CITY OF VANCOUVER

CITY CLERK'S DEPARTMENT
Access to Information & Privacy Division

File No.: 04-1000-20-2023-793

April 16, 2024

[Corrected for proactive release]

Re: **Request for Access to Records under the Freedom of Information and Protection of Privacy Act (the "Act")**

I am writing regarding your request dated December 18, 2023 under the ***Freedom of Information and Protection of Privacy Act*** for:

> **Record of final acoustic report prepared by local or international acoustic engineer regarding the new PNE amphitheatre. Date range: December 18, 2020 to December 17, 2023.**

All responsive records are attached. Some information in the records has been severed (blacked out) under s.22(3)(d) of the Act. You can read or download this section here: http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/96165_00.

Under section 52 of the Act, and within 30 business days of receipt of this letter, you may ask the Information & Privacy Commissioner to review any matter related to the City's response to your FOI request by writing to: Office of the Information & Privacy Commissioner, info@oipc.bc.ca or by phoning 250-387-5629.

If you request a review, please provide the Commissioner's office with: 1) the request number (#04-1000-20-2023-793); 2) a copy of this letter; 3) a copy of your original request; and 4) detailed reasons why you are seeking the review.

Yours truly,

Kevin Tuerlings, FOI Case Manager, for

[Signed by Kevin Tuerlings]

Cobi Falconer, MAS, MLIS, CIPP/C
Director, Access to Information & Privacy
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If you have any questions, please email us at foi@vancouver.ca and we will respond to you as soon as possible. Alternatively, you can call the FOI Case Manager at 604-871-6584.

Encl. (Response Package)

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PNE Ampitheatre Renewal

Vancouver, BC

Acoustic Consultant's Design Development Report

2024-01-10

Damian Doria, FASA
Partner - Stages Consultants, LLC

stages

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Introduction

Stages is providing this acoustics report to document acoustical progress on the overall project and to provide a reference document that describes acoustical parameters and our best practices for achieving them. Our main focus on this project is addressing noise mitigation, which is communicated in Part 1 of this report; Part 2 of this report includes our recommendations for room acoustics comfort and noise control for the enclosed spaces of the facility, ongoing design for optimal audio system, and reports of August and September 2023 test concerts performed with rented audio systems similar to those included in the intended design. Also included are reviews of partitions, door types, and fan noise levels in the back of house spaces.

Part 1. Noise Mitigation

A key consideration for the project's design is how the Amphitheatre can offer a high-quality, well-balanced, and adaptable acoustic environment for performers and audience members while being a good neighbour to its adjacent residential community. Revery has worked closely with acoustic consultants throughout the design of the new Amphitheatre to achieve this goal; the mass timber roof will be an essential part of the acoustic strategy, and will be complemented by a number of more targeted solutions.

Figure 1 – Hastings Park and the PNE Amphitheatre site (marked in orange) are surrounded by residential neighbourhoods.

The existing PNE amphitheatre operated in a nearly "free field" environment (Figure 2) where there was virtually no mitigation of sound propagation from obstacles, boundaries, or reflecting surfaces. In these scenarios, audience members (particularly those seated more than 30m from the stage) rely almost exclusively on amplification provided by sound systems; very little of the sound heard by the audience comes directly from the performer. This requires that venues raise sound levels to provide a strong, well-balanced listening experience. Furthermore, sound systems used in the amphitheater to date are rental or touring systems that are neither optimized for the venue nor for minimizing propagation to neighboring properties.

Figure 2. The existing amphitheatre offers no mitigation of sound spread.

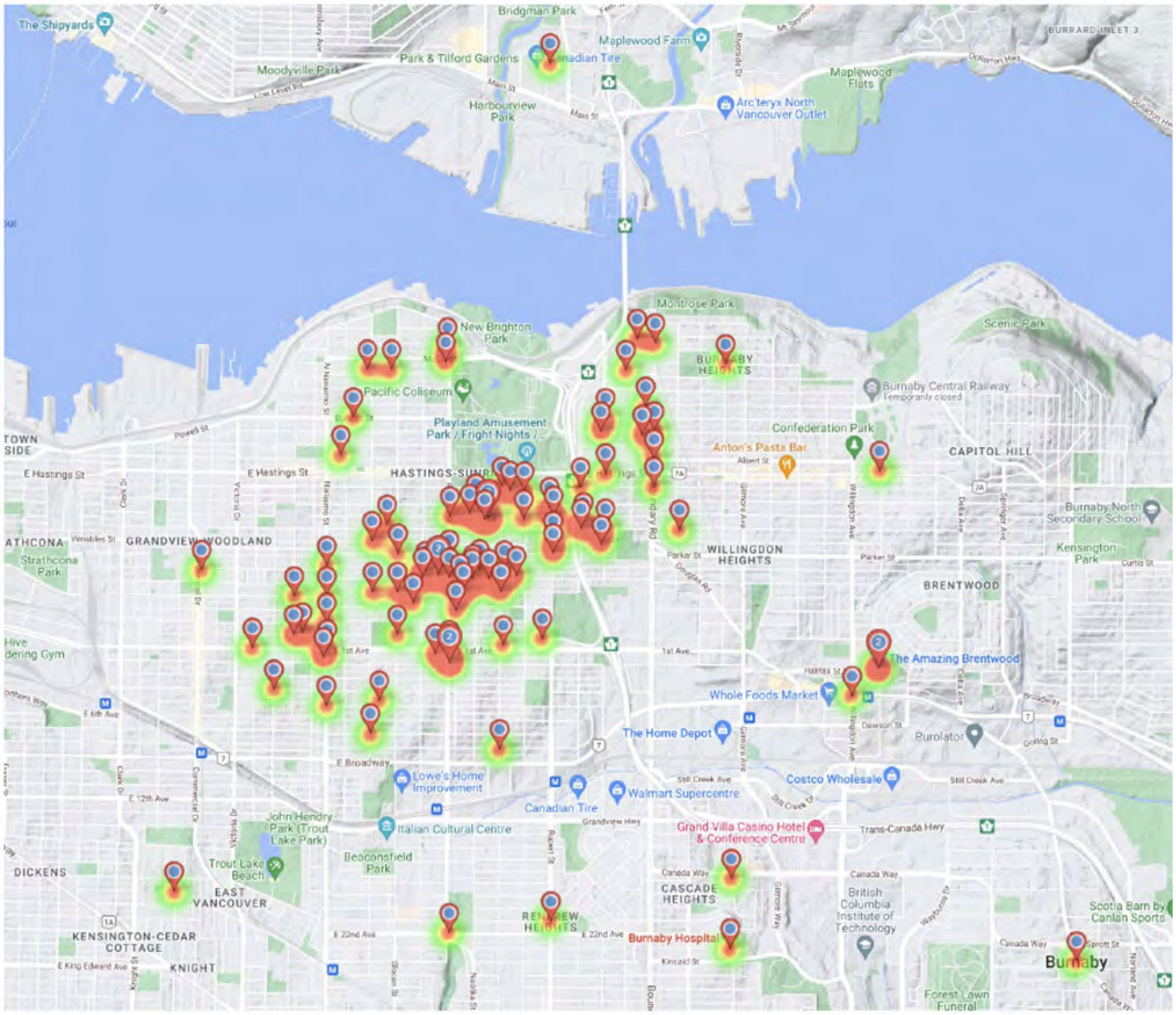


Figure 3 – Noise complaints in Summer 2022 were concentrated in the immediate vicinity to the south and east of Hastings Park. We also notice complaints almost 6 km away, which are explained by temperature inversions that are typical of summer evenings.

