Report Prepared
for
Boral Resources (Qld) Pty Ltd

Blasting Impact – Gold Coast Quarry

April, 2013.

Reference #121307
EXECUTIVE SUMMARY

Boral Resources (Qld) Pty Limited (Boral) is carrying out an Environmental Statement for its proposal to develop a new quarry to the south west of the existing West Burleigh Quarry. It is proposed that the extraction area lie within Lot 105 on SP144215.

It is proposed that the environmental impact conditions for the proposed quarry, in regard to blasting impacts, will be in line with Ecoaccess 2006 Guidelines. These regulations effectively limit ground vibration from blasting to 5 mm/s, and overpressure levels to 115 decibels (Linear) on at least 9 out of any 10 consecutive blasts. Further, no vibration levels are to exceed 10 mm/s and no overpressure levels are to exceed 120 decibels (Linear) at any affected residence. For the purposes of modelling, this report has used a 95 percentile criterion in order to comply with the Ecoaccess Guidelines. Compliance with these levels of vibration and overpressure effectively ensures a very low chance of damage to residential or commercial structures. The new proposed conditions are more onerous than the existing West Burleigh Quarry conditions.

Estimated impacts at locations surrounding the proposed quarry site have been derived from consideration of both the Australian Standards (AS 2187.2: 2006), and the historical impacts from the nearby Boral West Burleigh Quarry. The impact study consistently uses the higher impact levels (i.e. the worst case scenario) from those two sources as an indication of potential impacts on surrounding residences. Trial blasting will be conducted in the early stages of development of the Processing Plant Pad, where small charges (20 – 35 kg) are expected to be used, and the minimum distance to a sensitive receiver is approximately 450 metres.

Blasting practices and procedures for implementing the blasts at the proposed site are also based on the most up-to-date procedures currently implemented at the Boral West Burleigh Quarry. Impact statistics at the West Burleigh Quarry, since 2005, show 100% compliance with the current West Burleigh Quarry Environmental Licence Condition 1651.

Blasting activities are not expected to be required for clearing of the top 10 metres of material – this is expected to be completed by ripping using bulldozers. During the Development Phase, blasting activities are not expected to occur closer than approximately 280 metres to existing allotments in the Tallebudgerra Creek Road area, and no closer than 420 metres to residential structures in Old Burleigh Town (NW). Once the Development Phase is finalised, blasting activities will move away from Old Burleigh Town and towards the Stockland Observatory, at which stage blasting will not be conducted closer than 450 metres to any existing allotment or residential structure.
The minimum separation distance between the quarry pit (all stages of development) and the Approved Stage 20 at the Observatory Estate will be approximately 240 metres. Currently there are no residential structures in this area. By applying the practices currently in place at the nearby Boral West Burleigh Quarry, the operation is expected to fully comply with Ecoaccess 2006 Guidelines even if, or when, residential development commences in Stage 20 at the Observatory. Once residential development commences in this area, some adjustments to blasting practices may be required when blasting near the north-western pit wall. The modified practices which may be required in this zone are not substantially different from the standard operating practices at the existing Boral West Burleigh Quarry.

All blasts will be monitored for vibration and overpressure at a minimum of two locations, with additional monitoring conducted to investigate complaints. All monitoring data will be saved to a monitoring database and results will be reported to the administering authority as required. In addition, if complaints are received, they will be saved to a complaints database and managed as per Boral’s Complaint Management Procedures.

All blasting will be conducted by highly trained professionals with extensive experience in blasting in an urban environment, and who have the necessary safety standards and operating procedures to ensure very high standards of impact control. No explosives will be stored on site.
Report to Boral Resources (Qld) Pty Ltd

Environmental Impact (Blasting) – Gold Coast Quarry

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1. INTRODUCTION

Two types of impacts are generated by blasting activities, with the intensity of the impacts controlled principally by the separation distance between the blasting activity and the receptor, and the size of the explosive charges.

