Construction Noise Management for Hinze Dam Stage 3

Joseph Lee and Jackson Yu

Water and Environment, SKM, Brisbane, Australia

ABSTRACT

This paper considers what is practical in managing construction noise by presenting results from noise monitoring conducted for the construction of Hinze Dam Stage 3 in Advancetown, Australia. A continuous noise monitoring program was used to compare construction noise levels to project day time noise limits of $L_{eq,1hour}$ 58 dB(A), and $L_{1,10min}$ 63 dB(A). Both statistical indicators and sound recordings were used to analyse and identify construction related exceedances on a weekly basis. No official noise complaints were received with regards to project construction activities. However, construction activities did result in exceedances of noise limits and twenty four noise related enquiries were addressed by the Hinze Dam Alliance from 2007 to May 2011. There is currently little formal guidance on noise limits for construction. Given that the expectation large infrastructure projects will continue to be developed in Queensland it is recommended we develop a suitable set of noise goals that are practical to implement and protect the noise amenity of the community.

INTRODUCTION

Hinze Dam is the main source of water for the city of Gold Coast, Australia. Hinze Dam Stage 3 involved almost doubling the capacity of the dam to 309,700 ML by raising the dam wall by 15 m with the aim of providing additional water supply and flood mitigation for Gold Coast.

Land use surrounding the Hinze Dam is primarily rural residential. The noise environment is quiet during both the day and night time with the absence of significant industrial and road traffic noise sources in the area (Hinze Dam Stage 3 Environmental Impact Statement, 2007).

Noise generated by Hinze Dam Stage 3 construction activities was a key environmental constraint for the project with potential to cause nuisance noise impacts at nuisance sensitive receivers. This paper aims to further add to the understanding of what is practical in the management of construction noise and benefit the development of suitable noise goals for similar large infrastructure projects through:

- an overview of noise limits and noise management measures applied for Hinze Dam Stage 3;
- analysis of the relationship between noise limit exceedances and noise related complaints;
- an overview of construction noise limits and management measures in similar projects; and
- assessment of the performance of noise goals for Hinze Dam Stage 3.

CONSTRUCTION HOURS AND ACTIVITIES

Construction hours

Standard construction hours for the project were:

- Monday to Friday 6:30 am to 5 pm; and
- Saturday 6:30 am to 2:30 pm on one week each month where a rostered day off was scheduled for Monday.

An evening maintenance shift in the workshop was proposed from 3 pm to midnight, Monday to Friday.

Cut off wall operations were conducted beyond standard construction hours between August 2008 and May 2009 at the following times:

- Monday to Saturday 5 pm to 10 pm.

Between October 2009 and November 2010 work was also carried outside standard construction hours for the placement of filter material and work on the clay core on the main embankment during the following times:

- Monday to Saturday 5 pm to 12 am.

Description of major construction activities, locations and timeline

Major construction activities with potential to cause nuisance noise impacts were:

- site establishment including the construction of haul roads, clearing and grubbing of vegetation, establishing work areas, and set up of fixed plant;
- operation of the quarry, and crushing and screening plants, approximately 800 m from the nearest sensitive place;
- operation of concrete batching plant approximately 300 m from the nearest sensitive place;
- clay extraction from the clay borrow area approximately 200 m to the nearest sensitive place;
- excavation and laying of rock fill and filter material on the main embankment and saddle dam, approximately 450 m to 500 m from the nearest sensitive places;
- construction of a cut-off-wall on the main embankment, including out of hours work;
- extension of the main embankment and saddle dam;
- concrete works on the spillway and fishway; and
- out of hours work on the main embankment clay core and filter laying.

Construction activities started in November 2007 for the site establishment, and major construction activities occurred between early 2008 and May 2011.

CONSTRUCTION NOISE CRITERIA

Construction noise limits for Hinze Dam Stage 3

The noise limits for nuisance sensitive places as set out in the Project development approval are shown in Table 1.

Table 1. Noise limits at nuisance sensitive places

	Monday to Saturday		Sundays and Public Holidays
Period	6:30am -10pm	10pm-6:30am	Anytime
$L_{Aeq,1\ h}$	58	Not audible	Not audible
$L_{A1,adj,\ 10\ min}$	63	Not audible	Not audible

The $L_{Aeq,1\ hr}$ 58 dB(A) limit was based on a $L_{Aeq,12hr}$ 58 dB(A) recommended in the Environmental Impact Statement (EIS) study. This level recognised the *Environmental Protection (Noise) Policy 1997* acoustic quality objective of L_{Aeq} 55 dB(A) for a 24 hour period, however, adjusted by 3 dB(A) for a proposed 12 hour construction day period.

