roundness does not meet the specifications, the wheels are scheduled for maintenance.

The lack of any identifiable wheel flats during the measurements performed for this study is evidence that Metro Transit's policy on wheel maintenance is successful at controlling the occurrence of wheel flats.

SPECIAL PROVISIONS

St. Louis, King of France Catholic Church, the Central Presbyterian Church, and St. Agatha's Conservatory of Music and Fine Arts are the three buildings identified by MacDonald and Mack requiring special provisions due to potential for damage during high vibration construction activities. The concerns and special provisions for each of the three buildings follow below:

- **St. Louis, King of France Catholic Church**: There are chandeliers and wall sconces with glass shades that are easily displaced; vibrations may cause them to fall. Some of the stained-glass windows are bowed, and both vertical and horizontal vibrations may accentuate this bowing; all the stained glass is on the sides, not on the Cedar Street façade. There also was concern that vibrations may disturb the delicate balance on the bells in the two towers.

  In addition to the standard vibration mitigation measures of the pre-construction survey and vibration monitoring, it is recommended that glass shades of the wall sconces be removed or secured prior to the start of construction and that the stained glass windows be visually inspected during construction to verify that no degradation is occurring. The vibration limit for the church is 0.12 PPV in accordance with the FTA criteria for a fragile historic building.

- **Central Presbyterian Church**: The Cedar Street stained glass window installed in 1974 is as originally designed, but the original supports were under-structured ; there are numerous "hinge points" that are easily offset by both horizontal and vertical movement.

In addition to the standard vibration measures, visual inspection of the windows during construction is recommended to ensure their condition does not deteriorate during construction. The vibration limit for the church is 0.12 PPV in accordance with the FTA recommended criteria for a fragile historic building.

- **St. Agatha's Conservatory of Music and Fine Arts**: The loose sheet-metal cornice is an existing condition that may be exacerbated by vibrations. The loose sheet-metal should be repaired or secured prior to construction. Assuming that the repairs are performed by an experienced craftsman, the lower vibration limit of (0.12 in/sec PPV) will not be necessary for this building. If there is any question about the repairs or repairs have not been performed, the lower vibration limit should be used and visual inspection during construction should be periodically performed to ensure that the condition of the sheet metal does not degrade during construction.

PUBLIC NOTIFICATION AND INVOLVEMENT

The pre-construction survey and construction monitoring results will be made available to both owners of historic properties and to the Minnesota State Historic Preservation Officer (MnSHPO).

If any vibration or noise effects on the above-referenced properties are observed, the Metropolitan Council (MC) will be notified. When problems such as exceeding vibration thresholds or identification of damage during a visual inspection occur, the contractor will identify specific provisions to address those problems including, but not limited to, cessation of construction activity during implementation of mitigation measures and repair of damage.

If public complaints arise during construction, the complaints will be handled in accordance with the complaint procedure described in Attachment E.

CONCLUSION

Historic properties along the Central Corridor can be protected from adverse vibration effects during construction with the implementation of the appropriate mitigation measures. The FTA recommends thresholds for vibration during construction to ensure that damage doesn't occur due to these activities. The threshold for fragile buildings is 0.12 PPV and the threshold for standard residences and buildings is 0.5 PPV. The application of these thresholds to the corridor along with a pre-construction survey, applying alternative construction procedures where possible, vibration monitoring, visual inspection, and removal or repair of sensitive elements where appropriate will sufficiently protect historic buildings along the corridor.

Ground-borne and airborne noise mitigation requirements were discussed in detail in the FEIS. This VNMRP summarizes the necessary mitigation measures at historic properties identified in the Programmatic Agreement.

A review of the corridor was conducted to identify any historic buildings with potential for damage due to vibration during construction. A visual inspection was conducted to determine the likelihood of damage to any susceptible architectural elements, and subsequently determine an appropriate vibration limit. Based on the review, the buildings with most likelihood of damage are St. Louis, King of France Catholic Church; Central Presbyterian Church, and St. Agatha's Conservatory of Music and Fine Arts. Special provisions were outlined for these properties to ensure protection during construction.

ATTACHMENT A: BACKGROUND ON VIBRATION LIMITS

Most limits on construction vibration are based on minimizing the potential for damage to nearby structures. The construction activity that is most commonly associated with building damage is blasting during mining operations or excavation. Blasting would not be required for construction of the Central Corridor LRT, which substantially reduces the potential for structural damage.

The construction processes for the Central Corridor LRT project that are expected to generate the highest vibration levels include demolition using jackhammers and hoe rams, and operation of heavy tracked equipment such as bulldozers and backhoes. Source levels for common construction equipment are shown in Table 2. The source levels are given in terms of a peak particle velocity (PPV) measured at a distance 25 feet from the equipment.

Table 2: Vibration Source Levels for Construction Equipment

Equipment		PPV at 25 feet (in/sec)
Pile Driver (impact)	upper range	1.518
	typical	0.644
Pile Driver (sonic)	upper range	0.734
	typical	0.170
Clam shovel drop (slurry wall)		0.202
Hydromill (slurry wall)	in soil	0.008
	in rock	0.017
Vibratory Roller		0.210
Hoe Ram		0.089
Large bulldozer		0.089
Caisson drilling		0.089
Loaded trucks		0.076
Jackhammer		0.035
Small bulldozer		0.003

Source: FTA, "Transit Noise and Vibration Impact Assessment" (May 2006) (FTA-VA-90-1103-06), page 12-12.