One of the impacts from blasting activities is air-borne vibrations which include both audible and sub-audible (frequencies less than 20 Hz) components. While the audible component of air-borne vibration from blasting operations may be easily identified, the sub-audible component can manifest as shaking or rattling of windows or objects on shelves inside a residential structure. While the sub-audible component of overpressure is generally imperceptible outside a residence, it can be responsible for secondary noises inside a residence. In the context of Australian regulations aimed at protecting personal amenity, the air-borne disturbance from blasting is commonly referred to as overpressure, and represents an impulsive pressure wave resulting from the release of high pressure gasses to the atmosphere from the blast and/or the pressure front generated by the movement of air at the face of the free rock surface. In accordance with Australian regulations and standards, overpressure is measured as a peak linear sound pressure level in decibels (dBL), though the levels should not be confused with A-weighted noise levels (dBA).

The second impact from blasting is ground-borne vibration which radiates in all directions from the blast via the rock mass or soil, and is an inevitable consequence of the blasting process. Due to attenuation and scattering, vibration levels reduce with increasing distance from the source. In accordance with Australian regulations and standards, vibration is measured as a peak particle velocity (mm/s).

Overpressure and vibration levels are each affected by the blasting parameters as well as local geology or topography between the source and the receiver. In the absence of field data from historical blasting activities at the proposed site, references can be made to two useful sources:

- Australian Standard AS 2187.2: 2006, and;
- Historical data from the nearby Boral West Burleigh Quarry.

Of the two possible sources, the historical database from the Boral West Burleigh Quarry provides the higher estimate of impacts and is therefore considered the most conservative basis for estimating vibration and overpressure impacts. Blastechnology has used the historical blast impact data from the Boral West Burleigh Quarry to provide estimates of the likely impacts from blasting at the proposed Gold Coast Quarry. The historical data include 1131 measurements obtained from 296 blasts over the period January 2010 to November 2012. The use of such a large database of monitoring results, plus the close proximity with which the historical data were collected, mean that a high level of confidence is associated with the anticipated future predictions.
2. THE EFFECTS OF BLASTING

The effects of blasting can be considered in two lights – the effect on the surrounding rock mass, and the effect on nearby people and structures such as houses. The former represents the zone within which the impacts are sufficiently high to cause damage to the rock mass and fracturing of the rock matrix.

2.1 Effects on the Rock Mass

The action of rock breakage by blasting in quarries is, by nature, a high energy process, designed to transform relatively massive and hard rock into a pile of relatively fine fragments for crushing and subsequent use in concrete and asphalt. The ability of the explosive to break rock, however, is limited in the case of typical Australian quarrying operations, to a small radius around the explosive charges, typically of the order of a few metres. As an indication, the photograph of Figure 1 shows the face of a quarry bench after normal production blasting, in which the line of the explosive charges from each blasthole is still evident in the face, approximately half a metre behind the original location of the holes. Beyond this distance there is relatively little damage to the rock mass, and after approximately 10 to 20 metres, there is no measurable damage to the rock mass.

![Figure 1. A quarry bench face in which the line of each blasthole is still visible after a normal production blast (120 mm diameter blastholes).](image)

Blasting is the almost-universal means deployed for extracting hard rock for construction aggregate material, both in Australia and around the world, and quarries are usually located in quite close proximity to urban centres, to provide the essential construction materials at the most affordable prices. This requires that all aspects of quarrying activities be tightly controlled so as to minimise negative impacts on surrounding or nearby communities. The negative impacts from blasting relate to ground-borne vibrations, air-borne vibrations, and the potential for flyrock. In all cases, the effects are best mitigated by ensuring a minimum separation distance between the blasting activities and nearby residential or commercial structures. A summary of blasting-induced effects as a function of separation distance, for normal quarrying operations with 10 to 15 metre bench faces, is:
• Within 0 to 5 metres of charges – ability to crush and fragment fresh rock (vibration levels of the order of 5000 mm/s);
• 5 to 20 metres – ability to create occasional light cracking and block dislodgement in the surrounding rock mass (vibration levels of the order of 1000 mm/s);
• Up to 200 metres – ground and air-borne vibration levels uncomfortable and disturbing (vibration levels up to 25 mm/s);
• 200 metres to 1000 metres – ground and air-borne vibration levels usually within limits considered by Australian Standards to be appropriate for Human Comfort (less than 10 mm/s);
• Greater than 1000 metres – ground and air-borne vibration levels generally close to human day-time perception levels (less than 1 mm/s).