The $L_{A1,adj,10\ min}$ 63 dB(A) limit was an additional condition in the project approval that was imposed by the Coordinator-General (Coordinator-General's report Hinze Dam Stage 3 Project 2007).

Out of hours cut of wall activities occurred after geotechnical investigations during construction determined that a cut off wall was required near the saddle dam. In order to meet the scheduled completion of construction, out of hours construction of the cut off wall occurred between August 2008 and May 2009 between 5 pm and 10 pm.

The construction noise limits for the cut off wall construction at nuisance sensitive receivers were the same as those shown in Table 1, as well as the following additional external noise criteria for sleep disturbance:

- L_{Amax} of ≤ 52 dB(A)

During the latter part of the project night time construction work was carried out for filter placement and clay core works between 5 pm and 12 am following extended periods of rainfall impacting on the project timeframe. Table 2 shows construction noise limits for this activity which were based on the *Environmental Protection (Noise) Policy 2008* which states noise levels of $L_{A1,adj,1\ h}$ 40 dB(A) and $L_{Aeq,adj,1\ h}$ 30 dB(A) are to be achieved indoors during the night time for health and wellbeing in relation to sleep. A 10 dB difference between internal and external noise levels was approximated to calculate the criteria.

Table 2. Noise limits for filter placement and clay core works measured outside nuisance sensitive places

	Monday to Friday
	5pm-12am
$L_{Aeq,adj,1\ h}$	40
$L_{A1,adj,1\ h}$	50

MODELLING RESULTS AND PREDICTIONS

Predictions of potential construction noise levels were made using SoundPLAN modelling in the EIS stage for the 36 months during which construction was proposed to take place. Predicted noise levels were compared against a $L_{Aeq,1\ h}$ 58 dB(A) criteria for standard construction hours.

Three scenarios were modelled; one scenario for the site preparation and initial works; a second scenario for construction at 12 months; and a third scenario of the scaling back of construction activities at 24 months. Modelling took into account major activities from clearing of vegetation, quarrying activities, rock filling at the dam and clay extraction at a clay borrow area, with vehicle movements around the main embankment and a saddle dam.

$L_{Aeq,1\ h}$ construction noise levels were predicted to be approximately 5 dB(A) below the noise limit for the site preparation and initial works, while noise levels during dam wall construction were predicted to exceed the criteria by 8 dB(A) and 4-6 dB(A) at the nearest nuisance sensitive receivers for the 12 months and 24 months scenarios respectively without noise mitigation.

Modelling for out of hours cut off wall activities predicted compliance with construction noise limits including the sleep disturbance criteria.

For after hours filter placement and clay core works, noise levels were predicted to comply with the $L_{Aeq,adj,1\ hr}$ and $L_{A1,adj,1\ hr}$ criteria at nuisance sensitive receivers with noise mitigation measures.

CONSTRUCTION NOISE MANAGEMENT FOR HINZE DAM STAGE 3

Construction noise management measures

Some of the key measures to mitigate noise impacts that have been implemented in the project include:

- 24 hour monitoring of noise levels were conducted at two locations representative of the closest residential areas to construction activities;
- noise monitoring was conducted at other sensitive receiver locations on an ad hoc basis to monitor specific work activities;
- weekly noise monitoring reports were used to review noise monitoring data and sound recordings, and identify construction noise exceedances;
- an analysis was carried out of beeper reverse alarms, broadband alarms, and self-adjusting alarms based on 1/3 octave measurements for tonality, overall loudness, and public perception from feedback from residents. Following this analysis project construction vehicles were fitted with broadband alarms;
- the mechanical workshop was lined with acoustic insulation to provide a minimum attenuation of 26 dB(A);
- a communication program was used to provide a system of notifying the community of noisy events, and facilitate investigations and responses to community feedback and enquiries;
- construction works were undertaken in accordance with Australian Standard 2436-1981: Guide to noise control on construction, maintenance and demolition sites;
- noise impacts on surrounding residents were managed on a case-by-case basis, which included acoustic treatment of a residence near the clay borrow with double glazed windows and roller doors after investigation of noise impacts from clay borrow operations; and
- attended monitoring was carried out each week at nuisance sensitive receivers for out of hours filter placement and clay core works. Where noise exceedances were deemed likely to occur, the foreman was contacted to address the noise source.