To further compound the issue, the evening inversion of air temperatures (Figure 4) in the summer months commonly causes sound energy to refract, meaning that more sound is spilled into surrounding areas, and sound is radiated to areas far beyond the local neighbourhoods that are typically affected. Figure 3 shows a map of noise complaints over the course of the 2022 summer evening concert series at the existing amphitheatre. Residents in areas as far as Renfrew Heights (4 km from Hastings Park) and East Burnaby (almost 6 km away) reported being disturbed by sound from these concerts.

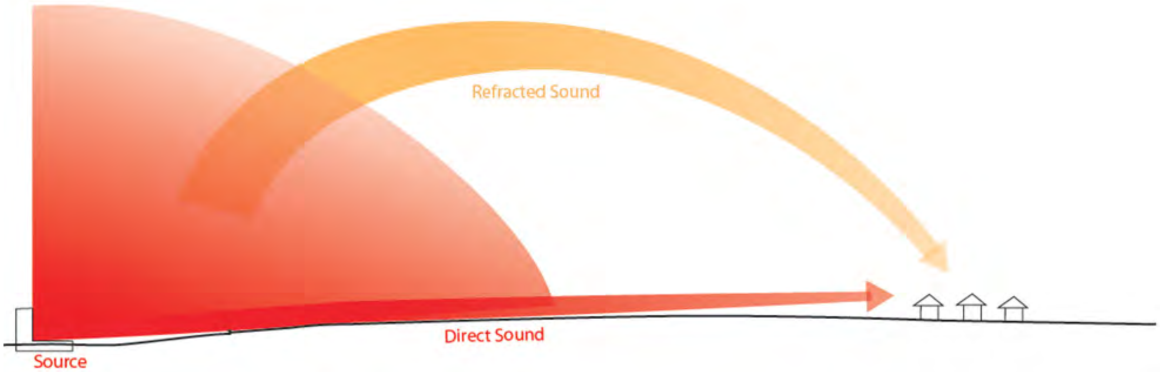


Figure 4 -Evening sound refraction in the existing amphitheatre condition, causing disturbances to non-local neighbourhoods.

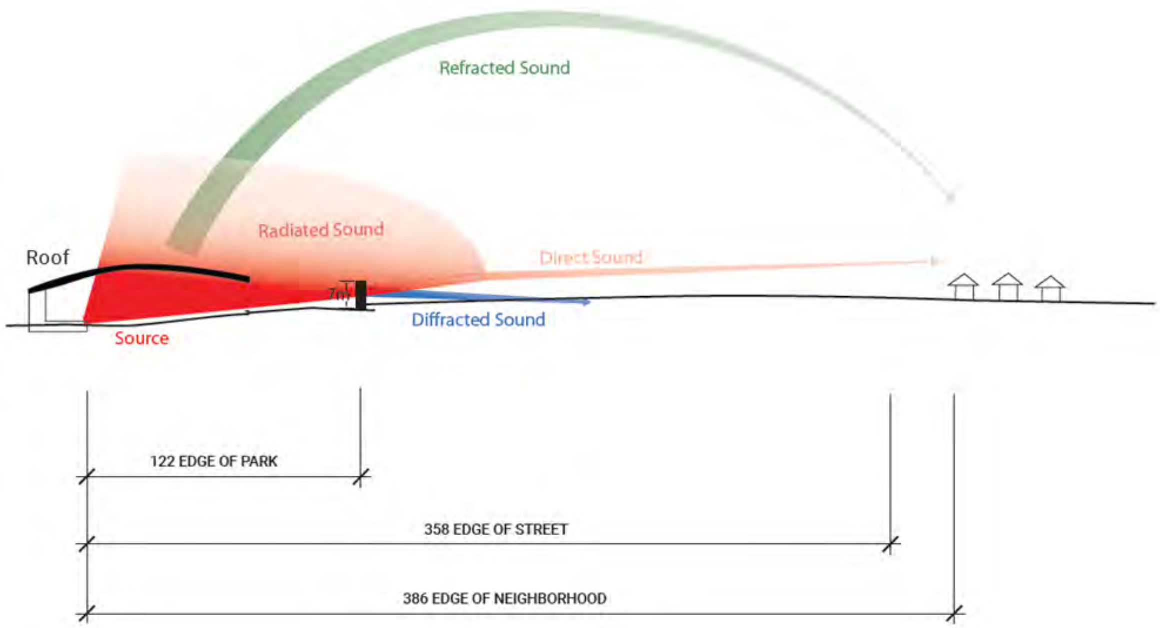


Figure 5 -Reduced sound propagation to surrounding neighbourhood from the new PNE Amphitheatre.

The strategic addition of the roof on the new PNE Amphitheatre provides an effective line-of-sight barrier between sound sources (both speakers and audience) and the surrounding residential area (Figure 5). In creating a barrier, the mass timber roof will reflect sound back to the audience, requiring lower source levels of sound amplification; it will also isolate the audience's acoustic environment from competing background noise, which altogether will create a more focused listening experience.

The roof of the Amphitheatre is planned to be of significant acoustic mass, making the use of mass timber especially beneficial in this regard. The high surface density and rigid structural support of the roof helps to direct sound toward the audience and provide some supporting sound reflections within the covered areas. The main acoustical benefit of the roof results from its surface density, which is independent of the finish of its underside. This surface density reduces sound propagation to the atmosphere and ultimately to neighboring and more distant properties.

The roof also offers a framework for hanging loudspeakers in locations more optimal for providing even coverage of amplification across audience areas than a ground-stacked or stage-truss supported system located at the stage only. By distributing loudspeakers and properly optimizing their phase relationships, overall sound power emanating from sources may be reduced while the apparent loudness and quality of amplification is enhanced for patrons in the lawn and seating areas, and lower sound power levels at the sources will propagate less audibly to neighboring properties. Modern loudspeakers, even subwoofers for bass amplification, have a directivity that is predictably controlled, and significantly more energy radiates in the direction that the speakers are pointed than to areas off-axis.

Finally, the roof will allow for distributed sound reinforcement to be suspended over the audience area and directed toward the audience, resulting in a more targeted, efficient sound transmission and reducing the overall sound pressure (loudness) spreading to areas beyond the amphitheatre. Distributing subwoofers in a similar way can also reduce the amount of bass frequencies that are propagated to neighbours of the venue without diminishing the audience experience.