The most common vibration limit for construction projects is a PPV of 2 in/sec, which is largely based on studies performed by the U.S. Bureau of Mines. A study reported on in USBM Bulletin 656 (1971) investigated the effect of blasting vibration on roadways, bridges, concrete structures, and residential structures. The results indicated that minor damage such as cracks in masonry, drywall, and plaster in old residential structures can occur at a vibration level above 5.4 in/sec. The "threshold of damage" limit recommended by the USBM was 4.0 in/sec, which was considered sufficient to avoid structural or cosmetic damage to residences. A recommendation by the US Office of Surface Mining is to use a limit of 0.75 in/sec to protect against growth of hairline cracks in weak residential structures including hairline cracks that may be too small to be seen without magnification.

In addition, there are several European standards that specify substantially lower limits to protect against damage to fragile historic structures. One example is Swiss Standard SN640312a (April 1992) from the Association of Swiss Highway Professionals, Committee VSS 272. The values from the Swiss Standard are shown in Table 3. Based on the definitions in the Swiss Standard, residences in the project area would be categorized as "Average Sensitivity" and the three buildings identified by MacDonald and Mack as particularly sensitive would be classified as "Particularly High Sensitivity." The rate of occurrence would be considered "Frequent." The Swiss Standard indicates that a vibration limit of between 0.12 and 0.24 in/sec (PPV) for vibration below 30 Hz would be appropriate for the sensitive historic structures. This is substantially lower than the vibration limits in most other standards.

Table 3: Guideline Values for Construction Vibration (Swiss Standard SN640312a)

Sensitivity Category	Rate of Occurrence	Guideline Value (in/sec)		
1. Very Low Sensitivity		Up to 3 times the values for Sensitivity Category 3		
2. Low Sensitivity		Up to 2 times the values for Sensitivity Category 3		
3. Average Sensitivity		< 30 Hz	30 to 60 Hz	> 60 Hz
	Occasional	0.59	0.79	1.18
	Frequent	0.24	0.31	0.47
	Permanent	0.12	0.16	0.24
4. Particularly High Sensitivity		Between 0.5 and 1 times the values for Sensitivity Category 3		

The Federal Transit Administration (FTA) manual recommends a range of limits for vibration during construction to protect buildings and to avoid annoyance to residences and institutions located near construction. Table 4 below includes the limits for fragile historic buildings and normal buildings. Limits for identified historic buildings along the Central Corridor will be either the FTA recommended thresholds for fragile buildings or for normal buildings, depending on their current condition. Applying the fragile historic building threshold, the only construction activities of concern along the length of the project corridor, at a distance 25 feet according to Table 2, is the vibratory roller.

Table 4: Impact Thresholds for Construction Vibration

Land Use	Threshold		Comments
	PPV[1] (in/sec)	RMS[2] (VdB)	
Fragile historic buildings	0.12	90	Avoiding vibration that exceeds this threshold should be sufficient to protect the most fragile buildings.
Normal single family residences, office buildings and commercial buildings	0.5	102	This limit is considered sufficient to avoid even minor cosmetic damage to typical construction.

Source: ATS Consulting (2008)

Notes:

[1] PPV is peak particle velocity.

[2] RMS is the root mean square velocity with a 1-second time constant. A crest factor of 4 has been assumed to convert between PPV and RMS vibration velocity.

ATTACHMENT B: HISTORIC BUILDING REVIEW

Following is the memorandum prepared by MacDonald & Mack Architects on their review of the historic structures in the CCLRT corridor.

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Memorandum

Project	Central Corridor LRT NVMRP
Project #	2919
Date	October 23,2009
To	Kathryn O'Brien
From	Bob Mack
Subject	Historic Building Review

On September 11, 2009, the Metropolitan Council selected MacDonald & Mack Architects to assist with the Vibration and Noise Management and Remediation Plan (VNMRP) as it relates to historic buildings along the Central Corridor LRT. The Council's retention of a historical architectural consultant was in partial fulfillment of the Programmatic Agreement concerning historic properties along the LRT route. This memo will present our findings and recommendations.

Preliminary Review

We divided our work into two parts. The first was a preliminary review of all the buildings in Attachment A of the Programmatic Agreement that are within 50' of the proposed LRT route. The purpose was to identify those buildings that merited a second look with a more in-depth investigation. We considered the fragility of building elements visible from the street but did not enter any buildings for the purposes of this initial step. Although many historic buildings lie within the area affected by the LRT, we considered only those buildings within 50' of the tracks. While we looked at all the buildings identified in Attachment A, we paid particular attention to the buildings identified in paragraph V.2., "Vibration from PROJECT Construction" plus the University-Raymond Commercial Historic District; this District was added to the study at the request of the State Historic Preservation Office (SHPO) and other parties during a meeting on September 14. We also inspected the Cedar Street Bridge and adjacent walls at the request of the staff of the Department of Administration.

Most of the buildings along the corridor are stout industrial structures with limited decoration. These buildings were designed for heavy loads and operating

equipment, and we believe that there is little likelihood of physical damage from vibration. Buildings that we decided to investigate further are the following:

- Mack Truck building in the University-Raymond Commercial Historic District: Ornamental terra-cotta
- 2356 University Ave.: Applied art-deco veneer
- Porky's Drive-in Restaurant: Sign and metal panels of the building, itself
- 1885 University Avenue: Ornamental terra-cotta
- Norwegian Evangelical Lutheran Church: Stained-glass windows, towers
- Minnesota State Capitol: Marble veneer (identified by State personnel)
- St. Louis, King of France, Church: Stained-glass windows, towers with bells
- Central Presbyterian Church: Stained-glass windows
- St. Agatha's Conservatory of Music and Fine Arts: Loose sheet-metal cornices
- St. Paul Athletic Club: Ornamental terra-cotta
- Pioneer-Endicott Building: Interior leaded-glass arcade

