Arup**Acoustics**

Mather & Associates

Domain Master Plan Acoustic Report

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AIMS

To describe the existing acoustic environment within the Domain and outline the current activities that occur throughout the year.

To identify noise sensitive neighbours and describe their existing acoustic environment.

To outline existing acoustic criteria relating to the operation of events during the year and comment on the current acoustic impact on surrounding neighbours.

To outline any acoustic constraints on events occurring in the Domain.

To consider the options for the location of the temporary stage in Phillip Precinct.

To consider the option of a permanent or temporary stage in the Crescent Precinct.

EXECUTIVE SUMMARY

Location of stage in Phillip Precinct

A comparison of the three proposed options for the location of the temporary stage in Phillip Precinct has been made. It is concluded that the best location for the stage, in acoustic terms, is the current location.

This location provides the best acoustic conditions both in the audience area and for the performers on stage. With Option 1, reflections from the Parliament building and Sydney Hospital would cause significant echoes in the audience area which would be highly distracting and also would potentially cause disturbance to the performers on stage. Poor sound coverage in the audience area could also occur with Option 2 due to the steep fall of the ground away from the stage.

In terms of protection of noise-sensitive receivers located in the vicinity of the Domain, the existing stage location is the preferable option. With improvements in loudspeaker technology in the future, (particularly greater control of loudspeaker radiation patterns), it should be possible to deliver higher sound levels to the audience area whilst still controlling noise levels at the Hospital and residential areas in Woolloomooloo. This may also be possible with Option 2 but would require greater investigation to ascertain such variables as exact loudspeaker locations, aiming angles and screening.

Option 1 is not considered viable since the location of the stage would be such that the loudspeakers would aim towards Sydney Hospital. Even with highly directional loudspeakers the noise criterion at the hospital could not be met without having unacceptably low sound levels at the rear of the audience area or by locating a barrier of significant height (6 m) and length along Hospital Road.

The sound quality in the audience area with the current temporary stage location is not optimal. Listeners have commented on poor audibility towards the rear of the audience area. This area is currently dominated by traffic noise from the Cahill Expressway. The situation could be significantly improved by the provision of an acoustic barrier along the edge of the Cahill Expressway and the implementation of such a barrier is strongly recommended. Further work would be necessary to design a suitable barrier but it is estimated that it would need to be approximately 3m high with an absorptive face on the park side of the barrier. The barrier could be designed to integrate with the park landscape by the use of appropriate

designs and/or paintwork. It is also considered likely that the sound-system design is not optimal and hence the sound levels currently achievable are limited.

Strategy for further consideration of Option 1

Since preparation of the draft of this report, we have been advised by Mather & Associates that the Royal Botanic Garden's Trust (RBGT) strongly favours Option 1 for the location of the stage. Noting that Arup Acoustics considers this to be the least desirable option of the three options, we offer a sequenced strategy for further consideration of the acoustic impacts of this option.

1. Carry out detailed acoustic modelling of Option 1 to establish the exact extent of the acoustic difficulties with this option. We would :
   a) determine the likely noise levels at Sydney Hospital.
   b) determine the extent of disturbance to the audience and performers from reflections from the Parliament building and the Sydney Hospital.

2. Arup Acoustics to meet with the RBGT and Sydney Festival to discuss the outcomes of this modelling and the impact on live concerts in the Domain.

3. Discuss the noise impact of this option with the Environment Protection Authority and the Sydney Hospital.

4. Possible auralisation of Option 1's acoustic conditions, in particular the acoustic reflections. This would enable the Royal Botanic Gardens Trust to hear on headphones the sound that the audience and performers will hear.

Permanent or Temporary Stage in Crescent Precinct

It is recommended that this option is not pursued. A previous study carried out in 1998[1] which looked at this option found that, even with the provision of significant acoustic barriers, the site is only suitable for small scale events. The two constraining issues were the impact of noise on residents and St Mary's Cathedral and the effect of reflections from the Cathedral and its associated school degrading the sound both in the audience area and on stage.