Figure 6 - The mass timber roof envelops the audience area, strategically limiting sound spread, improving acoustic performance, and allowing for distributed and targeted sound reinforcement. (Image by Mir courtesy of Pacific National Exhibition [PNE])

In addition to the comprehensive acoustic benefits provided by the mass timber roof, the design team is also implementing a number of strategies to optimize the acoustic experience of audience members while at the same time minimizing sound spread to the neighbouring residential areas:

A **seven-metre-high** acoustic wall along the south adjacency with Playland amusement park will create a continuous line-of-sight barrier between the eastern and western points of the Amphitheatre's roof, directly behind the lawn seating area (Figure 7). The addition of this wall creates an acoustic barrier that will limit direct sound spread and diffract sound into the ground (as shown in Figure 5)

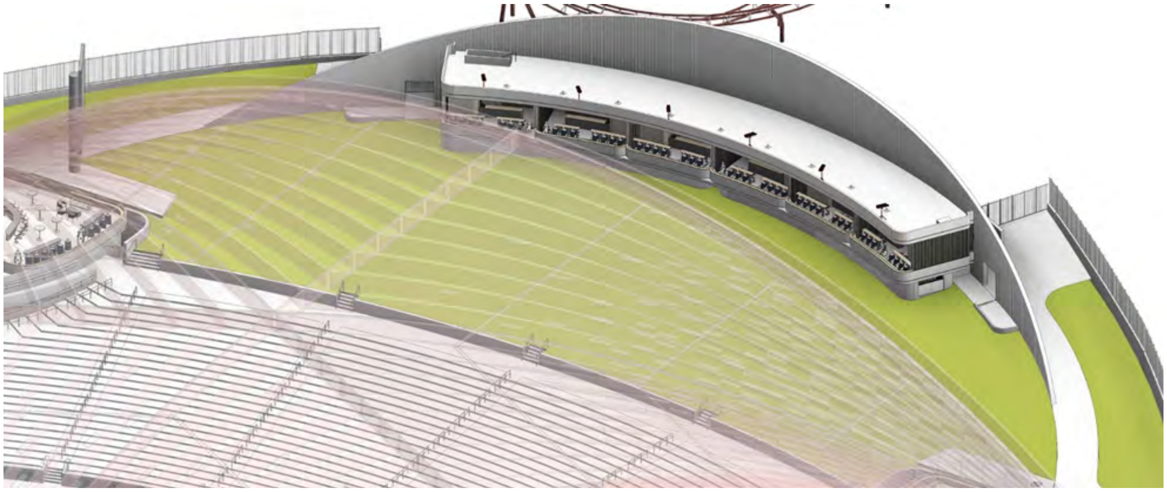


Figure 7 - The acoustic wall will provide an effective line-of-sight barrier behind the audience area.

Landscape integration will leverage dense plantings and species well-known for their ability to support sound insulation. For example, Western Red Cedars will be planted to flank the acoustic wall (Figure 8). In addition to benefiting the acoustics of the new Amphitheatre, these plantings will also maximize the natural setting and create an enjoyable environment for patrons.

Figure 8 - The acoustic wall will provide an effective line-of-sight barrier behind the audience area.

Throughout the design development phase, Stages has continued to study the acoustic conditions under the Mass Timber roof along with new technology audio systems and the sound propagation to neighbours along the main axis of the Amphitheatre, as well as neighbours to the south and east of the property, who report the most complaints (vibration from bass, and intelligible spoken/sung word that's sometimes "foul" language). The goal is to provide a substantially improved and consistent sonic concert experience for patrons in the covered seating and lawn, while minimizing transmission to the areas beyond the PNE properties.

The most recent adjustment to the amphitheater on the site (rotation and shifting) appears promising for reducing sound propagation to neighbors where the most significant grouping of complaints occur. The roof design is somewhat triangular in concepts and is supported at three points to occlude line of site sound transmission. This supporting portion of the roof that acts as a sound barrier now aligns with our most critical neighbors to the south and east of the amphitheater. While bass frequencies would still diffract around these portions of the roof, there should be reduction of intelligible mid and high frequency sound along these axes, Additionally, the optimized sound systems will not need to provide audio coverage along these axes, since no patrons will be seated behind the roof supports. This will eliminate the need to aim sound in these critical directions.

In addition, recent in-situ testing of loudspeakers under consideration for the project proved successful in providing even and satisfactorily loud coverage (102dBA LEqMax / 106dBC LEqMax at the mix position) for the August hip hop performance while projecting only minimally audible sound to the neighboring community (61dBA LEqMax / 79dBC LEqMax). This data was captured during the performance by the audio systems provider and reported to Stages. The subjective reports of those present during the events was that the music from the concert was barely audible in the surrounding neighborhoods over traffic and other typical background noise. We are attempting to gather and compare noise complaint information from PNE to confirm these results along with typical measurements captured by PNE during these performances. Presumably, noise complaints during the test events should be substantially reduced compared to those received in 2022 shown in Figure 3.

Based on what was learned in these tests and subsequent sound system modeling in ArrayCalc (Figure 9) we developed loudspeaker arrays included in our 100% DD drawings that will provide even and loud coverage for patrons of the amphitheater. The most intense sound levels are concentrated under the covered audience areas, while distributed arrays cover the lawn seating. Sound levels fall off rapidly beyond audience areas.

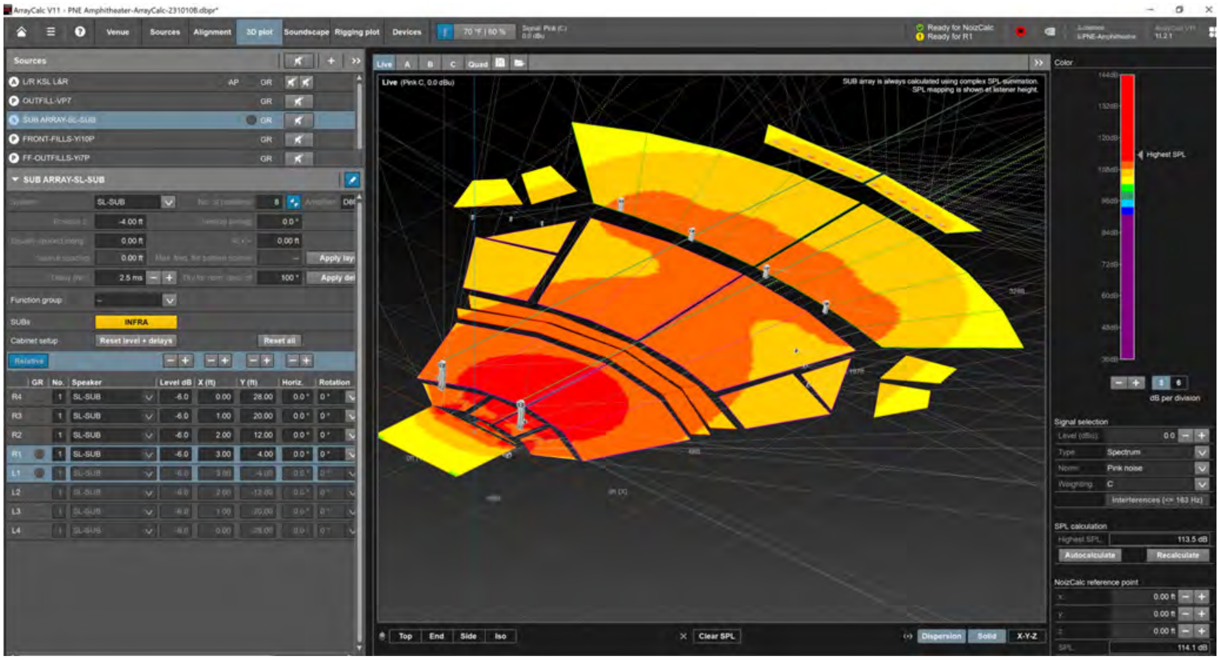


Figure 9 - Array Calc computation of audio systems coverage under the roof and lawn.