Vibrations are an inevitable outcome of the use of explosives for rock breakage, and the intensity of both ground and air-borne vibrations decreases rapidly with the distance of propagation. While quarry operators sometimes receive complaints relating to ground and air-borne vibrations from blasting operations, all developed countries have standards to ensure that blast-induced vibrations cannot cause damage to residential or commercial structures. The Australian Standard (AS 2187.2: 2006), and the Ecoaccess 2006 Guideline are the most stringent of all known international standards as regards permissible levels of ground and air-borne vibrations, and address personal amenity. Vibrations which comply with AS 2187.2: 2006 and the Ecoaccess Guidelines are well below the levels capable of causing damage to residential structures. For example, the level of stress induced by vibration levels of 5 mm/s in concrete (25 MPa grade) is less than 2% of the yield stress of the concrete, and therefore incapable of causing cracking of slabs, walls, concrete driveways or swimming pools. Vibrations are not expected to crack concrete, for example, until levels exceed 200 mm/s.

### 2.2 Effects on Personal Amenity

Vibrations are readily perceived by humans, with the threshold of perception commonly considered to be in the range 0.2 to 0.5 mm/s for short duration impulsive vibrations such as those generated by blasting. Various standards exist around the world to identify levels of impulsive, short-duration vibration considered acceptable by most people. Such standards include the Australian Standard AS 2187.2: 2006, the Australian and New Zealand Environment Council (ANZEC) 1990, the Queensland Environmental Protection (Noise) Policy 2008, and the Queensland Government Environmental Protection Agency Ecoaccess Guideline (noise and vibration from blasting) 2006. Australian standards are considerably more stringent than all other known international standards for both ground-borne and air-borne vibrations from blasting.

The Qld EPP(Noise) is directed specifically towards human amenity, and states:

*The environmental values to be enhanced or protected under this policy are —*

1. *the qualities of the acoustic environment that are conducive to protecting the health and biodiversity of ecosystems; and*
2. *the qualities of the acoustic environment that are conducive to human health and wellbeing, including by ensuring a suitable acoustic environment for individuals*
to do any of the following – sleep, study or learn, be involved in recreation, including relaxation and conversation; and

c) the qualities of the acoustic environment that are conducive to protecting the amenity of the community.

With respect to disturbances from blasting activities, the Qld EPP (Noise), Section 6I states:

Noise from blasting is not unlawful environmental nuisance for an affected building if

(a) the airblast overpressure is no more than 115 dB (Lin) Peak for 4 out of any 5 consecutive blasts; and

(b) the ground vibration is -

(i) for vibrations of more than 35 Hz – no more than 25 mm a second ground vibration, peak particle velocity; or

(ii) for vibrations of no more than 35 Hz – no more than 10 mm a second ground vibration, peak particle velocity.

The Qld Ecoaccess Guideline 2006 goes beyond the Qld EPP (Noise) regulations and specifies that ground-borne vibrations must be less than or equal to 5 mm/s, and that air-borne vibrations must be less than or equal to 115 dBL, for at least 9 out of any 10 consecutive blasts.

It is therefore clear that vibration and overpressure levels generated by blasting activities must be considerably higher than the levels of human perception before they are considered unlawful or having a significant negative effect on human health and well-being. Experience also shows that some people will find any level of perceptible vibration to be bothersome and unacceptable. While that concern sometimes reflects a fear that vibration must be causing damage to the structure inside which the vibration is perceived, a review of technical literature shows that acceptable limits for vibration and overpressure in Australia are well below levels capable of causing any level of damage to residential or commercial structures.

2.3 Blasting Related Complaints

The Boral West Burleigh Quarry maintains an incident log in which all complaints received directly by the quarry or regulatory authorities are recorded. Some complaints come directly from the community to the quarry, while others are directed to the Explosives Inspectorate or other government departments.