More Detailed Review

Subsequent inspections of each of these buildings resulted in determining that the following the buildings do not need further consideration:

- Mack Truck building in the University-Raymond Commercial Historic District: Ornamental terra-cotta seems to be firmly attached and of little concern for vibrations
- 2356 University Ave. Applied art-deco veneer is firmly attached and is of little concern for vibration
- Porky's Drive-in Restaurant: Signage. From our observation the sign seems well built and firmly attached. We do not believe that vibration will be a problem.
- 1885 University Avenue: Ornamental terra-cotta is sound and is of little concern for vibrations
- Norwegian Evangelical Lutheran Church (Christ Lutheran Church): Stained-glass windows are sagging with age, and vibrations may accelerate continuing deterioration. On the other hand, the windows are set back from the street and are on the sides, rather than the façade facing the street, so they likely are less vulnerable to problems than at other buildings. The church organ is at the end of the nave closest to University Avenue, so vibrations may cause it to go out of tune, but there is no problem with re-tuning it.
- Minnesota State Capitol: Although Department of Administration personnel initially expressed concern about the marble veneer, they subsequently said that the problems had been fixed and that there are no current concerns. They also mentioned that vibrations during an earlier project caused the chandeliers to sway; we do not think that this poses a problem. On the other hand, there are art-glass elements that do merit

further consideration. Lead cames, the "H" shaped members between pieces of art glass, have limited strength, especially in tension, so anything that might deflect them from their initial plane can cause problems. Vibrations may accentuate any sagging of the horizontal stained glass, and they may overstress the elements of the barrel-vaulted leaded glass.

- St. Paul Athletic Club: The ornamental terra-cotta seems well anchored and of little concern for vibration. Similarly, the interior decorative finishes seem sound and of little concern.

Pioneer Endicott Building: Although we were unable to gain access to the interior of the building, the leaded-glass arcade is visible through the glass doors. As with other leaded-glass items, these are fragile elements that are easily damaged. On the other hand, these areas were rebuilt approximately 20 years ago and should still be sound.

The investigations indicate that the following buildings should receive further consideration in planning for noise and vibration control:

- St. Louis, King of France, Catholic Church: There are chandeliers and wall sconces with glass shades that are easily displaced; vibrations may cause them to fall. Some of the stained-glass windows are bowed, and both vertical and horizontal vibrations may accentuate this bowing; all the stained glass is on the sides, not on the Cedar Street façade. There also was concern that vibrations may disturb the delicate balance on the bells in the two towers.
- Central Presbyterian Church: The Cedar Street stained glass window was poorly designed when it was installed about 20 years ago; there are numerous "hinge points" that are easily offset by both horizontal and vertical movement.
- St. Agatha's Conservatory of Music and Fine Arts: The loose sheet-metal cornice is an existing condition that may be exacerbated by vibrations.

Conclusion

Based on our review, the buildings with most likelihood of damage due to vibrations during Central Corridor LRT construction are St. Louis, King of France, Catholic Church; Central Presbyterian Church, and St. Agatha's Conservatory of Music and Fine Arts. Interestingly, these three are all in the areas subject to special vibration control due to the nearby Minnesota Public Radio Building.

ATTACHMENT C: PHOTOGRAPHS

Figure 1: Photograph of Porky's Drive in Restaurant.

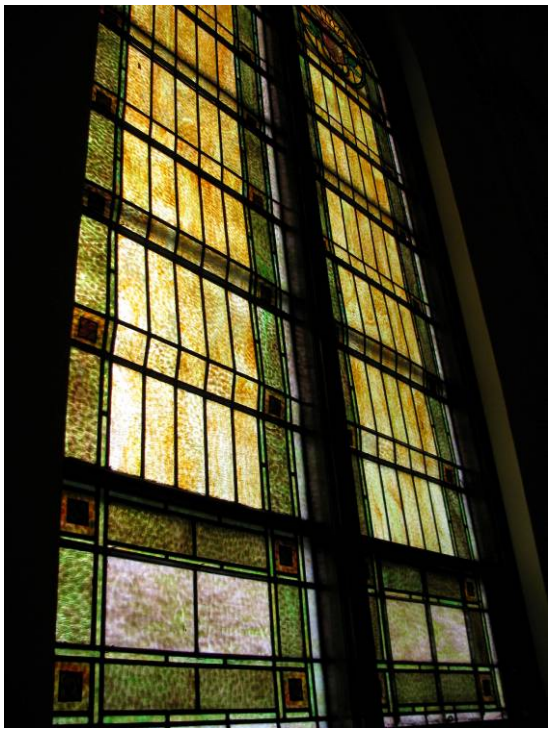

Figure 2: Photograph of stained-glass windows in the Norwegian Evangelical Lutheran Church