Using these optimized audio systems for performances will result in substantial improvements to the existing conditions for neighbors compared to the temporary touring audio systems that are typically used in past events. We expect to provide a more detailed sound mapping for the audience and areas beyond the PNE in collaboration with a loudspeaker supplier using NoizeCalc software that predicts outdoor sound propagation with consideration of terrain, buildings, and other propagation factors beyond those considered in ArrayCalc. While we expect that the NoizeCalc modeling will further support the choices made based on recent tests on site and modeled in ArrayCalc, it may result in further refinements to speaker selection, positioning, and array configurations to further reduce propagation beyond the PNE audience.

The atmospheric component of sound propagation can be significant, given the evening hours for many performances and the common temperature inversion that naturally occurs. By providing optimized house systems and the roof we expect to eliminate a portion of the variables, Beyond that, it may be necessary to install and use sound level monitoring at various points around the PNE property to maintain sound levels that do not exceed regulatory limits at neighboring properties.

In conclusion, the total sum of these myriad acoustic design features stated above will be a fully optimized experience for guests, performers, and neighbours of the new PNE Amphitheatre. For guests, the sound will be balanced and clear, and always at a comfortable level. Performers and sound engineers will be able to achieve a nearly unparalleled sound thanks to the inherent acoustic properties of the roof and the custom-built in-house sound system. Finally, neighbours of the new venue will enjoy improved peace and quiet during performances.

Part 2. Basic Acoustical Guidelines

In this part of the report we compile our Noise and Vibration Control Guidelines (Appendix A) and Table of Acoustics Room Descriptions (Appendix B). As an open-air amplified music venue, the main stage and audience areas are not greatly impacted by the parameters outlined in those appendices. However, there are several spaces included in the overall building program where acoustic comfort of performers and patrons is important. The Appendix A material guides the engineers in providing HVAC and electrical systems that meet the noise level criteria stated in Appendix B. There are also basic architectural finish recommendations in Appendix B which are useful as a starting point in material section, but are not intended to determine or limit final finish choices. The acoustical criteria in Appendix B are gathered from the earlier space planning worksheet developed by the design team before and during SD, and it should not be new or conflict with our past recommendations.

Recently, we have provided Revery with a more specific markup of locations of interior acoustic wall assemblies and acoustic doors in the back of house to ensure adequate privacy for performers in spaces such as dressing rooms; these markups are included in Appendix C for convenience. We have also reviewed the Mitsubishi fan coil units and found them to be acoustically acceptable as and where indicated on the mechanical documents: manufacturer data claims noise levels under NC-25 under normal operating conditions, which is in line with our previous recommendations.

Appendix A:

MEP Noise and Vibration Control Guidelines

Introduction

These guidelines are provided as an acoustical framework for best noise and vibration control practices for the PNE Ampitheatre facilities. They should be considered in order to maintain the acoustical goals of the project, but are subject to adjustment and revision as coordination within the design team occurs and project design is reconciled with budget. We're providing recommendations through these guidelines and they are not intended to be immutable. They are based on best practices and positive outcomes for projects of similar vision, budget and geographic location. **These guidelines are unchanged from those issued at 50% SD, and reissued at 100%SD. They do not need to be reviewed if already part of ongoing development by the design team.**

The acoustic criteria found in the *Room Acoustic Descriptions* informs the acoustic design of continuous noise sources such as HVAC systems and in some cases the choices for electrical lighting fixtures and sound isolation of mechanical, electrical and plumbing equipment. Confirming noise criteria now will avoid both problems with spaces that are too noisy for lecture, film and other public and private activities later, and avoid unnecessary costs of noise and vibration control where it is not necessary.

Our choice for criteria describing background noise in new spaces are based upon the "Preferred Noise Criteria" (PNC) Levels. The PNC-criteria assigned to a room indicates the maximum permissible sound pressure level in each of nine octave bands. PNC criteria are similar to the more commonly used NC criteria with slight difference that they better mimic human perception of sound. N-1 is the threshold of human hearing and is provided for reference only. None of the activities planned for PNE demand complete silence, so the N-1 criteria is not applicable. Octave band levels for PNC criteria are shown in the following table:

Preferred Noise Criteria (PNC) Criteria Sound Pressure Levels (dB)

Octave Band (in Hz)	*31*	*63*	*125*	*250*	*500*	*1000*	*2000*	*4000*	*8000*
N-1	57	36	22	13	8	5	3	3	3
PNC-15	58	43	35	28	21	15	10	8	8
PNC-20	59	46	39	32	26	20	15	13	13
PNC-25	60	49	43	37	31	25	20	18	18
PNC-30	61	52	46	41	35	30	25	23	23
PNC-35	62	55	50	45	40	35	30	28	28
PNC-40	64	59	54	50	45	40	35	33	33

Mechanical System Space Planning

The following are general recommendations that will be refined as the design progresses and expanded to address specific project conditions. In order to provide detailed analysis, we will need manufacturers / model and inlet, outlet, and radiated sound levels for all equipment as it is available. We also evaluate duct sizes to confirm appropriately low velocities for avoiding air-rush noise when air volumes are available. In the later design phase we can help specify dynamic insertion loss for duct attenuators, optimize thickness and location for duct lining, and help choose air terminals and grilles to keep noise levels within project goals

Silencers or Acoustic Plenums

For off-the-shelf units 3 meter silencers on supply and return of PNC-20 or less spaces should be anticipated. We are often able to reduce silencer lengths as designs are refined, but ensuring space to coordinate a 3 meter silencer early in design is prudent. Where space allows, acoustic plenums could be used instead. They may be useful devices for balanced distribution in addition to providing acoustical benefit. Plenums are constructed of 100mm plenum wall panels and should be approximately 3x4x4m in size in order to be more effective than a silencer.

Where external silencers are required, they should be located as close to the unit as possible to allow for attenuation of any self-generated noise. Plenums do not regenerate noise and can be located anywhere in the duct system that is useful for distribution and balance. The transitions from duct to silencer should have an included angle of about 30 degrees, and airflow should approach the silencer smoothly. If silencers are located too close to sources of turbulence such as duct size changes, elbows, or take-offs they can generate more noise than they attenuate.

Vibration isolators

50mm static deflection springs under fan/motor sled and neoprene waffle pads under AHU casing. Entire AHU's should be mounted on concrete housekeeping pads. See the Equipment Vibration Isolation table found later in this report for more detailed guidelines.

Duct Lining

Internal duct lining is essential to achieving low background noise levels in critical spaces without extending duct lengths and adding considerable sheet metal costs. Assume glass-fiber or mineral wool duct lining (density 25-50 kg/m^3) in all ductwork that serves noise-critical areas. Lined ductwork may be required between supply and return fans, fan fresh-air inlet and exhaust ducts, and elsewhere, as specified by Stages. (Note that additional thermal insulation is not usually required for acoustically lined ducts.) Should exposed duct liner not be permitted, insulated double wall duct with the internal layer perforated should be used. As a guideline, we recommend lining that is 50 to 100 mm thick in mechanical rooms, and a minimum of 50mm thick lining near air terminals. In short duct runs it may be necessary to use 100mm thick lining throughout.