COMMUNICATION OF CONSTRUCTION NOISE CONCERNS

The role of the communication team

The project communication team had the crucial role of interacting with the community. They informed the community of the progress of the project and potentially disruptive construction activities through meetings, house visits, emails, phone calls, sms's, letter drops, barbeques, and site tours. They were also the contact point for all incoming comments and enquiries, which were relayed to relevant members of the project and the project management team.

Incoming enquiries were categorised according to the subject of the enquiry, which ranged from noise and dust enquiries to queries about the recreational area to be built. All enquiries were also grouped into the three categories of "supporter", "neutral", and "objector", relating to whether the enquiry was perceived as supportive or negative towards the project.

Assessment of noise related enquiries

Over the 40 months from February 2008 to May 2011, a total of 24 "objector" noise related enquiries were received; 22 during standard construction hours and two during the out of hours works.

"Objector" noise related enquiries were assessed and counted with regards to the nature of the enquiries, the date and time enquiries were made, and who made the enquiries. Only enquiries regarding noise events were counted, and where multiple enquiries were received from the same person on the same day on the same noise issue, only one enquiry was counted for the day.

Of the 24 noise related enquiries, 21 of the enquiries were received from three stakeholders located about 1 to 1.5 km from the saddle dam to the east of the project site. The other three enquiries were received from stakeholders 450 m to 500 m north of the main embankment and the saddle dam.

Also, of the 24 enquiries, ten enquiries were directed at the use of beeper reverse alarms, and eight enquiries were directed at the use of air horns on loaders. A number of enquiries concerned mulcher noise, truck exhaust breaking, noise from early morning construction activities, and noise due to unidentified sources from the project site.

Management of enquiries

Mitigation actions applied by the project to accommodate noise concerns include:

- ad hoc noise monitoring at locations other than the two permanent monitoring locations;
- assessment of potentially noisy plant operations prior to their use through noise measurements and predictions;
- investigation into the use of alternative reversing alarms resulting in a site wide refitting of beeper reverse alarms to broadband alarms;
- periodic audits of vehicles on site to ensure the use of broadband alarms; and
- use of a visual alert system within loader and truck cabins to avoid air horn use.

CONSTRUCTION NOISE MONITORING RESULTS

24 hour noise monitoring

24 hour noise monitoring was conducted at two locations that were representative of nuisance sensitive areas most exposed to construction activities for 37 months, between March 2008 and March 2011 inclusive.

Two Rion NL-22 sound level meters with sound recording capabilities were used to record L_{A1} and L_{Aeq} noise levels in 10 minute intervals. The monitors were set to record wave files where noise levels exceeded user set thresholds.

The noise measurements were collected on a weekly basis and the results were analysed to identify exceedances. The exceedances were reviewed against sound recordings to determine whether they were construction related. Where there were large numbers of exceedances, a sample of sound recordings were reviewed and the percentages of construction related exceedances were used to extrapolate an estimate of the total number of construction related exceedances.

Standard construction hour noise exceedances

The results of monitoring for the standard day time construction hours are shown in Figures 1 and 2 where the number of construction related exceedances per month is compared against total number of exceedances and number of noise related enquiries received for standard construction hours.

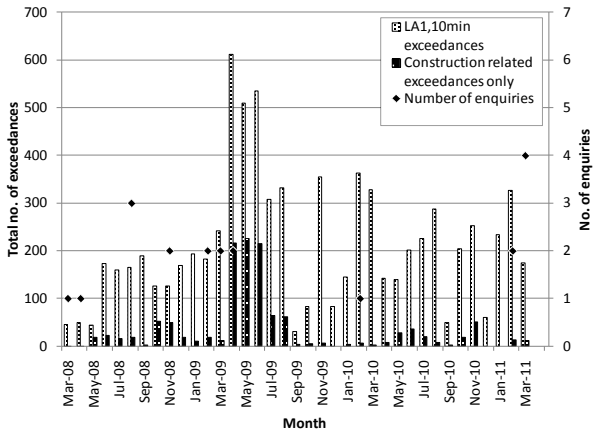

Figure 1. Number of $L_{A1,adj,10\ min}$ exceedances

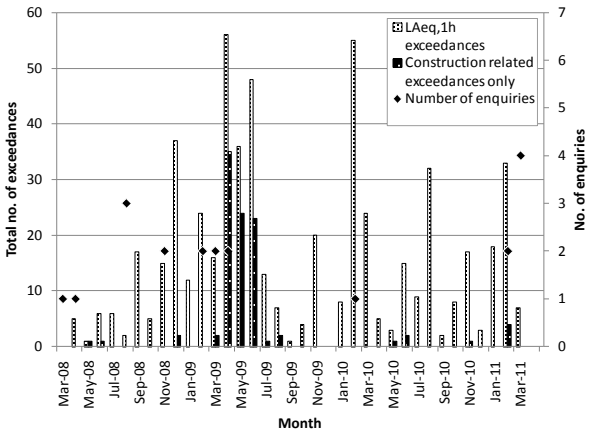

Figure 2. Number of $L_{Aeq,1\ h}$ exceedances

From sound recordings, the review of construction related $L_{A1,adj,10\ min}$ exceedances identified a mixture of plant engines,