Over the period November 2006 to November 2012, six complaints have been received relating to vibration and/or overpressure impacts. Over the same period, it is estimated that approximately 600 blasts have been fired in approximately 300 events (averaging two blasts per event, or two blasts within approximately 10 minutes on the same day). The complaint rate appears to be very low, suggesting that the vibration and overpressure impacts from blasting operations at the West Burleigh Quarry are considered acceptable by almost all
people in the surrounding communities. The impacts from blasting at the proposed Gold Coast Quarry are expected to be less than those from the West Burleigh Quarry due to the greater separation distances to the sensitive receptors.

Any complaints that may be received will be recorded to a complaints database and will be reported to the Administering Authority as required, along with a record of follow-up actions undertaken by the quarry.

2.4 Effects on Structures

It has been repeatedly demonstrated, by all studies conducted on the topic, that the levels of vibration and overpressure required to cause even very light cosmetic damage (such as cracking of paint on plaster-board joins) are greater than the levels of human perception. Further, levels required to produce cosmetic damage such as cracking of paint are also higher than the levels recommended in AS 2187.2: 2008 and the Ecoaccess 2006 Guidelines. Studies conducted in US\(^1\), for example, showed that the probability of cosmetic damage could be reduced to very low levels by complying with the RI 8507 Z curve, permitting vibration levels in the range 12 to 50 mm/s for frequencies in the range 3 Hz to 100 Hz. Studies conducted in Australia\(^2\) showed that no damage occurs due to vibration until levels around 70 mm/s are reached, and even these levels result in only minor damage such as crack extensions, hairline cracking and cracks around nail-heads in plasterboard.

The studies conducted in the US also showed that repeated exposure to low levels of vibration will not result in "cumulative damage" unless the structure is exposed to hundreds of thousands of vibration cycles of levels around 12 mm/s.

If vibration levels induced by blasting activities comply with the levels of vibration permitted in the Ecoaccess 2006 Guidelines, the probability of even light, cosmetic damage to structures such as cracking of paint is very low.

3. QUARRY BLASTING PRACTICES

Blasting is planned to be conducted on 12 metre benches using 89 mm diameter blastholes with a pattern which depends on proximity to private properties. The explosive is pumped into the blastholes and has an average density of approximately 1.2 g/cc, for a maximum charge per blasthole of around 75 kg. A column of inert aggregate material (stemming) of length 2.5 metres is loaded on top of the column of explosive, and acts to contain the high pressure gases generated by the detonating explosive. Blasts will average around 140 blastholes, will generate an average of around 40,000 tonnes of broken rock, and will be fired on average every 7 days. Vibration and overpressure impacts for each weekly event will have a duration of around 2 seconds, amounting to approximately 1.7 minutes of disturbance per year, and 1 hour 40 minutes over the 40 year life of asset.


Table 1. Recommended blast design parameters for zones of different sensitivity at proposed Gold Coast Quarry.

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Distance &gt; 450 m</th>
<th>Distance 300 – 450 m</th>
<th>Distance 240 – 300 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bench height</td>
<td>12 m</td>
<td>12 m</td>
<td>12 m</td>
</tr>
<tr>
<td>Blasthole diameter</td>
<td>89 mm</td>
<td>89 mm</td>
<td>89 mm</td>
</tr>
<tr>
<td>Spacing</td>
<td>3.3 m</td>
<td>3.1 m</td>
<td>3.0 m</td>
</tr>
<tr>
<td>Burden</td>
<td>2.7 m</td>
<td>2.5 m</td>
<td>2.2 m</td>
</tr>
<tr>
<td>Sub-drill</td>
<td>0.7 m</td>
<td>0.7 m</td>
<td>0.7 m</td>
</tr>
<tr>
<td>Top stemming</td>
<td>2.5 m</td>
<td>2.5 m</td>
<td>2.5 m</td>
</tr>
<tr>
<td>Explosive type</td>
<td>Emulsion</td>
<td>Emulsion</td>
<td>Emulsion</td>
</tr>
<tr>
<td>No. of Decks</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Max. charge wt.</td>
<td>75 kg</td>
<td>35 kg</td>
<td>20 kg</td>
</tr>
<tr>
<td>Powder Factor</td>
<td>0.71 kg/m$^{3}$</td>
<td>0.72 kg/m$^{3}$</td>
<td>0.73 kg/m$^{3}$</td>
</tr>
</tbody>
</table>