Duct Sizing

Maximum air velocities are provided to aid in the design of the size of ducts, particularly to low noise spaces. We have separate recommendations for velocities where no terminal devices (grilles or diffusers) are used and for systems with such terminal devices. By avoiding the use of grilles and diffusers, higher velocities can be maintained. Higher velocities equals smaller duct sizes, saving money and increasing the acoustic benefits for reflecting noise back towards the fan and reducing the effect of the openings absorbing sound in the room.

For the purpose of this report, we will assume that there will be no terminal devices (grilles or diffusers) within the theater space, though it may be necessary to consider outlets that can "throw" air farther into the theater, depending on final layout of ductwork and terminals. For the theater and other spaces where grilles and diffusors may be omitted, the following velocities should be used:

No Terminal Devices – Supply Air Velocities (m/s)				
Criteria	*PNC-15*	*PNC-20*	*PNC-25*	*PNC-30+*
At Terminal	*1.5*	*1.8*	*2.1*	*3.3*
To 7 Diameters	*1.8*	*2.1*	*2.6*	*3.5*
Header Duct	*3.0*	*3.5*	*4.3*	*5.6*
Riser Duct	*4.8*	*5.7*	*6.9*	*7.1*
Maximum in MER	*6.0*	*7.1*	*8.6*	*9.1*

No Terminal Devices – Return Air Velocities (m/s)				
Criteria	*PNC-15*	*PNC-20*	*PNC-25*	*PNC-30+*
At Terminal	*1.8*	*2.1*	*2.5*	*2.8*
To 7 Diameters	*2.1*	*2.5*	*3.0*	*3.3*
Header Duct	*3.0*	*3.5*	*4.3*	*5.5*
Riser Duct	*5.1*	*6.0*	*7.3*	*7.6*
Maximum in MER	*7.1*	*8.1*	*8.6*	*9.1*

Where grilles and diffusers are used, the following velocity guidelines should be observed (final terminal velocities might be adjusted once specific selections for grilles and diffusers are made):

With Terminal Devices – Supply & Return Air Velocities (m/s)						
Criteria	*PNC-15*	*PNC-20*	*PNC-25*	*PNC-30*	*PNC-35*	*PNC-40*
At Terminal	*0.5*	*0.7*	*1.0*	*1.2*	*3.3*	*4.4*
To 7 Diameters	*2.1*	*2.5*	*3.0*	*3.3*	*4.0*	*5.0*
Header Duct	*600*	*3.5*	*4.3*	*5.5*	*5.8*	*7.1*
Riser Duct	*5.1*	*6.0*	*7.3*	*7.6*	*8.3*	*8.6*
Maximum in MER	*7.1*	*8.1*	*8.6*	*9.1*	*10.0*	*10.0*

Variable Air Volume and Fan Powered Boxes

VAV and FPBs should be located over corridors or other unoccupied spaces, rather than more noise sensitive spaces. For spaces below PNC-35, we recommend the following attenuation measures:

Variable Air Volume Box Attenuation			
Background Noise Level	*Extent of Lined Duct*		*Silencer*
PNC-25	5 to 6m 50mm thick lining between the box and the nearest diffuser	*or*	1.5 m silencer with a maximum pressure drop of 10 Pa.
PNC-30	3 to 5m 50mm thick lining between the box and the nearest diffuser	*or*	1m silencer with a maximum pressure drop of 15 Pa.
PNC-35	1.5 to 3m 50mm thick lining between the box and the nearest diffuser	*or*	1m silencer with a maximum pressure drop of 20 Pa

Notes:
1. The above are guidelines and the exact extent of attenuation will be determined with unit selection is finalized.
2. Wire helix type flexible duct may be used in place of lined duct for no more than 1.5m.
3. These recommendations assume box sizes of no more than 35cm. The use of larger boxes is discouraged and will require further analysis.
4. We do not recommend VAV or FPBs for spaces PNC-20 or quieter.

Mechanical Equipment Selection

The following acoustical guidelines are provided for the selection of mechanical equipment.

Fans

We recommend identifying manufacturers of air handling units and using estimated inlet, outlet and case-radiated noise levels provided by manufacturers as soon as possible to achieve the most accurate, cost-effective design.

- The larger, noise critical spaces are best served by dedicated air handling systems.
- We recommend Class-1, built-up centrifugal fans with backward-inclined airfoil blades for spaces below PNC-20.
- Selection and final balancing of fans for maximum efficiency is critical, since a fan operating at 80% efficiency will usually be about 10 to 12 decibels quieter than when operating at 40% efficiency. Ten decibels of extra noise control in ductwork length, lining, silencers or plenums may be very difficult and expensive to achieve. These units should be constant volume, on a variable speed drive, or multi-zone.
- For control rooms and dimmer or sound equipment rooms, a dedicated split system fan-coil unit sized to run in “quiet” mode may be employed.
- Variable air volume or dual conduit systems are not recommended for noise critical spaces, though there are some quiet VAV units we can work with if alternatives prove impractical.

Pumps

Centrifugal pumps should be selected for maximum efficiency for the quietest operation. We recommend that pumps be selected at 1800rpm with a pump impeller of less than 80% of the pump’s inside case diameter.

Chillers and Cooling Towers

Air-cooled chillers should be scroll-type rather than screw-type. The sound generated by a screw chiller is highly tonal, and it is often difficult to sufficiently attenuate the sound. Reciprocating chillers are also not recommended unless used together with an ice storage system such that the chiller does not run during performance events.

Diffusers and Grilles

Diffusers and Grilles should be selected based on the manufacturers NC-rating minus 10 NC points. Manufacturer reported levels typically include a 10dB adjustment for the effect of the room based on typical room sizes and overall absorption. As most rooms are not “typical” it is important to remove the manufacturers room effect adjustment.

Stages recommends avoiding terminal diffusers in noise-critical spaces; an open termination of the duct generates the least amount of noise. Mass produced diffusers and grilles are almost never suitable when low noise levels are required; they are not designed to be silent. In noise-critical spaces with low ceilings or other situations where some diffusing of air will be required, there are a number of quality exceptions to this rule made by Titus and a few other manufacturers, though these terminal devices always carry a premium cost.

Electrical Equipment Selection

The following section describes some basic acoustical guidelines for electrical equipment selection and isolation. More specific recommendations will be provided as the design progresses and there is a better understanding of the electrical scope for the project.

Power Distribution & Transformer Location

Since electrical transformers of all sizes and electromechanical transducers are capable of inducing vibration into the supporting structure and generating airborne noise, it is strongly advised to locate larger components in a main electrical equipment room or rooms where all power distribution equipment will be located. While it is not possible to completely structurally separate the electrical rooms from all noise critical spaces in this existing building, there is an economy to isolating racks of equipment and conduit together instead of in more distributed locations. To the extent possible, main electrical equipment should be located on grade. Transformers larger than 45kVA capacity should not be located above grade or suspended – the hum and vibration from transformers of this size is difficult to control and can spread through structure very easily.

Dimmer Room

To the extent conventional dimming is utilized, dimmer racks for house and production lighting produce considerable noise and vibration and should be located in an acoustically isolated dimmer room. Locate the dimmer room to conserve electrical wiring while ensuring appropriate reduction of noise and vibration. The current location of dimming equipment adjacent to the orchestra pit is already very close to noise-critical spaces and not ideal. Assuming no new or noisier dimming equipment is installed, we should maintain present isolation measures and be sure to include noise control considerations in space planning and development of mounting and connection details, such as vibration isolators and isolated conduit tray/racks.