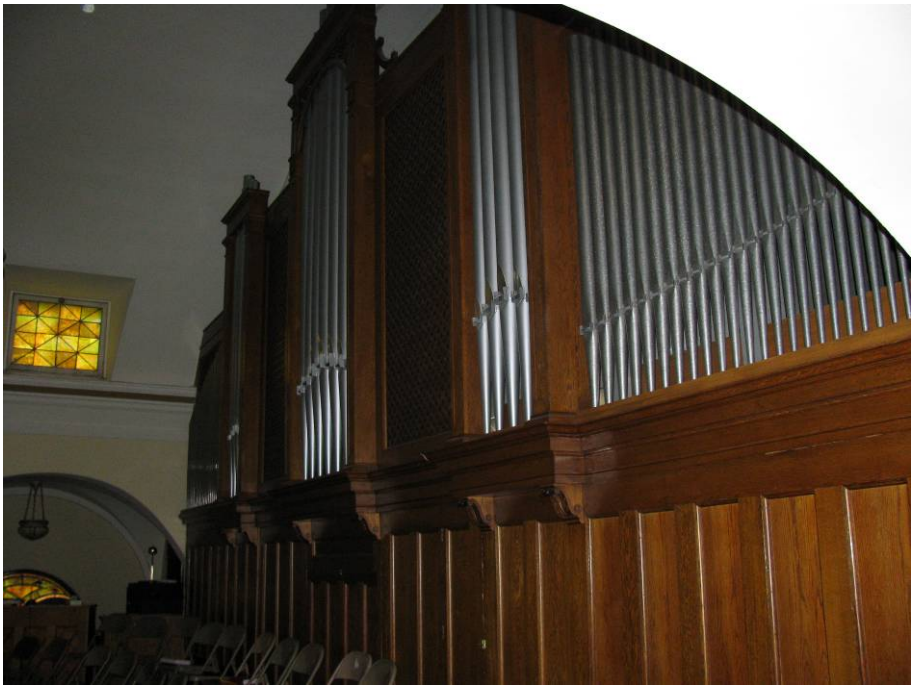

Figure 3: Photograph of the organ in the Norwegian Evangelical Lutheran Church

Figure 4: Art-glass in the Minnesota Capitol building

Figure 5: Art-glass in the Minnesota Capitol building

Figure 6: Decorative plaster in the Minnesota Capitol building

Figure 7: Chandelier in the St. Louis, King of France, Catholic Church

Figure 8: Stained glass window in St. Louis, King of France, Catholic Church

Figure 9: Example of wall sconces in the St. Louis, King of France, Catholic Church

Figure 10: Loose sheet-metal on St. Agatha's Conservatory of Music and Fine Arts building

Figure 11: Loose sheet-metal on the St. Agatha's Conservatory of Music and Fine Arts building

Figure 12: Loose sheet-metal on St. Agatha's Conservatory of Music and Fine Arts building

HISTORIC STRUCTURES ALONG CENTRAL CORRIDOR LRT

Only buildings within 50' of corridor are included.

Inventory No.	Property Name	Address	Susceptability to Vibration Damage
HE-MPC-4636	Fire Station G, Engine House 5 (Mixed Blood Theatre)	1501 4th St. S, Mpls	Little
HE-MPC·4918	Washington Avenue Bridge	Washington Ave. between Pleasant St. SE and 21st Ave. S., Mpls.	Little
Historic District	University of Minnesota Campus Mall Historic District	U of M Minneapolis Campus	Little
Historic District	Prospect Park Residential Historic District	Vicinity of 1-94, SE Williams Ave, University Ave SE and Emerald St SE. Mpls	Little
	KSTP Production Studios & Transmission Tower	3415 University Ave, W., St. Paul	Little
Historic District	University-Raymond Commercial Historic District	Along University Ave. W between Hampden and Cromwell Aves, St. Paul	
	Mack Building	2505 University Ave. W, St. Paul	Little
	Conditioned Air Equipment Company	2459-2451 University Ave. W., St. Paul	Little
	Johnson Wax Company	2447 University Ave. W, St. Paul	Little
	Brown-Jaspers	2441 University Ave. W, St. Paul	Little
	New Wine Church	2429 University Ave. W, St. Paul	Little
	Security Building	2401-2389 University Ave. W, St. Paul	Little
	Borchert-Ingersoll Machinery Corp.	2375 University Ave. W, St. Paul	Little
	Redwing Stoneware Company	2345 University Ave. W, St. Paul	Little
	2295 Building	2295 University Ave. W, St. Paul	Little
	Midway Commerce Building	2285 University Ave. W, St. Paul	Little
	Wright Building	2233 University Ave. W, St. Paul	Little
	Louis F. Dow Company	2242 University Ave. W, St. Paul	Little
	Midtown Commons	2324 University Ave. W, St. Paul	Little
	Specialty Building	2356-2362 University Ave. W, St. Paul	Little
	Twin Cities Bank	2388 University Ave. W, St. Paul	Little
	GM Truck Garage	2390-2400 University Ave. W, St. Paul	Little
	Chittenden & Eastmen Building	2402-2414 University Ave. W, St. Paul	Little
	Irving Hudson Commercial	2418-2422 University Ave. W, St. Paul	Little
	Frigidaire Building	2446 University Ave. W, St. Paul	Little
	Midway Commercial Building	2470-2512 University Ave. W, St. Paul	Little
RA-SPC-3931	Fire Station No. 20	2179 University Ave. W., St. Paul	Little
RA-SPC-6103	Great Lakes Coal and Dock Company Office Building	2102 University Ave, W. St. Paul	Little
RA-SPC-6309	Minnesota Transfer Railway Company including Main Line,	East and west of Cleveland and Transfer Road, University Ave.	Little
RA-SPC-6310	Minnesota Transfer Railway Company University Avenue Bridge	Bridge over University Ave near Prior St., St. Paul	Little
RA-SPC-3927	Krank Building (Iris Park Place)	1885 University, St. Paul	Little
RA-SPC-6102	Porky's Drive-In Restaurant	1884 University Ave, W. St. Paul	Little
RA-SPC-3923	Griggs, Cooper & Company Sanitary Food Manufacturing Plant	1821 University Ave. W., St. Paul	Little
RA-SPC-3912	Quality Park Investment Company Building	1577-1579 University Ave. W., St. Paul	Little
RA-SPC-3903	8t. Paul Casket Company Factory	1222 University Ave, W., St. Paul	Little
RA-SPC-3895	Brioschi-Minuiti Company Building	908-910 University Ave, W., St. Paul	Little
Not assigned	Raths, Mills & Bell Company Building	823 University Ave. W., St. Paul	Little
RA-SPC-3887	Fire Station No. 18	681 University Ave. W., St. Paul	Little
RA-SPC-3889	Owens Motor Company Building		Little
RA-SPC-3877	Minnesota Milk Company Building	370-378 University Ave. W., St. Paul	Little
RA-SPC-3868	Ford Motor Company Building	117 University Ave, W., St. Paul	Little
RA-SPC-3867	Norwegian Evangelical Lutheran Church (Christ Lutheran Church)	105 University Ave. W., St. Paul	Stained-glass windows, organ
RA-SPC-5619	State Capitol Mall Historic District	University Ave and Robert St., S1. Paul	Leaded glass,
RA-SPC-0229	Minnesota State Capitol	75 Constitution Ave, St. Paul	Stained-glass windows
RA-SPC-0557	Minnesota Historical Society Building (Judicial Center)	690 Cedar St, St. Paul	Little
RA-SPC-6109	State Capitol Power Plant	691 Robert S1., St. Paul	Little
RA-SPC-0553	Central Presbyterian Church	500 Cedar St, St. Paul	Stained-glass windows
RA-SPC-0554	S1. Louis, King of France Church and Rectory	506 Cedar St., St. Paul	Stained-glass windows, chandelier globes, bells
RA-SPC-1200	S1. Agatha's Conservatory of Music and Fine Arts	26 Exchange St., St. Paul	Loose sheet metal
RA-SPC-0550	S1. Paul Athletic Club	340 Cedar St., St. Paul	Little
RA-SPC-5222	Minnesota Building	46 E. 4th St., St. Paul	Little
Historic District	St. Paul Urban Renewal Historic District	Approximately Wabasha, Kellogg, Robert, and East 6th St., St. Paul	Little
RA-S PC-3167	Pioneer Press Building	336 Robert St N, St. Paul	Leaded-glass vault
RA-SPC-4645	First National Bank Building	107 E. 4th St, St. Paul	Little
RA-SPC-5223	Endicott Building	141 E. 4th St, St. Paul	Leaded-glass vault
RA-SPC-4580	Lowertown Historic District	Vicinity of Kellogg Blvd & Jackson, 7th and Broadway Sts, St. Paul	
RA-SPC-5225	St. Paul Union Depot Induding elevated railroad track deck	214 E. 4th St, St. Paul	Little