Site of Original Ladies Bathing Pool

This site has been considered as a possible location for small events such as cocktail parties. This area would be suitable for such events as small cocktail parties or acoustic music. It would not be suitable for any reinforced music or speech systems due to the proximity of residents at the Woolloomooloo Wharf Apartments and the Wharf Terraces.

[1] Elecoustics Report No: 519-2-A, *Acoustical Assessment of the proposed outdoor performance venue above the Domain Car Park*, July 1998

1. INTRODUCTION

Arup Acoustics has been commissioned to produce an acoustic report as part of an overall Site Master Plan for the Domain in Sydney. This report addresses the current and proposed uses of the Domain in the context of the acoustic environment of the park and acoustic impacts on adjacent noise sensitive receivers.

Mather and Associates have produced a number of possible locations for the stage that is erected annually in Phillip Precinct as part of an Events Strategy Plan.

A plan of the site is shown in Figure 1. An explanation of the acoustic terminology used in this report is given in Appendix A.

2. CURRENT USES OF THE DOMAIN AND EXISTING EPA LIMITS

There are a number of events that occur annually within the Domain. Many of these events occur within the Phillip Precinct including Homebake, Carols in the Park and various concerts in January as part of the Sydney Festival.

There is also an open air cinema in the Yurong area, that operates between January and February as part of the Sydney Festival.

These events are currently subject to certain noise limits and operational hours as defined in the licence issued by the EPA under the Control of Pollution Act 1970.

The current licence issued by the EPA covers the following events:

- Open Air Concerts with a crowd capacity in excess of 10,000 people
- Open Air Concerts with a crowd capacity of less than 10,000 people
- Marquee Functions
- Open Air Cinema
- Fireworks

The number of some types of events are limited by the licence to a certain amount per year.

Event	No. of events	Hours of Operation	Noise Limit at boundary of nearest residence	Exceptions
Open Air > 10,000 people	10	1000 - 2300	70dB L_{Amax}	80dB(A) @ Sydney Hospital 90dB(A) @ Sydney Hospital during Carols in the Domain and Sydney Festival Events
Open Air < 10,000 people	not specified	1000 - 2300	As above	80dB(A) @ Sydney Hospital
Fireworks	as part of concerts above	1000 - 2300	110B L_{Amax}	
Marquee Functions	not specified		$L_{A10} < L_{A90}$ + 5dB (0700 - 2400) $L_{A10} < L_{A90}$ (all other times)	
Open Air Cinema	7 films per week	2030 - 2330	$L_{Amax} < L_{90}$ + 5dB	

Table 1: Summary of current EPA noise criteria for the Domain (valid until 10/01/00)

The EPA currently require events with more than 10,000 people to be monitored by an Acoustic Engineer for compliance with the EPA criteria.

3. NOISE SENSITIVE RECEIVERS

3.1 Location of receivers

The location of potentially noise sensitive receivers are shown in Figure 2.

Philip Precinct
There are a number of noise sensitive receivers located in the environs of the Domain. To the east of the Domain is Wooloomooloo and this area is generally residential. The most exposed residents in terms of noise emanating from the Phillip Precinct are the Domain Apartments and the former Sydney Eye Hospital.

To the southwest of the site is St Mary's Cathedral and its associated buildings. Some of these buildings contain activities such as teaching at the Cathedral School and could be considered to be noise sensitive.

To the west of the site is the Sydney Hospital. This building currently has specific noise criteria applied to it by the EPA, given its close proximity to the Phillip Precinct.

Wooloomooloo/Yurong Areas
The Wooloomooloo and Yurong areas of the Domain are bounded to the west by the Royal Botanical Gardens, to the south by the Cahill Expressway and the Phillip Precinct and on the north and the east by Sydney Harbour. Also located to the east of the site is the restored Wooloomooloo Wharf apartments, the Wooloomooloo Wharf Terraces and the Garden Island Defence Department.

3.2 Background Noise Levels at Receivers

In 1998 noise level measurements were made at various receiver locations surrounding the site as part of a study on the possible development of a permanent venue in the Crescent area[2].

Measurements were conducted on Monday, Friday and Saturday at around 2pm, 8pm and 10pm. These times were chosen to represent the range of possible times and background noise levels during which concerts could be held in the Domain.