haul truck exhausts, tracks of dozers, loaders and trucks dumping material, and drilling operations. Reversing alarms were also audible on some occasions but may not have been loud enough to cause exceedances. The characteristic of the overall construction noise was not tonal or impulsive. Construction related $L_{Aeq,1\ h}$ exceedances were due to prolonged periods of plant noises as mentioned above.

Non-construction related $L_{A1,adj,10\ min}$ exceedances were most often caused by birds. Other non-construction related exceedances included aircraft noise, dog barks, and noise from lawn mowing.

Lawn mower use was also a common cause of non-construction related $L_{Aeq,1\ h}$ exceedances. Exceedances were also caused by extended periods of insect noise and thunder and heavy rain.

Out of hours cut off wall noise exceedances

Out of hours works for the cut off wall involved excavating a narrow trench that is stabilised by bentonite slurry from the onsite bentonite mixing plant. Once a segment is complete, trench backfilling is undertaken during the day time using a concrete mix.

The excavation was carried out by a cutter head which was lubricated and silenced by the bentonite slurry. A crane and grab was used to operate the cutter head, with all equipment fitted with exhaust silencers.

The noise level was not expected to vary significantly during the construction. Attended noise monitoring was carried out at nuisance sensitive places to assess noise from the cut off wall construction and to confirm modelling predictions of compliance with noise limits including sleep disturbance. Monitoring results at the two permanent noise monitoring locations and an additional third location showed compliance of the construction noise limits.

Out of hours filter placing noise exceedances

Noise monitoring data from the two 24 hour monitoring locations were used to monitor out of hours clay core works and filter laying over 16 months between October 2009 to January 2011. Out of hours clay core works and filter laying noise monitoring results are shown in Figure 3 and Figure 4 where the number of construction related exceedances per month is compared against total number of exceedances and number of noise related enquiries. Works involved a flowcon truck laying down filter material, and a moxie, loader, and compactor working on the clay core.

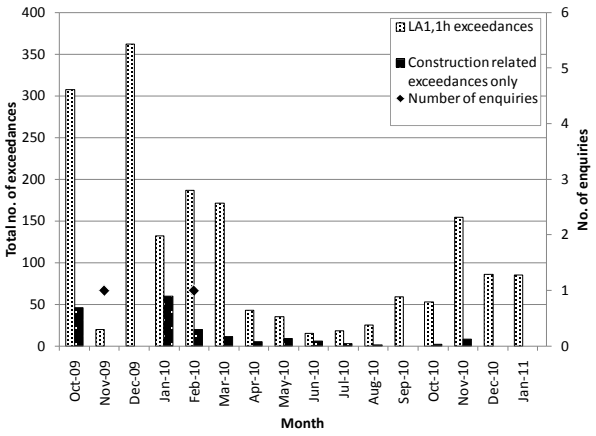

Figure 3. Number of $L_{A1,adj,1\ h}$ exceedances

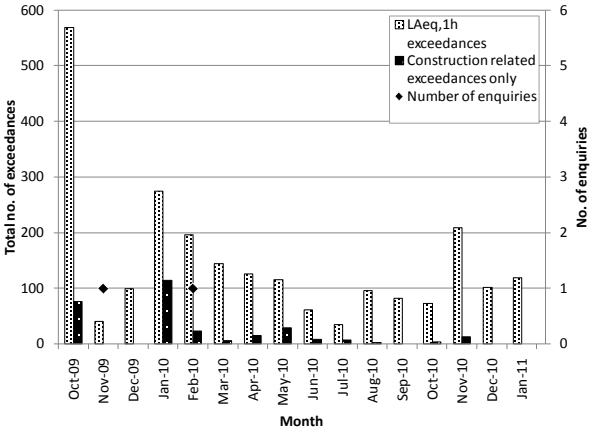

Figure 4. Number of $L_{Aeq,1\ h}$ exceedances

From sound recordings, the review of construction related $L_{A1,adj,1\ h}$ exceedances identified a mixture of haul truck engine noise, clanging of dozer tracks, and occasionally the sound of loader bucket shaking. Reversing alarms were also audible on a few occasions but were not loud enough to cause exceedances. The characteristic of the overall construction noise was not tonal or impulsive. Causes of construction related $L_{Aeq,adj,1\ h}$ exceedances were also due to sources as mentioned above.