ATTACHMENT D: MAPS OF HISTORIC BUILDING

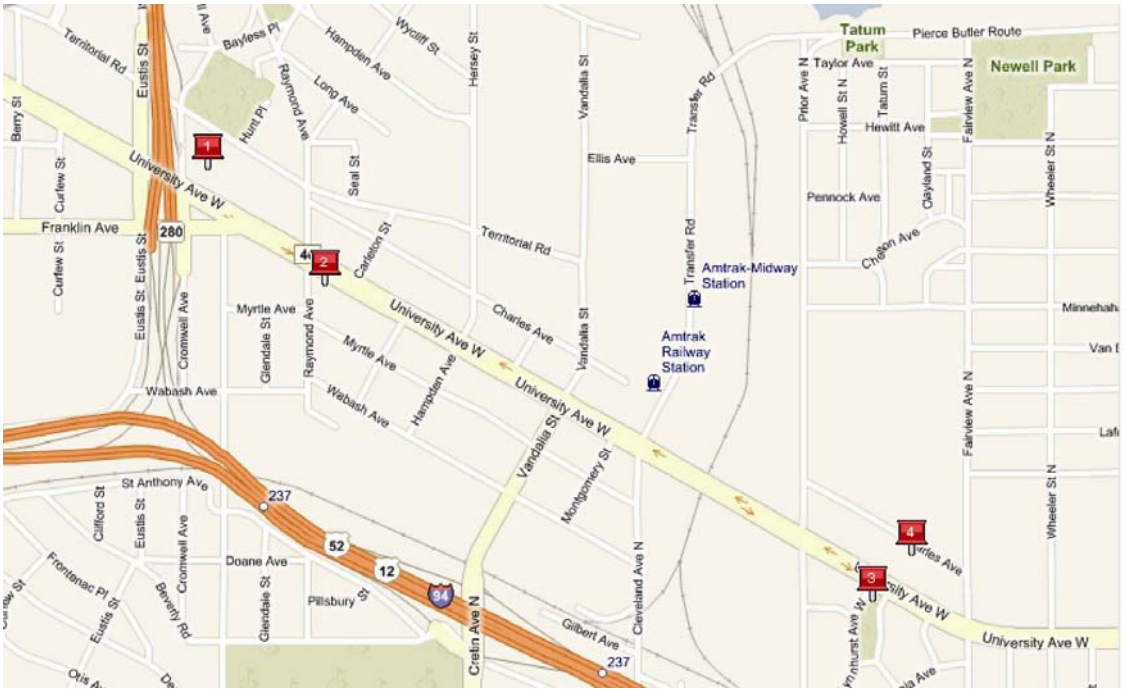

Figure 13: Map of historic buildings 1-4, as labeled in Table 1.