Ballasts for Fluorescent Fixtures and Drivers for LED Fixtures

While most lighting is trending toward LED sources, some fluorescent lighting is still considered efficient and cost-effective. Fluorescent fixtures may be used for worklights (only) in the performance and connected spaces. Use electronic ballasts (such as the Mark-7) for these fixtures. Fluorescent fixtures may be used in dedicated studio/classroom spaces, but the ballasts for them must be remotely located. In control rooms and similar spaces, fluorescent fixtures may be acceptable with either electronic ballasts, or remote ballasts.

LED lighting is still evolving and acoustical performance of different fixtures, LED drivers, and sources is somewhat unpredictable. Most LED sources that work in place of line-voltage incandescent fixtures are reliably quiet, even when dimmed. However, the manufacturing inconsistencies among these lamps still result in some noise sources among every batch. Remotely driven LED fixtures are quiet, as long as the drivers are sized accordingly and located/isolated properly. There are distance limits between drivers and fixture/lamps to consider in planning for LED lighting.

LED performance lighting fixtures are also in the process of becoming more present across the performance industry. Here again, there are different types of fixtures for different applications and some are quiet enough for low-noise theater spaces. Stages has recent and ongoing experience with the LED performance lighting options on the market and can help guide selection of fixtures that meet both theatrical and acoustical goals.

Low-Noise Dimmers

Stages will specify dimmers used with performance and house lighting in the theater, to minimize noise generated by the filaments or LED sources.

Cable Routing and Sound Isolation

Sound isolating walls can be compromised severely by chases or penetrations for electrical trunking or conduit. Cable routes should not pass directly between noise-critical spaces or from noisy to noise-critical spaces.

Many problems can be avoided if the design team carefully considers the cable routes at an early design stage. Any new cable routes to and from the dimmer room must be considered with particular care.

Emergency Power

Do not locate contactors for emergency lighting fixtures in noise-critical spaces. Such relays are normally on and can generate disturbing hums.

Exit signs in performance and rehearsal spaces should not contain relays, transformers or contactors, and must not be fluorescent. Incandescent or LED line-voltage fixtures are acceptable. Low voltage fixtures may be acceptable if all are fed by transformers located outside of the noise-critical space.

Aisle Lights

We recommend incandescent line-voltage fixtures. Low voltage and LED fixtures may be acceptable if fed by transformers or drivers located outside of the noise-critical space.

Equipment Vibration Isolation

Equipment location is the most efficient way to avoid vibration transfer into noise sensitive spaces. The following is a summary of vibration isolation recommendations. Specific details will be provided as the design progresses.

Equipment Type	Isolator	Min. Defl.
Mechanical		
Cooling Towers	Vertically-restrained, spring type	4 in. / 100 mm
Chillers & Boilers	Vertically-restrained, spring type	2 in. / 50 mm
Pumps & Compressors		
5 hp or greater	Spring-and-neoprene type	2 in./ 50 mm
5 hp or less	Spring-and-neoprene type	1 in. / 25 mm
Fans, Fan Coil Units, Heat Pumps, and Factory-Assembled Air Handling Units		
60,000 cfm or greater	Spring-and-neoprene type	2 in. / 50 mm
4,000 to 60,000 cfm	Spring-and-neoprene type	2 in. / 50 mm
4,000 cfm or less	Spring-and-neoprene type	1 in. / 25 mm
Ductwork (within MER and across acoustic joints)	Spring-and-neoprene type & flex connectors at equipment	Equal to defl. of equipment
Plumbing		
Pumps & Compressors		
5 hp or greater	Spring-and-neoprene type	2 in. / 50 mm
5 hp or less	Spring-and-neoprene type	1 in. / 25 mm
Piping (within MER and across acoustic joints)	Spring-and-neoprene type & flex connectors	Equal to defl. of equipment
Passive devices connected to rotating equipment (Expansion Tanks, Heat Ex-changers, Deaerators, etc.)	Use the same type of isolator as required for the equipment to which it is attached.	
Electrical		
Transformers		
< 500 VA	Neoprene pads	0.1 in. / 3 mm
500 VA to 50 kVA	Neoprene mounts	0.3 in. / 9 mm
> 50 kVA	Sprint-and-neoprene type	1 in. / 25 mm
Dimming Racks & Switchgear	Neoprene pads	0.1 in. / 3 mm
Emergency Generators	Per manufacturer recommendation	
Conduit (within MER and across acoustic joints)	Spring-and-neoprene type & flex connectors at equipment	Equal to defl. of equipment

Appendix B:

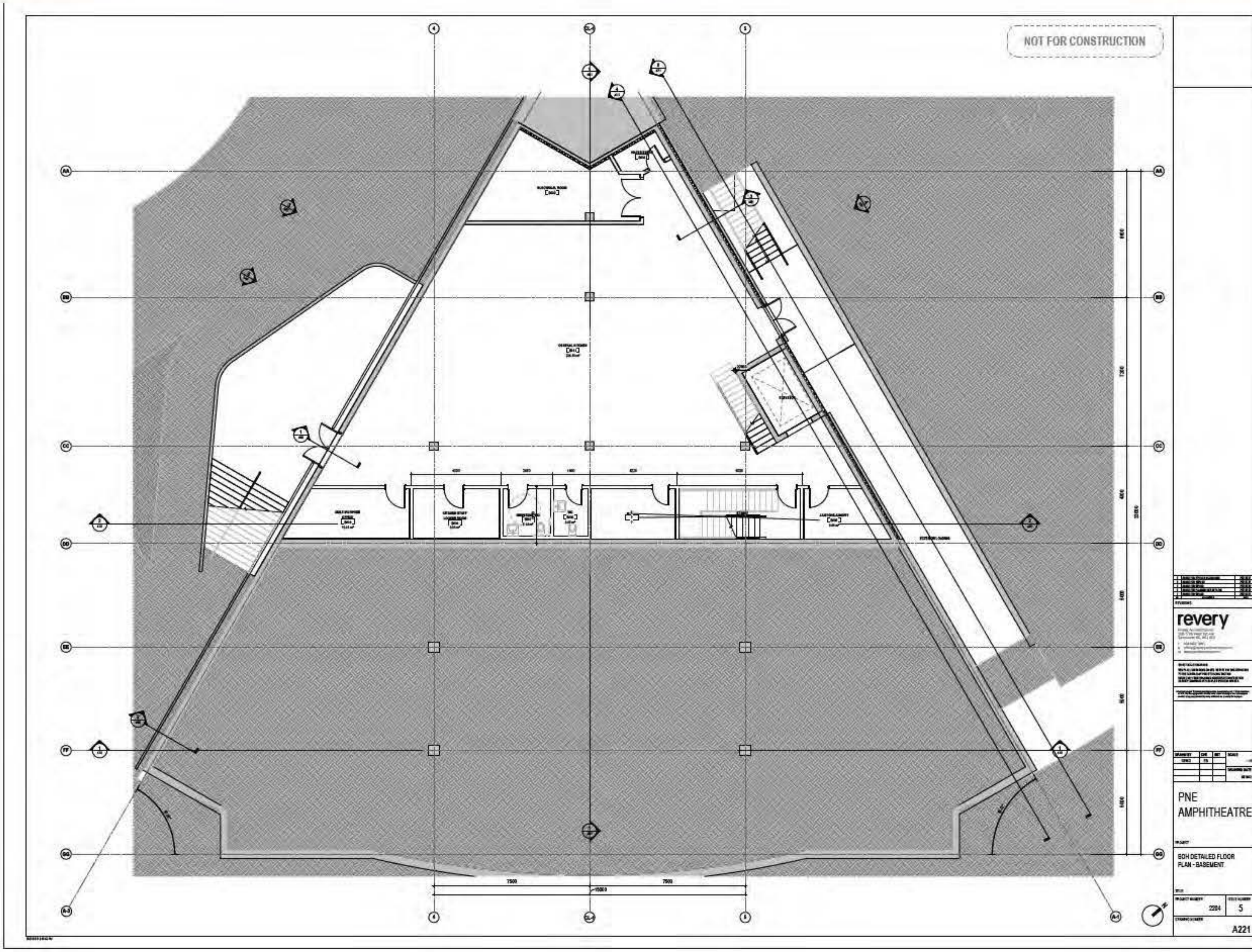
Acoustics Room Descriptions

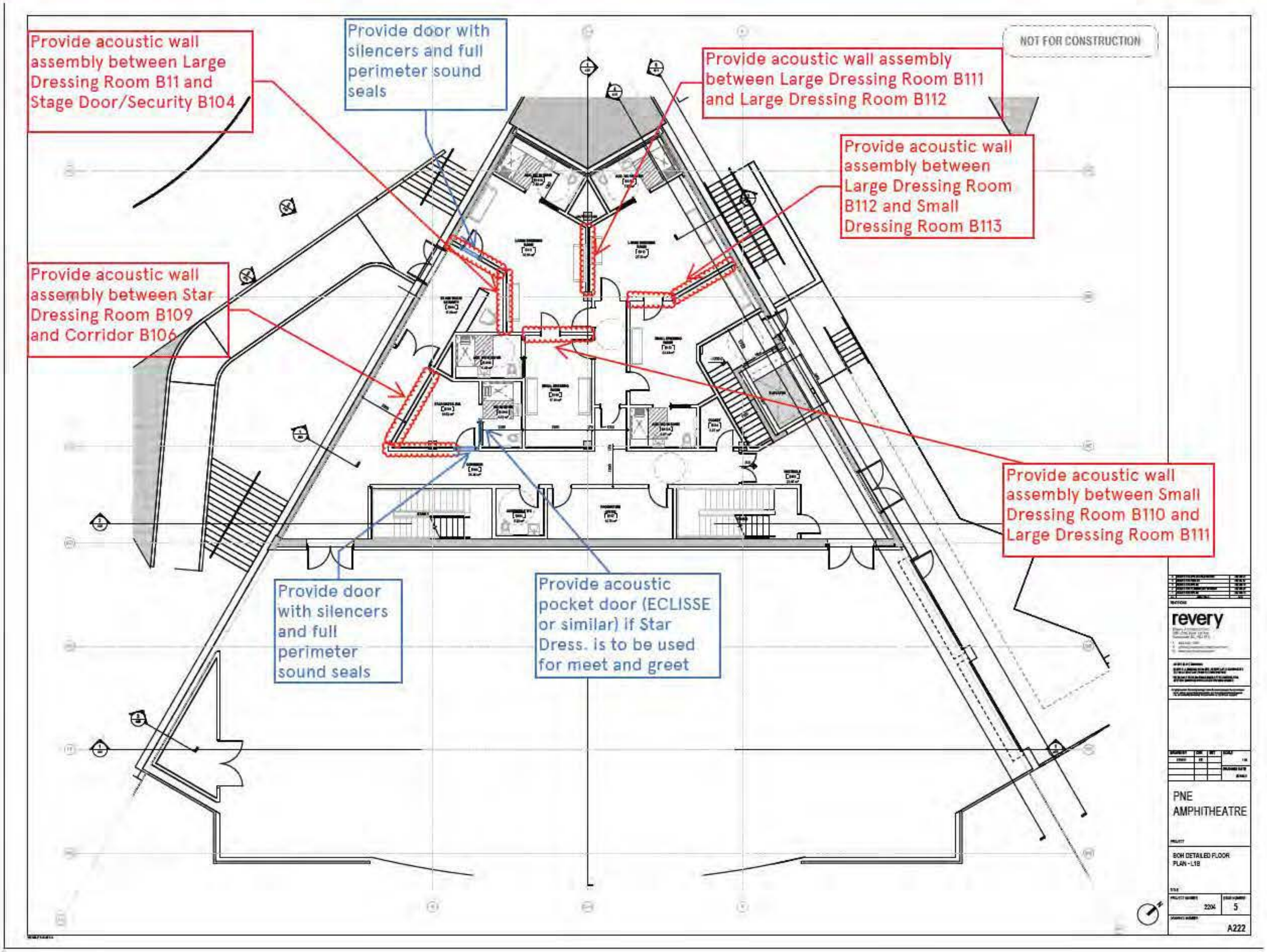
Room Name	Preferred Noise Criteria (PNC)	Ceiling	Floor	Walls	Sound Seals
Box Office	35	N/A	Carpet	Painted GWB	N/A
Universal & Barrier Free Washrooms	45	N/A	Tile	Tile	N/A
VIP Restrooms	45	N/A	Tile	Tile	N/A
Food Concessions/ Bars (enclosed)	35	N/A	Tile	Exposed concrete block/Tile	N/A
Bar Concessions (enclosed)	35	N/A	Tile	Exposed concrete block/Tile	N/A
VIP Bar Concession	35	N/A	Incorp. w/ suites	Incorp. w/ suites	N/A
Central Kitchen (Back of House)	45	N/A	Tile	Exposed concrete block/Tile	N/A
Merchandise Vendor	45	N/A	Existing concrete	Exposed concrete block	N/A
Crew Lounge (Back of House)	40	ACT	VCT	Exposed concrete block	N/A
Office, Manager/Visitor	35	ACT	Carpet	Painted GWB	N/A
Office, In-House Services	35	ACT	Carpet	Painted GWB	N/A
Engineer's Office	35	ACT	VCT	Exposed concrete block	N/A
Stage Lighting Utility Room	45	Exposed	Existing concrete	Exposed concrete block	Yes
AV Utility Room	45	Exposed	Existing concrete	Exposed concrete block	Yes