These measurements were made before the completion of the Eastern Distributor, however the predicted impact was a drop in noise levels of between 1dB and 4dB dependant upon the receiver location.

[2] Elecoustics Report No: 519-2-A, *Acoustical Assessment of the proposed outdoor performance venue above the Domain Car Park*, July 1998

The measured and predicted future background noise levels are shown below:

Location	Measured Background Noise Level (L_{A90}), dB	Predicted Background Noise Level (L_{A90}), dB (after completion of Eastern Distributor)
4 - 6 Riley Street	55 - 60 (2 to 3pm) 50 - 52 (9 to 10pm)	51 - 56 (2 to 3pm) 46 - 48 (9 to 10pm)
Domain Apartments	63 - 65 (2 to 3pm) 54 - 60 (9 to 10pm)	59 - 61 (2 to 3pm) 50 - 56 (9 to 10pm)
Sydney Eye Hospital Apartments	55 - 61 (2 to 3pm) 52 - 56 (9 to 10pm)	51 - 57 (2 to 3pm) 48 - 52 (9 to 10pm)
St Mary's Cathedral	53 - 55 (2 - 3pm) 48 - 51 (9 to 10pm)	51 - 53 (2 - 3pm) 46 - 49 (9 to 10pm)
Sydney Hospital	52 - 55 (2 to 3pm) 50 - 53 (9 to 10pm)	51 - 54 (2 to 3pm) 49 - 52 (9 to 10pm)

Table 1: Measured and Predicted Background Noise Levels at various receiver locations

4. FUTURE EVENT USAGE

The current usage of the Domain for the Sydney Festival and Carols in the Park as well as various other events throughout the year, is likely to continue and as part of the Master Plan a number of options are being considered. The options that are under consideration are:

- ♣ the location of a permanent or temporary performance space in the Crescent area.
- ♣ the relocation of the existing temporary stage within the Phillip Precinct. A number of possible locations are considered.

4.1 Permanent or Temporary Stage in the Crescent Precinct

The option of locating a structure above the Domain Car Park has been considered previously in an in depth study carried out in 1998[1]. This study was commissioned by the NSW Department of Public Works and Services. The work considered the use of the stage for both large scale events with audiences above 10,000 people and also small scale events with an audience of up to 2000 people.

The study investigated two main aspects of the proposal:

1) The impact of noise from concerts on nearby residents and buildings of cultural and social significance such as St Mary's Cathedral and Sydney Hospital

2) The effect of the acoustic environment within the Domain on the quality of sound in the audience area and on the stage.

The main primary conclusions of the report were that:

- ♣ In acoustic terms the proposed venue was impractical for large scale concerts.
- ♣ If suitable barriers were used, the site is reasonably suitable for small scale events.

The primary recommendation of the report therefore was that the site should be used for small scale events only.

The acoustic barriers that would be necessary even for small scale concerts are significant, up to approximately 7m in height. An estimate of the acoustic barriers in terms of size and location would require significant design work and was not included in the scope of the study.

4.2 Relocation of the existing temporary stage within the Phillip Precinct

As part of the Events Strategy Plan a number of options for the location of the current temporary stage in the Phillip Precinct have been considered, in terms of both their likely acoustic impact on nearby residents and their acoustic suitability for audiences and performers.

The options are shown in Figures 3 to 5.

[1] ibid

4.2.1 Option 1

Figure 3 shows Option 1 which considers the stage located to the north of the Phillip Precinct with the stage angled at approximately 45 degrees to the Cahill Expressway. An acoustic barrier would be located along the Cahill Expressway. The loudspeakers on stage would aim towards Hospital Road.

Advantages

- The provision of an acoustic barrier would reduce the noise impact from traffic on the audience area and on stage. The location of the speakers between the listener and the Cahill Expressway would provide a better sound coverage in the audience area. Listeners at the rear of the area would not suffer the intrusion of traffic noise as is currently the case.

- Both of these provisions would increase the signal to noise ratio of the events (ie the mathematical difference between the sound level from the performance programme and the background noise level) in the audience area. A signal to noise ratio of at least 20dB during speech or quiet sections of a music programme is required for enjoyment. With this arrangement, the signal to noise ratio in the audience area would be considered good.