All blasts fired at the proposed Gold Coast Quarry will utilise state-of-the-art electronic initiation, and single-hole firing. This means that no two holes in any blast will fire at the same instant, and the weight of explosive contributing to the peak vibration levels will be the maximum weight contained in any blasthole within a pattern. Table 1 presents a summary of the expected blast design parameters for zones of different sensitivity, and includes different designs for blasts conducted at greater than 450 metres from property boundaries, blasts fired between 300 metres and 450 metres, and those fired between 240 metres and 300 metres.

Blasting at the quarry is conducted by highly trained and experienced shot-firers operating according to well-defined Blast Management Procedures developed jointly by Boral Resources and its explosives supplier (Orica, the world’s largest explosives manufacturer and service provider and an Australian company).

4. PIT DEVELOPMENT PLAN

Boral propose to develop the Gold Coast Quarry in 4 stages. The Establishment Stage, the Development Stage, the Construction Stage, and ultimately the Quarrying Stage. The processing plant pad will be constructed during the Development Stage and the crushing and screening plant constructed in the Construction Stage. The quarry pit is planned to then be developed in 5 phases, Q1 to Q5. Figure 2 presents the proposed development plan.

According to Boral’s development plan, the processing plant pad will not be completed until mid-June 2020. The final pit profile for the proposed quarry requires excavation down to a reduced level of -66 m, with the final pit plan and cross section shown in Figure 3.
Figure 2. Development plan for proposed Boral Gold Coast Quarry.

Figure 3. Plan and section view of final pit profile for the proposed Boral Gold Coast Quarry.
5. BLASTING IMPACTS

The impacts of the blasting operations at the proposed Gold Coast Quarry, addressed in this report, are those for ground vibration, air-borne vibration (overpressure). Since there is currently no quarry at the proposed site, the anticipated future impacts must be estimated based on assumed conditions such as those in AS 2187.2: 2006, or the conditions which are known to apply at the Boral West Burleigh Quarry. Since the latter provides the most conservative estimate (i.e. the vibration attenuation conditions at the West Burleigh Quarry produce higher assumed impact levels than those predicted by the Australian Standard), they will be used in this report.

Figure 4 presents a cadastral map of proposed Gold Coast Quarry, and identifies a number of residential, rural and industrial areas surrounding the site. Table 2 presents a summary of the range of separation distances between the nearest property boundary in each of seven residential/rural communities to production-scale blasting operations in the proposed Boral Gold Coast Quarry.

![Cadastral map of the proposed Gold Coast Quarry, identifying nearby residential, rural, and industrial areas.](image)

Particular note is made of Stage 20 at the Observatory, being an approved area for future development, but in which no development has yet occurred. The nearest property boundary
in this estate will be approximately 240 from the closest part of the proposed quarry pit, though all but one allotment is more than 250 metres from the pit edge.

Table 2. Range of separation distances for the nearest residential structure in each of seven rural/residential areas surrounding the proposed Gold Coast Quarry.

<table>
<thead>
<tr>
<th>Receptor Area</th>
<th>Name</th>
<th>Range of Separation Distances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area A</td>
<td>Kingsmore Estate</td>
<td>690 – 1200 metres</td>
</tr>
<tr>
<td>Area B</td>
<td>Old Burleigh Town (NW)</td>
<td>420 – 1600 metres</td>
</tr>
<tr>
<td>Area C</td>
<td>Old Burleigh Town (SE)</td>
<td>620 – 1800 metres</td>
</tr>
<tr>
<td>Area D</td>
<td>Tallebudgera Creek Road</td>
<td>280 – 1300 metres</td>
</tr>
<tr>
<td>Area E</td>
<td>Tuesday Drive</td>
<td>1000 – 1500 metres</td>
</tr>
<tr>
<td>Area F</td>
<td>Stockland Observatory Estate</td>
<td>740 – 1200 metres</td>
</tr>
<tr>
<td>Area I</td>
<td>Stage 20 at the Observatory</td>
<td>240 – 1900 metres</td>
</tr>
</tbody>
</table>