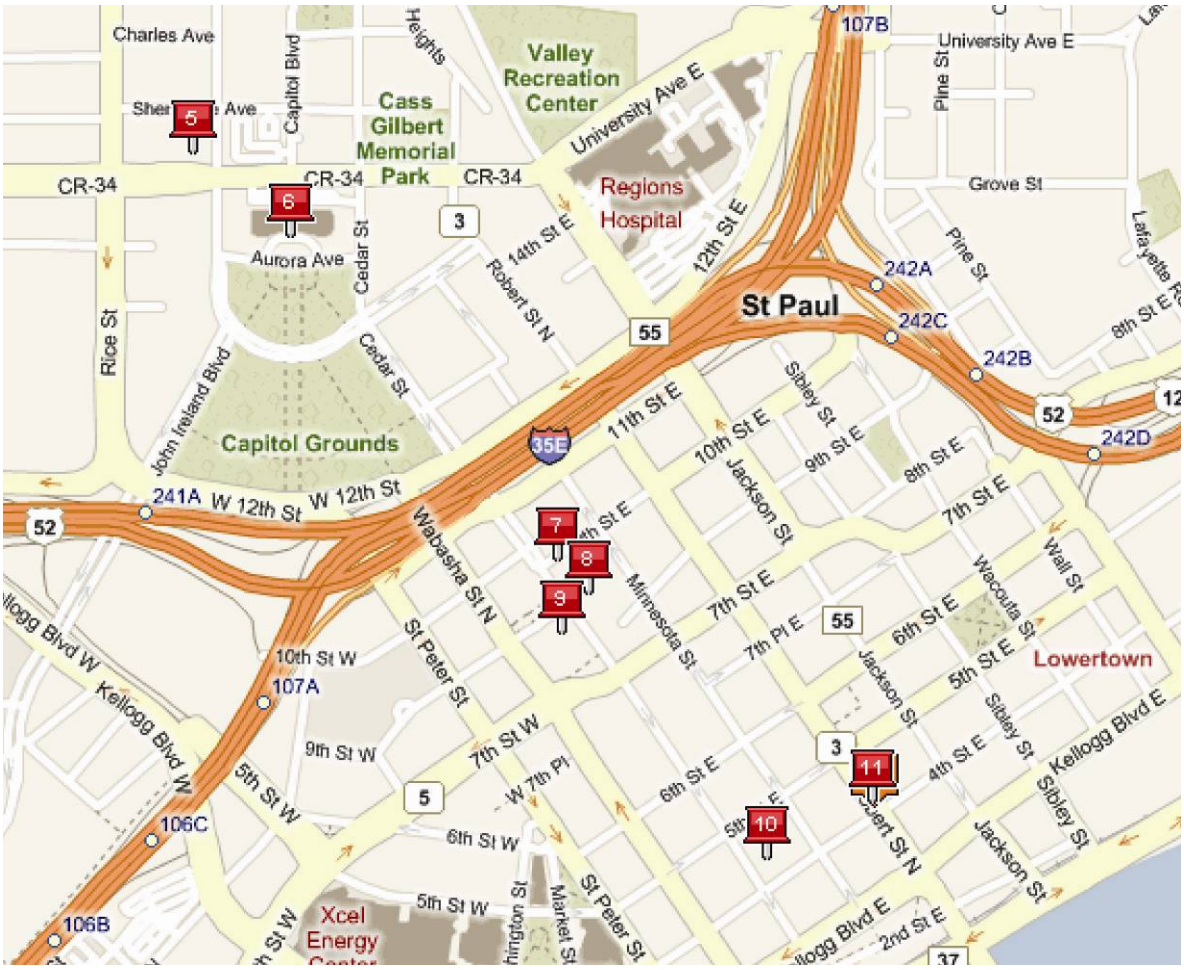

Figure 14: Map of historic buildings 5-11, as labeled in Table 2.

ATTACHMENT E: DRAFT SPECIFICATIONS

This attachment includes the requirements for minimizing noise and vibration generated by construction activities and complying with the applicable regulations, specification requirements, and noise and vibration limits.

Part 1. Cited Standards

A. Chapter 293 of the City of St. Paul Code of Ordinances

B. American National Standards Institute (ANSI):

1. S1.1 - Acoustical Terminology
2. S1.4 - Sound Level Meters
3. S1.13 - Methods of Measurement of Sound Pressure Levels
4. S2.4 - Auxiliary Analog Equipment for Shock and Vibration Measurements

C. International Electrotechnical Commission (IEC):

1. 179 - Precision Sound Level Meters

D. Society of Automotive Engineers (SAE):

1. SAE J994 - Alarm - Backup - Electric Laboratory Performance Testing
2. SAE J1446 - On-Machine Alarm Test and Evaluation Procedure for Construction and General Purpose Industrial Machinery

Part 2. Instrumentation

Unless otherwise indicated, noise level measurements will be recorded using an A-weighted decibel scale and a "slow" response of instrument complying with Type 2 requirements of ANSI S1.4.

Vibration measurements will be taken using the maximum peak particle velocity (PPV) level in inches/second. The PPV is the maximum of the ground motion velocities measured in the vertical, longitudinal, and transverse directions; not the vector sum of the three components of motion. Appropriate instrumentation for vibration measurements are vibration transducers, amplifiers, peak detectors, and frequency band filters complying with ANSI S2.4.

Crack monitoring gauges will be used to measure any cracks noted in the pre-construction survey.

Part 3. Noise and Vibration Thresholds

VIBRATION LEVEL LIMITS

The contractor will adhere to the vibration limits specified in the VNMRP. In no case shall vibration levels for any construction activity exceed the following:

A. For the historic buildings identified in the VNMRP, ground motion generated by construction activities shall not exceed a PPV limit of 0.50 inches per second at any location within 10 ft of any part of the building.