Non-construction related $L_{A1,adj,10\ min}$ and $L_{Aeq,adj,1\ h}$ exceedances were mostly caused by insects and birds in the warmer months of the year.

Discussion on noise monitoring results

Figure 1 and Figure 2 show increased numbers of standard construction hour exceedances for the months of April, May, and June 2009. Up to 226 construction related $L_{A1,adj,10\ min}$ exceedances occurred per month during these three months compared a maximum of 64 exceedances occurring in other months. For $L_{Aeq,1\ h}$ in April, May, June 2009, up to 35 construction related exceedances occurred per month, compare to a maximum of four exceedances in other months.

A review of the construction schedule show an extensive period of excavation for the new embankment foundation and rockfill placement at the Main Embankment close to the nearest permanent noise monitoring location, at elevations similar to the noise monitoring location.

For the night time filter and clay works, most months recorded less than 10 construction related $L_{A1,adj,1\ h}$ and $L_{Aeq,adj,1\ h}$ exceedances. Increased numbers of exceedances were recorded for October 2009 and January 2010 where up to 60 construction related $L_{A1,adj,1\ h}$ exceedances were recorded per month, and 114 construction related $L_{Aeq,adj,1\ h}$ exceedances were recorded per month.

The number of exceedances in October 2009 was attributed to one week where rock filling took place out of hours. Subsequently this was rectified by restricting rock filling activities to standard construction hours. The number of exceedances in January 2010 is likely to be incorrect as exceedances were estimated on a very limited number of reviewed sound files. This data has been excluded from further analysis.

The small number of enquiries was not considered significant enough to assess a correlation between noise enquiries and exceedances. This is shown in Figure 1 to Figure 4 where noise related enquiries were plotted with the number of noise

limit exceedances, where it is difficult to see a correlation between the two parameters.

The graphs also suggest that noise enquiries for the project concerned a small number of irritating noise sources rather than the overall loudness of construction noise.

PRACTICALITY OF NOISE LIMITS

Figure 1 to Figure 4 show construction noise related exceedances were only a small percentage of the total number of exceedances. The number of construction related exceedances and the percentage of construction related exceedances against total number of exceedances were compared for the different noise limit parameters to assess whether a particular parameter was more effective in capturing construction noise related exceedances.

These are shown in Table 3 and Table 4. Data from January 2010 has been excluded as per the reasons given above. As mentioned previously, it should be noted that the number of construction related exceedances presented below are estimates of the total number of construction related exceedances.

Table 3. Summary of number of construction related exceedances

	Standard construction hours		*Out of hours*	
	$L_{A1,adj,\ 10\ min}$ 63 dB(A)	$L_{Aeq,\ 1\ h}$ 58 dB(A)	$L_{A1,adj,\ 1\ h}$ 50 dB(A)	$L_{Aeq,ajd,\ 1\ h}$ 40 dB(A)
Number of construction related exceedances	1251	99	172	179^

^ Excludes January 2010 data

Table 4. Summary of percentage of construction related exceedances

	Standard construction hours		*Out of hours*	
	$L_{A1,adj,\ 10\ min}$ 63 dB(A)	$L_{Aeq,\ 1\ h}$ 58 dB(A)	$L_{A1,adj,\ 1\ h}$ 50 dB(A)	$L_{Aeq,ajd,\ 1\ h}$ 40 dB(A)
% of construction related exceedances	16%	17%	10%	9%^

Excludes January 2010 data

There were 1251 construction related exceedances of the $L_{A1,adj,10\ min}$ construction noise limit for standard construction hours over the 37 months monitoring period. In comparison 99 $L_{Aeq,1\ h}$ exceedances were recorded over the same period.

Over the 16 months of out of hours works were carried out, 172 and 179 exceedances were recorded for $L_{A1,adj,1\ h}$ and $L_{Aeq,1\ h}$ respectively.

The percentages of construction related exceedances per total number of exceedances during standard construction hours for $L_{A1,adj,10\ min}$ and $L_{Aeq,1\ h}$ were 16% and 17% respectively. L_{A1} and L_{Aeq} noise limits captured a similar proportion of construction related exceedances.