In the case of Old Burleigh Town, the minimum separation distance increases to 800 metres once the Development Stage is completed, and for the Tallebudgera Creek area, minimum separation increases to 450 metres after completion of the Development Stage.

The following analysis of expected blasting impacts is based on Environmental Licence Conditions generally consistent with those recommended in the Ecoaccess 2006 Guideline, i.e. 95% of vibration levels less than 5 mm/s and 95% of overpressure levels less than 115 dBL. While the Ecoaccess Guideline conditions refer to “9 out of 10 consecutive blasts”, such a condition is impossible to design for. Therefore, analysis has been conducted on the basis that each blast will be designed at a 95% Level of Confidence to generate levels less than 5 mm/s, and 115 dBL. This is considered to be generally consistent with the objectives in the Ecoaccess Guidelines.

5.1 Controlling Ground Vibration

Blast-induced ground vibration levels are affected primarily by a combination of the weight of explosive, and the distance between the nearest blasthole and the point of measurement. For any particular blast, levels of induced vibration are expected to be highest at the nearest residence. The equation commonly used to predict the 95 percentile level of vibration, $PPV_{95}$, is:

$$PPV_{95} = K_{95} \times \left(\frac{\text{Dist}}{\sqrt{Wt}}\right)^{-n}$$

where $PPV_{95}$ is the vibration level which will not be exceeded on more than 5% of occasions, $\text{Dist}$ is the distance in metres between the blast and the sensitive receiver, $Wt$ is the average weight in kilograms of explosive contained in each blasthole, and $K_{95}$ and $n$ are site-specific regression parameters used to determine the 95 percentile level of induced vibration.


According to the above relationship, vibration levels can be adjusted as required at any fixed receptor, by reducing the weight of explosive used in each blasthole. This is achieved by...
various means including the use of blastholes of reduced diameter, the use of multiple small and independent charges within each hole, or a reduction in the length of blastholes (i.e. a reduction in bench height). Each one of these adjustments has been made, as appropriate, at the Boral West Burleigh Quarry, to enable full compliance with that quarry’s Environmental Authority for residences as close as approximately 80 metres to blasting operations.

Figure 5. All vibration data recorded from Boral West Burleigh Quarry from January 2010 to November 2012.

The data recorded from blasting at the Boral West Burleigh Quarry since January 2010 are presented in Figure 5, and provide a good insight into anticipated blasting practices and vibration/overpressure impacts at the proposed Gold Coast Quarry. Standard regression analysis of the West Burleigh data yields the site specific parameter values of $K_{95} = 4422$, and $n =1.728$.

Based on the above analysis, which includes all data collected since January 2010 by the independent company which conducts the blast monitoring (Saros Group), the minimum distance between blasting and sensitive receivers for charges of 75 kg is 440 metres.

5.2 Controlling Air-Borne Vibration (Overpressure)

Overpressure is any air-borne vibration produced by blasting, and includes both audible and sub-audible frequencies. The sub-audible frequencies are not detectable by people outside their houses, but may be detectable inside the house by a light rattling of loose windows, in the same manner that a light gust of wind can cause window rattling and secondary noises inside the house. Overpressure levels from blasting are affected primarily by a combination of the weight of explosive, and the distance from the blastholes, but also by local topography. For any particular blast, levels of induced overpressure are expected to be highest at the nearest residence. The equation commonly used to predict the 95 percentile level of overpressure, $OP_{95}$, is:

$$OP_{95} = C_{95} - m \times \log \left( \frac{Dist}{\sqrt[3]{Wt}} \right)$$
where $Dist$ is the distance (metres) between the blast and the sensitive receiver, $Wt$ is the weight of explosive contained in each blasthole (kg), and $C_{95}$ and $m$ are site-specific regression parameters used to determine the 5 percentile level of induced overpressure (i.e. the level which will not be exceeded on more than 5% of occasions).