B. For the fragile historic buildings identified in the VNMRP, ground motion generated by construction activities shall not exceed a PPV limit of 0.12 inches per second at any location within 10 ft of any part of the building. The three fragile historic buildings identified in the VNMRP are the St. Louis, King of France Catholic Church, the Central Presbyterian Church, and the St. Agatha's Conservatory of Music and Fine Arts.

C. At all other buildings along the corridor the PPV limit of 0.5 inches per second shall apply, in accordance with the FTA threshold for standard buildings.

The contractor shall notify the Metropolitan Council (MC) immediately in the event vibration level limits are exceeded. The contractor shall implement mitigation measures or alter construction methods to reduce vibration levels. The contractor shall not continue with any Work activity that exceeds vibration limits until mitigation measures are implemented to the satisfaction of the MC.

NOISE LEVEL LIMITS

The contractor will adhere to the following specifications:

A. Sound levels for public exposure to noise shall comply with the noise level restrictions included in this Section and Chapter 293 of the City of St. Paul Code of Ordinances. Noise level variances, if required, may be requested from the City of Saint Paul by submitting an Application for Sound Level Variance from the City. The contractor shall notify the appropriate authority if a variance is being requested. The contractor shall take into account processing time for variances and shall be prepared to take alternative approaches to the work if variances are not approved.

B. Equipment shall be tested and shall demonstrate compliance with noise limits specified herein whenever evidence of non-compliance is apparent or at the request of the MC.

C. Work shall be performed in a manner so as to prevent nuisance conditions. Examples of nuisance condition noises are noise that exhibits a specific audible frequency or tone (e.g., back-up alarms, un-maintained equipment, brake squeal) or impact noise (e.g. jackhammers, hoe rams) in accordance with city standards.

D. The contractor shall notify the MC immediately in the event the noise level limits are exceeded. The contractor shall implement mitigation measures or alter construction methods to reduce noise levels. The contractor shall not continue with any Work activity that exceeds noise limits until mitigation measures are implemented to satisfaction of the MC.

Part 4. Noise and Vibration Mitigation and Monitoring

PRE-CONSTRUCTION SURVEY

A. The pre-construction survey will provide a baseline of existing structural conditions to facilitate later identification of any structural and/or cosmetic damage caused by project construction. The survey shall include inspecting building foundations, exterior, and interior elements and documenting any pre-existing defects such as cracks, settlement, subsidence, corrosion, or water damage. Defects that should be monitored during construction will be noted and, where appropriate, crack monitors installed prior to the start of construction. The pre-construction survey for the 11 historic properties requiring vibration monitoring will also include an inspection of the historically significant features of the buildings as identified during the detailed historic review by MacDonald & Mack Architects in Attachment B of the VNMRP.

NOISE AND VIBRATION CONTROL PLAN

A. The Noise and Vibration Control Plan describes the procedure for predicting construction noise and vibration levels prior to performing construction activities and describes the noise/vibration reduction measures required to meet the noise/vibration level limitations and minimize nuisance conditions. The Plan shall be prepared by and bear the signature of the Acoustical Engineer and shall be submitted to the Council for approval prior to beginning any noise- or vibration-generating construction activity. Noise/vibration generating equipment shall not be operated prior to acceptance of the applicable Noise and Vibration Control Plan. The initial Noise and Vibration Control Plan is required no later than 15 Days after Notice-to-Proceed. Updated Noise and Vibration Control Plans shall be resubmitted every six months thereafter, or whenever the construction activities or the construction work hours have changed.

B. The Noise and Vibration Control Plan should include:

1. A scaled drawing of the Site indicating the Contract name and number; contractor's name; date; scale; Direction of North; and noise and vibration sensitive buildings near the Site. Drawings shall show historic buildings identified in the CCLRT Programmatic Agreement and published Final Environmental Impact Statement, as presented on the Central Corridor LRT website. The contractor shall develop photographic documentation of historic buildings during preconstruction survey.
2. Means and Methods for the implementation of all control and mitigation measures.
3. Vibration Calculations: Prepare calculations of the maximum peak particle velocity vibration level expected at the nearest vibration-sensitive building or structure.
4. Noise Calculations: Prepare calculations of anticipated noise levels expected at the nearest noise-sensitive receptor. Identify areas where noise problems may be encountered.
5. Description of construction operations, with an assessment of noise and vibrations generated. Provide descriptions of activities having the potential to generate high noise and vibration levels.
6. Design drawings of noise abatement enclosures and barriers.
7. Proposed locations of noise and vibration measuring equipment. The contractor shall measure noise and vibration impacts to structures within 150 feet of construction.
8. Equipment tests, including testing to demonstrate functionality of measuring equipment. For historic sites within 150 feet of construction, conduct tests of equipment that generates high vibration levels and record measurements to ensure vibration levels are compliant with allowable levels. If vibration test measurements exceed allowable limits, the contractor shall reduce adjust the equipment settings or test alternative equipment until vibration amplitudes at identified historic sites are compliant with applicable levels.
9. Description of physical noise mitigation materials, including the name of manufacturer and its specifications (all such materials shall be fire-resistant).
10. A detailed description of the noise and vibration monitoring plan including locations where measurements will be performed and a schedule for the measurements. The contractor and any subcontractors hired shall be specifically obliged to comply with the requirements of the Noise and Vibration Control Plan, including requirements to cease construction activities should

continuous monitoring indicate that established vibration level limits are being exceeded. The vibration limits apply to the maximum vibration in any one of three tri-axial directions.

11. Catalog Cuts and technical data sheets of construction equipment to be employed.
12. Method for predicting the construction noise impact shall be the Federal Highway (FHWA) prediction method or similar.
13. All special provisions for vibration mitigation as described in the VNMRP.