For out of hours filter and clay core works, the percentage of construction related exceedances for $L_{A1,adj,1\ h}$ and $L_{Aeq,adj,1\ h}$ were 10% and 9% respectively. L_{A1} and L_{Aeq} noise limits captured a similar proportion of construction related exceedances.

However, identifying construction related exceedances required review of sound recordings, and the large number of $L_{A1,adj,10\ min}$ exceedances required a significant amount of time to review. Also the $L_{A1,adj,10\ min}$ 63 dB(A) limit was regularly exceeded by birds which exacerbated this issue.

Limitations of the sound recording functionality of noise monitors

A key tool in the management of construction noise in the project was the ability to review sound recordings to determine if exceedances were construction related. Limitations in the use of this function included:

- the number of construction related exceedances was estimated based on the number of construction related exceedances per a sample of exceedances reviewed. It was not possible to review all exceedances given the large number of exceedances and associated sound recordings; and
- a number of construction exceedances were masked by extraneous noise sources. During the warmer months of the construction period there were significant amounts of noise from birds and insects which is likely to have masked construction noise in sound recordings.

NOISE MANAGEMENT FOR OTHER LARGE SCALE INFRASTRUCTURE PROJECTS

The noise limits and mitigation measures as well as the noise management performance for this project have been compared against a number of other large scale infrastructure projects.

Northern Sewerage Project - Victoria

In Victoria, a new sewer is being constructed by the Northern Sewerage Project which runs from Reservoir in the north to Pascoe Vale and Essendon in the south and connects into Melbourne's existing sewerage system at several locations. Construction work commenced in August 2007 and is scheduled to complete at the end of 2011.

Noise mitigation measures implemented for this project include:

- building a structure with significant sound proofing qualities (similar to the proofing qualities used in cinemas) over the shaft at each of the three drive shaft sites (Brearley Reserve, De Chene Reserve and Newlands Road). This structure allowed construction works to take place outside normal working hours;
- properties acquisition;
- taking noise impacts into account in selecting equipment and construction techniques;
- installing acoustic hoarding (site fencing) designed to reduce potential noise impacts; and
- conducting continuous noise level monitoring at the largest and busiest construction site, Brearley Reserve.

While there are no regulations that limit noise levels for construction in Victoria, the Environment Protection Authority (EPA) Victoria's Noise Control Guidelines (EPA TG 302/92) for construction noise were adopted.

Based on these guidelines construction work at all Northern Sewerage Project sites aim to remain within the target limits set out below:

Table 5. Northern Sewerage Project Noise Limits

Period	Time	Noise Limits specified in EPA Victoria's guidelines
Normal working hours	7:00 am to 5:30 pm Monday to Friday 7:00 am to 1:00 pm Saturdays	There are no recommended limits on noise levels during normal working hours.
Other Period	6:00 pm to 10:00 pm Monday to Friday 1:00 pm to 10:00 pm Saturdays 7:00 am to 10:00 pm Sundays & Public Holidays	The average maximum noise level (L_{A10}) at any residential premises is not to exceed the background noise level (L_{A90}) by: 10 dB(A) or more for up to 18 months after project commencement. 5 dB(A) or more after 18 months
Night time	10:00 pm to 7:00 am Monday to Sunday	Inaudible in a habitable room.

Since construction started in August 2007, the project has only received several noise complaints and has complied with the target noise limits above.

Airport link

Airport Link is a 6.7 km toll road in Brisbane, mainly underground, connecting the Clem 7 Tunnel, Inner City Bypass and local road networks at Bowen Hills, to the northern arterials of Gympie Road and Stafford Road at Kedron, Sandgate Road and the East West Arterial leading to the airport. This project is currently under construction. It will be the first major motorway linking Brisbane city to the northern suburbs and airport precinct, avoiding up to 18 sets of lights.

The construction noise goals for the Airport Link Project relate to goals for the avoidance of sleep disturbance for night time construction and internal noise for day time construction. The goals for evening and night time construction are presented in Table 6.