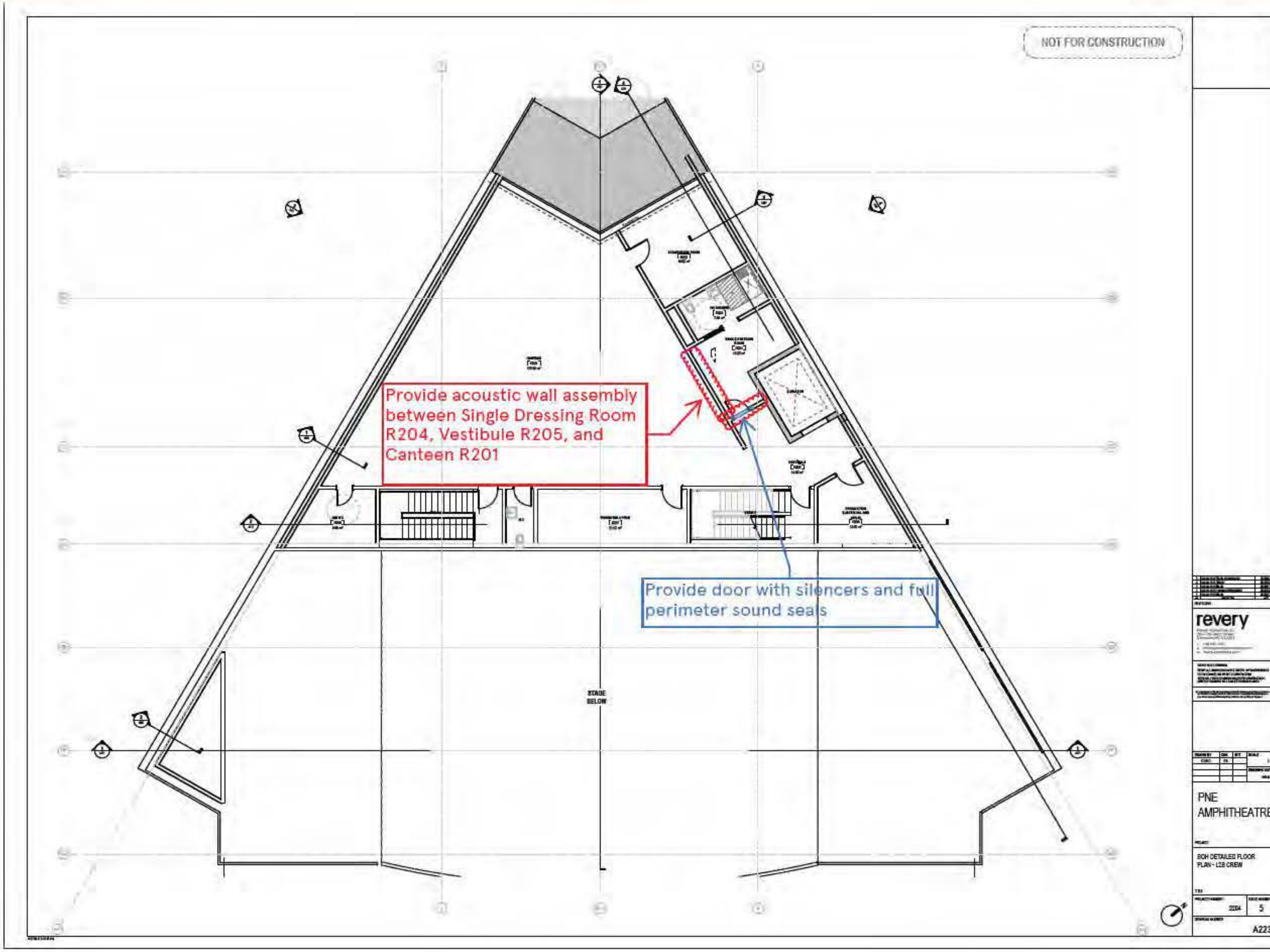
Room Name	Preferred Noise Criteria (PNC)	Ceiling	Floor	Walls	Sound Seals
Performer's Lounge	30	ACT	Carpet	Painted GWB	N/A
Stage Level Quick Change Washroom	30	ACT	Tile	Tile	N/A
Dressing Room (star suite)	25	ACT	VCT	Painted GWB	Yes
Dressing Room (6-person)	35	ACT	VCT	Painted GWB	N/A
Stage Door	30	ACT	VCT	Painted GWB	N/A
Security Office	35	ACT	VCT	Painted GWB	N/A
VIP Seating Boxes (capacity 164)	30	N/A	Existing concrete	1m plywood walls	N/A
Control Booth	20	N/A	Existing concrete	Exposed concrete	Yes
VIP Suites (capacity 25)	30	ACT	Carpet	Glass/timber/glass	Yes
Main Stage	25	Exposed	Painted concrete	Rear/ext. plywood	Into performance areas only
Stage Left Wing	25	Exposed	Painted concrete	Existing structure	Into performance areas only
Stage Right Wing	25	Exposed	Painted concrete	Existing structure	Into performance areas only

Appendix C:

Markup of Acoustic Partitions in Back of House Areas


NOT FOR CONSTRUCTION
revery
PNE AMPHITHEATRE
BOH DETAILED FLOOR PLAN - BASEMENT
5
A221


Provide acoustic wall assembly between Large Dressing Room B11 and Stage Door/Security B104
Provide door with silencers and full perimeter sound seals
NOT FOR CONSTRUCTION
Provide acoustic wall assembly between Large Dressing Room B111 and Large Dressing Room B112
Provide acoustic wall assembly between Large Dressing Room B112 and Small Dressing Room B113
Provide acoustic wall assembly between Star Dressing Room B109 and Corridor B106
Provide acoustic wall assembly between Small Dressing Room B110 and Large Dressing Room B111
Provide door with silencers and full perimeter sound seals
Provide acoustic pocket door (ECLISSE or similar) if Star Dress. is to be used for meet and greet
revery
PNE AMPHITHEATRE
BOH DETAILED FLOOR PLAN - L1B
2204
5
A222


NOT FOR CONSTRUCTION
Provide acoustic wall assembly between Single Dressing Room R204, Vestibule R205, and Canteen R201
Provide door with silencers and full perimeter sound seals
STAGE BELOW
revery
PNE AMPHITHEATRE
BOH DETAILED FLOOR PLAN - L2B CREW
A223

Appendix D:

Curriculum Vitae of Damian Doria, FASA

Curriculum Vitae of Damian Doria, FASA

Summary Description

Over the past 27 years, Damian has been directly involved in the design and construction of over 125 venues worldwide and directed or provided quality assurance for dozens more. Damian is recognized as an expert in his field, is a Fellow of The Acoustical Society of American and Served as General Chair for Society Conferences (New York Spring 2004 and Boston Spring 2017), and is a Lecturer in architectural acoustics at The David Geffen School of Drama at Yale University.

Professional Experience

s.22(3)(d)

[redacted]

Previous Professional Experience

s.22(3)(d)

[redacted]

- Damian Doria, Bob Essert. “Implementing acoustical designs – Non-acoustical project choice may help or hinder successful outcomes.” The Journal of the Acoustical Society of America Abstract. Vol. 144, Issue 3. 2019

- Damian Doria, Evelyn Way. "Rethinking libraries – Three case studies." The Journal of the Acoustical Society of America Abstract. Vol. 145, Issue 3. 2019
- Damian Doria, Dave Kotch, "A 240-Seat Recital Space for Amplified Performance" presented at the Acoustics New Orleans Conference, November 2017
- Damian Doria, Tom Clark, Todd L. Brooks and Bob McCarthys. "Vocal Intelligibility and Clarity in Amplification: Challenges for Concert Hall Acoustics." presented at the Acoustics Hong Kong Conference, May 2012.
- Damian Doria, Edward P. Arenius, Tateo Nakajima and Todd L. Brooks. "Artec Concert Halls – A New Generation." presented at the Acoustics Hong Kong Conference, May 2012.
- Clementh L. Abercrombie, Todd L. Brooks, Damian J. Doria, and Tateo Nakajima. "Acoustic re-radiation of structurally coupled instruments by stage floors and orchestra risers." presented at the Acoustics Hong Kong Conference, May 2012.

Additional publications available upon request.