C. The Noise and Vibration Control Plan shall be submitted for review prior to commencement of any construction work. The subcontractor shall be specifically obliged to comply with the requirements of the approved Noise and Vibration Control Plan in the provisions of his subcontract. The Plan must be updated and resubmitted prior to the start of any major change in work schedule, construction methods, or equipment operations not included in the most recent Plan.

CONSTRUCTION NOISE AND VIBRATION MONITORING

A. The contractor shall procure the services of an acoustical firm to perform baseline background noise measurements at the site and near the sensitive receptors identified above.

B. The background noise monitoring shall be performed to determine the "noise signature" or "noise level trend" for the site and immediate vicinity prior to the start of construction.

C. The contractor shall provide a weekly report summarizing the noise measurement readings taken at the site. All events that exceed the project limits shall be clearly indicated and the corrective action taken to address the cause.

D. The contractor shall conduct baseline vibration measurements prior to the start of construction to document the background conditions.

E. The contractor shall conduct all noise and vibration monitoring as described in the Noise and Vibration Control Plan. At a minimum, continuous vibration monitoring will be performed whenever construction activities that generate high vibration levels are active near the St. Louis, King of France Catholic Church, the Central Presbyterian Church, or St. Agatha’s Conservatory of Music and Fine Arts.

F. In the event vibration level limits are exceeded, construction activities shall be halted immediately and the Engineer shall be notified. Construction will not be allowed to commence until the Engineer approves the contractor’s approach for reducing the vibration levels. The Engineer will be responsible for notifying property owners that the vibration limits were exceeded.

DOCUMENTATION STANDARDS

A. Documentation for noise monitoring will include the equipment used; the date, time and duration of measurements; the location of the measurement; and the A-weighted sound level for the measurement period.

B. Documentation for vibration monitoring will include the equipment used; the date, time and duration of measurements; the location of the measurement; and the peak particle velocity (PPV) in inches/second for the measurement period.

CONSTRUCTION METHODS - EQUIPMENT

A. Minimize the use of impact devices, such as jackhammers, pavement breakers, and hoe rams. Where possible, use concrete crushers or pavement saws rather than hoe rams for tasks such as concrete deck removal and retaining wall demolition.

B. Pneumatic impact tools and equipment used at the Work Site shall have intake and exhaust mufflers recommended by the manufacturers thereof, to meet relevant noise ordinance limitations.

C. Equip noise producing equipment, i.e. jackhammers, pavement breakers, etc. with acoustically attenuating shields or shrouds recommended by the manufacturers thereof, to meet relevant noise ordinance limitations. Provide mufflers or shield paneling for other equipment, including internal combustion engines, recommended by manufacturers thereof.

D. As required to meet the noise limits specified herein, use alternative procedures of construction and selection of proper combination of techniques that generate least overall noise and vibration.

E. Use construction equipment manufactured or modified to dampen noise and vibration emissions, such as:

1. Electric instead of diesel-powered equipment.
2. Hydraulic tools instead of pneumatic impact tools.
3. Electric instead of air- or gasoline-driven saws.
4. Whisper Jet diesel powered generators.

CONSTRUCTION METHODS - OPERATIONS

A. Noise and Vibration Reduction Methods: To the extent required to meet the ground vibration PPV, ground-borne noise limits, and above-ground noise level limits specified herein, modify construction operations to reduce noise and vibration.

B. Operate equipment to minimize banging, clattering, buzzing, and other annoying types of noises, especially near residential areas and during the night-time hours.

C. Configure the Work Site in a manner that keeps noisier equipment and activities as far as possible from noise-sensitive locations.

D. Operate equipment with community-sensitive back-up alarms with either audible self-adjusting alarms or manual adjustable alarms. The self-adjusting alarms shall automatically adjust to a minimum of 5-dB and a maximum of 10-dB over the surrounding background noise levels and have an operating range between 77- to 97-dBA. Set the manual adjustable alarms at the low setting, 87-dBA. Installation and use of alarms shall be consistent with the performance requirements of the current revisions of SAE J994, J1446, and OSHA regulations.

E. Maximize physical separation, as far as practicable, between noise generators and noise receptors. Provide enclosures for stationary items of equipment and barriers around particularly noisy areas on site. Locate stationary equipment to minimize noise and vibration impact on community.

F. Minimize noise-intrusive impacts during most noise sensitive hours.

1. Plan noisier operations during times of highest ambient noise levels.
2. Keep noise levels relatively uniform; avoid excessive and impulse noises.
3. Turn off idling equipment.

4. Phase in start-up and shutdown of Work Site equipment.

G. Select truck idling locations and truck routes for excess materials disposal so that noise from heavy-duty trucks will have minimal impact on sensitive land uses (e.g. residential).

1. Conduct truck loading, unloading, idling, and hauling operations so noise and vibration are kept to a minimum.
2. Shut down stationary trucks on the Site to minimize noise except where engine operation is required, such as concrete trucks placing concrete.
3. Route construction equipment and vehicles carrying soil, rock, concrete other materials over streets and routes that will cause least disturbance to residents in vicinity of Work.

COMPLAINT PROCEDURE

A. If the Contractor receives a complaint regarding construction noise or vibration, immediately notify the Engineer.

B. Upon receipt or notification of a noise and/or vibration complaint from the Engineer, the Contractor shall promptly perform appropriate noise and/or vibration measurements at the complainant's location during activities representative of the offending operation. The complaint response measurements shall be immediately submitted to the Engineer.

C. In the event that the measured noise and/or vibration levels exceed allowable limits as specified in this Section, the Contractor shall immediately use mitigation materials and methods to reduce noise and/or vibration levels.