Table 6. Airport Link Evening and Night Time Noise Limits

Activity Environmental	Internal Noise Goal
Intermittent	45 dB(A) (L_{Amax}) for residences in R1 to R3 categories 50 dB(A) (L_{Amax}) for residences in R4 to R6 categories
Steady	For residences within R4 to R6 categories: 40 dB(A) $L_{Aeq,adj,15\ min}$ for temporary noise 35 dB(A) $L_{Aeq,adj,15\ min}$ for long-term noise For residences within R1 to R3 categories: 35 dB(A) $L_{Aeq,adj,15\ min}$ for temporary noise 30 dB(A) $L_{Aeq,adj,15\ min}$ for long-term noise

For day-time construction works, the noise goals for internal construction noise levels at affected adjacent premises are derived from levels in AS/NZS 2107:2000. Day time construction noise must be assessed by a $L_{Aeq,15\ min}$ parameter for steady noise sources and a $L_{A10,15\ min}$ parameter for non-steady noise sources. The goals for day time construction internal noise are presented in Table 7.

Table 7. Airport Link Daytime Noise Limits

Type of Building Occupancy Maximum Construction Internal Noise Targets	Type of Building Occupancy Maximum Construction Internal Noise Targets	
	Steady construction noise $L_{Aeq,15\ min}$(dB(A))	Non-steady construction noise $L_{A10(15minute)}$ dB(A)
Residential buildings (living areas)	45 (near major roads) 40 (near minor roads)	55 (near major roads) 50 (near minor roads)

Noise mitigation measures

The following noise mitigation measures were recommended during the construction:

- construction of noise screens to reduce construction noise;
- where reasonable and practicable, construction activity above ground and outside an acoustically-lined work enclosure, should be limited to the hours of 6.30 am to 6.30 pm Monday to Saturday, excluding public holidays;
- advance notification of the time and duration of earthworks and night roadworks;
- as required, assist owners of properties along Gympie Rd and Lutwyche Rd to temporarily upgrade the acoustical insulation and ventilation of rooms facing the worksite to address noise during both road widening/regrading and trough excavation; and

- consider minimisation of construction noise in selecting construction processes and plants.

This project received numerous complaints about noise from night-time surface work. There was evidence of regular and considerable excessive noise at the Kalinga Park worksite since 24-hour work started in August 2009.

Noise Limits Comparison Between Projects

During the daytime period, the Northern Sewerage Project does not have a noise criteria whereas the Hinze Dam Stage 3 project has a $L_{Aeq,1\ h}$ 58 dB(A) and $L_{A1,10\ min}$ 63 dB(A) noise limits and the Airport Link project has internal noise limits between $L_{Aeq,15\ min}$ 40 to 45 dB(A) and $L_{A10,15\ min}$ 50 to 55 dB(A) (equivalent to approximately an external limits of $L_{Aeq,15\ min}$ 50 to 55 dB(A) and $L_{A10,15\ min}$ 60 to 65 dB(A)).

Assuming the 15 minutes and 1 hour L_{Aeq} are similar, the L_{Aeq} daytime noise limit for the Airport Link Project is more stringent than Hinze Dam Stage 3. It is difficult to compare the other noise limits as they are of different statistical parameters.

During the evening period, the noise limit for the Hinze Dam Stage 3 project is the same as the daytime limit. For Northern Sewerage Project, L_{A10} should not exceed L_{A90} by 5 or 10 dB(A) depending on the duration of construction. For a suburban area with a evening L_{A90} of around 40 to 45 dB(A), the L_{A10} noise limits are between L_{A10} 45 and 55 dB(A).

The evening internal noise limits for Airport Link are between $L_{Aeq,adj}$ 30-40 dB(A) and L_{Amax} 45-50 dB(A) (equivalent to approximately an external limits of $L_{Aeq,adj}$ 40-50 dB(A) and L_{Amax} 55-60 dB(A)).

Assuming the 15 minutes and 1 hour L_{Aeq} are similar, the L_{Aeq} noise limit for Airport Link is more stringent than the Hinze Dam Stage 3 Projects. It is difficult to compare the other noise limits as they are of different statistical parameters.

During the night time period, the Airport Link night time noise limit is identical to the evening noise limit. For the Hinze Dam Stage 3 Project, the night time internal noise limit is $L_{Aeq,adj,1\ h}$ 40 and $L_{A1,adj,1\ h}$ 50 dB(A) (equivalent to an external limit of $L_{Aeq,adj,1\ h}$ 50 and $L_{A1,adj,1\ h}$ 60 dB(A)).

For Northern Sewerage Project, noise should be inaudible in a habitable room.

For construction projects, the $L_{A1,adj}$ levels are usually slightly lower than the L_{Amax} levels. Based on this assumption, the night time noise limit for Airport Link is more stringent than the Hinze Dam Stage 3 Project.

Out of the three projects, the night time noise limit for the Northern Sewerage Project is considered as the more stringent.