- Noise levels impacting on residents on the Wooloomooloo side of the park would be likely to be similar to, or slightly less than, the existing levels from the current stage arrangement. The actual impact would be dependant upon the exact location and aiming angle of the loudspeakers and would require significant prediction work that is beyond the scope of this study.

Disadvantages

- Converse to the improvement of the signal to noise ratio in the audience area, the signal to noise ratio on stage would be reduced due to the proximity of the stage to the Cahill Expressway. The acoustic barriers would reduce the impact of traffic noise but the signal to noise ratio would still be lower than at the existing stage location.

- The positioning of the stage is such that the loudspeakers will aim towards the Sydney Hospital and St Mary's Cathedral. The noise levels reaching Sydney Hospital would be likely to significantly exceed the current EPA criteria. Unless they are of significant height (at least 6m) noise barriers along Hospital Road would have minimal effects on the noise levels at the Hospital and would also be aesthetically unacceptable.

- There will be degradation of sound within the audience and stage area due to reflections of sound off the Parliament House and Sydney Hospital buildings. The extent to which this will be a problem has already been illustrated (albeit to a lesser extent) with the current stage location, by reflections from the temporary toilets (adjacent to the Cahill) which disturb the sound in the rear half of the audience area.

- For further discussion please refer to Appendix B.

Conclusion

In acoustic terms this option is not considered viable due to the impact on the Sydney Hospital, the reflections from Parliament House and the Sydney Hospital and the noise levels on stage from traffic on the Cahill Expressway.

4.2.2 Option 2

Figure 4 shows the second option which involves the location of the stage to the west of the Phillip Precinct.

Advantages

- Limited reflections from surrounding buildings degrading the sound in the audience area, although it is possible that there would be a reflection from the Art Gallery.

Disadvantages

- The stage is located closer to the Sydney Hospital. Although the loudspeakers will be angled to a greater degree from the hospital, the increase in noise level due to the closer distance is likely to result in a slight overall increase in noise level at the hospital, particularly at lower frequencies.

- There would be a slight increase in noise levels to residential receivers to the south-east of the site, due to the loudspeakers being angled slightly further in this direction. There would also be a slightly greater impact on the Art Gallery.

- The noise impact on the audience area from Cahill Expressway will be similar to the current situation.

- The steep fall of the ground away from the stage would make coverage of the audience area poorer. The loudspeakers would tend to aim above the heads of the audience.

Conclusion

This option is feasible but a more in depth study would be required, including information on exact loudspeaker locations and aiming angles, to assess the impact on the Sydney Hospital and residents in Wooloomooloo. For further discussion see Appendix B.

4.2.3 Option 3

Option 3 is shown in Figure 4 and represents the current location of the stage.

Advantages

- The loudspeakers are aimed away from the Sydney Hospital so controlling noise levels in these areas.

- No reflections from surrounding buildings degrading the sound in the audience area.

- Good signal to noise ratio on stage as stage located away from the Cahill Expressway.

- Technological advances in controlling loudspeaker radiation patterns will mean that in the future this option will provide the greatest flexibility in terms of covering the audience areas with good quality high level sound whilst still controlling the noise impact on neighbours.

Disadvantages

- As for Option 2, there will some intrusion of traffic noise at the rear of the audience ie those located close to the Cahill Expressway. The location of an acoustic barrier along the Cahill Expressway could greatly improve this situation.

Conclusion

This option is known to be acceptable acoustically although the number of events that can occur annually is controlled by the EPA criteria. We consider that this is the best option acoustically.

It is proposed that a noise barrier located along the edge of the Cahill Expressway is included in this option. Further work would be necessary to design a suitable barrier but it is estimated that it would need to be approximately 3m high with an absorptive face on the park side of the barrier. The barrier could be designed to integrate with the park landscape by the use of appropriate designs and/or paintwork.

4.3 Site of Original Ladies Bathing Pool

This site, located in Woolloomooloo bay opposite the Naval Base, has been considered as a possible location for small events such as cocktail parties.

The nearest residents are located in the Woolloomooloo Wharf Apartments (the finger wharf development) and the Woolloomooloo Wharf Terraces opposite the finger wharf.