Noise Management Performance Comparison

It is difficult to compare the noise limits between these projects as they are of different statistical parameters. However, amongst the three projects that were compared, the effectiveness of noise management and the amount of noise related enquiries and complaints received for Hinze Dam Stage 3 and Northern Sewerage Project were considered satisfactory. Airport Link however has received numerous complaints and community discontent.

While the noise limits adopted for Airport Link were generally more stringent than the other two projects, regular exceedances of the noise limits were evidenced during the night time surface work (Clarke, P 2011). This demonstrates the importance of:

- understanding the sensitivity of construction noise on the surrounding community particularly the characteristic of noise and time of occurrence; and
- effective noise management and the ability of the project team attending and resolving exceedances and complaints in a timely manner.

SUGGESTIONS FOR FUTURE CONSTRUCTION NOISE MANAGEMENT

Noise related enquiries for Hinze Dam Stage 3 were generally with regards to the irritating nature of individual noise sources. To address this issue, continued investigation is required for specific long-standing issues such as beeper reverse alarms, especially with recent research that has been conducted on alternative alert systems such as broadband reverse alarms.

For Hinze Dam Stage 3, the issue with reversing beepers continued after the fitting of broadband alarms on the alliance operated plants, where contractor vehicles working for short durations were fitted with conventional beeper reverse alarms and it was also not practical to refit such vehicles. One way to address this in the short term would be to require contractors to have broadband alarms as part of the project's tender process. A long term solution would require a change in industry standards and practices.

Another area of improvement is to require a more thorough examination of equipment before its introduction on the construction site. It was found that once noisy equipment was put into operation it was difficult to fix the noise issue or replace with alternative equipment. There is a need to address equipment selection prior to placement on site, which may require contractors to carry out simple noise testing of high risk equipments prior to operation.

During data analysis, it was difficult to identify construction related exceedances due to the large number of non-construction related exceedances and sound recordings. Such high incidence of non-construction related noise exceedances are likely to occur for other projects where the noise environment includes extraneous noise sources regularly exceeding the applicable construction noise criteria.

This indicates a need to improve methods of identifying construction related noise exceedances. For this project, extraneous noise commonly consisted of high frequency noise from birds and insects near noise monitors that constantly exceeded the construction noise criteria. Filtering out exceedances caused by such high frequency noise may have been a more efficient method for identifying construction related exceedances. It is suggested for future projects that the use of noise monitors with octave band analysis capability and the use of frequency analysis be explored. Further research into dominant frequencies for construction noise could also be used to filter out exceedances that are most likely to be construction related. The collection and analysis of frequency data is likely to require more time for data processing, and development of software to assist such data processing would be highly beneficial.

The information gathered from further data analysis may also help identify noise parameters that better address construc-

tion related noise and add to current noise limits for construction that are based on existing legislation and guidelines on the wellbeing of individuals.

CONCLUSION

This paper has presented noise management measures, project noise limits, and the analysis of noise measurement data for the Hinze Dam Stage 3 construction.

Construction activities for the project resulted in exceedances of noise limits, with most of the exceedances occurring around April, May, and June 2009 when excavation and rockfill placement was occurring near a permanent noise monitoring location.

Noise related enquiries from nuisance sensitive receivers concerned a small number of irritating noise sources rather than the overall loudness of construction noise. Many enquiries concerned beeper reverse alarms and the use of air horns on loaders, both of which were addressed by replacement with alternative technologies. However, the number of enquiries was not considered significant enough to assess a correlation between noise enquiries and exceedances.

The noise limits and mitigation measures as well as the noise management performance for this project have been compared against a number of other large scale infrastructure projects. The comparison of different projects was made difficult due to the differences in statistical parameters used as noise limits. However, amongst the three projects that were compared, the effectiveness of noise management and the amount of noise related enquiries and complaints received for Hinze Dam Stage 3 was considered satisfactory.

In the review of noise exceedances and associated sound recording, it was found that most noise limit exceedances were not construction related. It was also found that L_{A1} and L_{Aeq} noise limits captured a similar proportion of construction related exceedances.

Further actions are required in addressing reoccurring issues such as annoyance due to beeper reverse alarms. Construction noise management also should address equipment with high risk of causing nuisance noise impacts prior to their introduction on site. Future projects should explore the use of noise monitors with octave band analysis capability, to filter out non-construction related noise exceedances. The use of frequency analysis may help identify noise parameters that better address construction related noise, and aid in the development of practical noise goals for the assessment of construction noise.

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