The most likely noise criteria that would be set by the EPA would be that the L_{A10} of any event would need to meet the existing background noise levels (L_{A90}) + 5dB ie the same as the section in the current EPA licence covering marquee functions.

A visit to the area indicated that the current background noise levels within this area are reasonably low and at the time of the visit were dominated by activity noise from within the Naval Base. The location of the site is close to the residents discussed above, with water located in between. Water is acoustically reflective and hence gives very low levels of sound attenuation over distance.

Given the factors discussed above, the use of the space would be limited to small low key events with no use of reinforced speech or music systems. It could be suitable for acoustic music events with a small audience or private functions such as cocktail parties.

4.4 Open Air Cinema

As part of the annual Sydney Festival, an open air cinema operates at the Fleet Steps, Lady Macquarie's Chair between January and February. The operation of this cinema is covered by the EPA licence and as far as Arup Acoustics are aware operates satisfactorily. There are no residents located near to the area and the only significant impact would tend to be on the Royal Botanic Gardens themselves.

At present there are no significant acoustic constraints that would affect the continuation of this event in the future.

5 CONCLUSIONS

- The three options for the location of the temporary stage currently used in the Phillip Precinct have been considered from an acoustic perspective. The disadvantages of the two alternative options are such that we recommend that the location of the stage remains as is. We believe that this is the best solution for a difficult space. There will always be acoustic constraints both in terms of noise impact on neighbours and quality of sound in the audience/stage areas.

- With the implementation of a suitable acoustic barrier along the edge of the Cahill Expressway, the sound quality in the audience area with the current stage location will improve. A greater number of people will be able to enjoy the performances than at present.

- With the technology of controlled-directionality loudspeakers continuing to advance, the sound from performances in the future will be able to be aimed over a more controlled area, thereby increasing sound levels in the audience area whilst maintaining appropriate noise levels at residents. The current stage location is best suited to benefit from such technological advances.

- It is recommended that the proposal for a permanent or temporary stage located above the Domain Car park is not pursued due to the requirement for significant noise barriers to protect local residencies and poor sound quality in the listener area due to reflections from St Mary's Cathedral.

- The use of the site of the original ladies swimming baths in Woolloomooloo Bay has been considered and it is advised that this area would be suitable for small events such as cocktail parties, weddings or acoustic music. It would not be suitable for any event using amplified speech or music.

APPENDIX A - ACOUSTIC TERMINOLOGY AND UNITS

dB(A)

The unit generally used for the measurement of environmental, transportation or industrial noise is the A-weighted sound pressure level in decibels, denoted dB(A). The A-weighting is based on the frequency response of human hearing (for a given sound pressure level, low frequency sounds do not seem as loud as mid or high frequency sounds) and has been found to correlate well with human subjective reaction to various sounds.

An A-weighting network is built into sound level measuring instrumentation such that sound levels can be read directly from the meter in dB(A). An increase or decrease in sound level of approximately 10dB(A) corresponds to a subjective doubling or halving in loudness. A change in sound level of 2 to 3dB(A) is subjectively barely noticeable.

L_{eq}

The L_{eq} denotes the equivalent continuous sound level. It is used in the assessment of noise levels which vary with time (for example road traffic noise). The L_{eq} represents the notional steady level which would, over the relevant time period, deliver the same sound energy as the actual fluctuating sound level. Hence fluctuating sound levels can be described by a single value. A-weighted L_{eq} sound levels are denoted L_{Aeq}.

Statistical Indices (L_{90}, L_{10} etc)

Noise levels which vary with time may also be analysed using statistical indices. The L_{10} index represents the noise level which is exceeded for 10% of the measurement period. It was developed for use in the assessment of the potential for time varying noise to interfere with speech communication and represents an “intrusive noise level”. The L_{90}, the level exceeded for 90% of the time, represents the background noise level.

A-weighted statistical levels are denoted L_{A10}, L_{A90} etc.

Maximum and Minimum Noise Levels (L_{max}, L_{min})

The maximum noise level occurring during a measurement is referred to as the L_{max} while the minimum value is the L_{min}. A-weighted values are denoted L_{Amax} and L_{Amin}.