According to the above relationship, peak overpressure levels can be adjusted as required at any fixed receptor, by reducing the weight of explosive used in each blasthole. This is achieved by various means including the use of blastholes of reduced diameter, the use of multiple small and independent charges within each hole, or a reduction in the length of blastholes (i.e. a reduction in bench height). Additional reductions can be made by orienting blasts away from the nearest sensitive receiver, and by creating topographical barriers between the blasting operations and the sensitive receivers. Each one of these adjustments has been made, as appropriate, at the Boral West Burleigh Quarry, to enable full compliance with that quarry’s Environmental Authority for residences as close as approximately 80 metres to blasting operations.

The data recorded from blasting at the Boral West Burleigh Quarry since January 2010 are presented in Figure 6, for which the site specific parameter values are $C_{95} = 163.1$, $m = 24$.

Based on the above analysis, which includes all data collected since January 2010 by the independent company which conducts the blast monitoring (Saros Group), the minimum distance between blasting and sensitive receivers for charges of 75 kg is 430 metres.

![Figure 6](image)

*Figure 6. All overpressure data recorded from Boral West Burleigh Quarry from January 2010 to November 2012.*

6. **CONTROLLING FLYROCK**

Since flyrock has the potential to cause injury and death, it is considered the most important factor over which total control is required – flyrock can be eliminated through strict charging protocols. Flyrock can be considered as any rock fragment which is projected from the blast area beyond the clearance zone. Such events are required by law to be reported, and are considered extremely grave. To date there has never been a flyrock incident (projection of rock beyond the quarry’s boundary) at the West Burleigh site, and the practices to be adopted...
at the proposed Gold Coast Quarry will be heavily based on the very safe practices deployed at the West Burleigh operation for the past 20 years. Modelling suggests that with the charge configuration of 10.5 metres of explosive and 2.5 metres of stemming, an 89 mm diameter hole, and an explosive of density 1.2 g/cc, rock fragments will not be projected more than approximately 50 metres from any blast.

Blasting operations which occur within 300 metres of occupied structures or private land must deploy special procedures to ensure absolute public safety. Figure 7 presents areas of the proposed quarry development which lie within 300 metres of the boundaries of privately-owned properties.

In the case of the sensitive zone located in the southern section of the development pad, this area lies within 300 metres of the northern boundaries of 3 property boundaries in the Tallebudgera Creek Road area. The affected zone represents approximately 10% of the total area of the development pad, requiring special procedures for only a small number of blasts. Boral have demonstrated the ability to blast safely under even more stringent conditions (within approximately 80 metres of housing) at the West Burleigh Quarry. Furthermore, the sensitive receivers are located behind the affected area (i.e. the benches in this section of the quarry will be oriented such that rock projections from the bench faces will be directed away from the nearby properties) where flyrock risk is lessened.

In the case of the sensitive zone located in the north-western section of the proposed quarry pit, this area lies within 300 metres of three allotments at the north eastern end of the Approved Stage 20 at the Observatory Estate, within which no development has yet occurred. The affected area of the quarry pit also represents a small fraction of the proposed pit (less than 3%), and once again, benches in this section of the quarry will be oriented such that rock projections from the bench faces will be directed away from the nearby properties. Boral has

Figure 7. Areas within the proposed quarry footprint at which blasting operations will be conducted within 300 metres of residential properties.
developed the procedures and demonstrated over the past 20 years at the West Burleigh Quarry its ability to blast safely at these distances from residential structures.

The protocols required in order to control flyrock include:

1. Ensuring that every charged hole conforms to a minimum stemming length, such that rocks cannot be projected more than approximately 100 metres;

2. Ensuring that every face hole is surveyed for hole deviation, and that all sections of the charge column for face holes conform to a minimum burden such that rock fragments cannot be projected more than approximately 100 metres;

3. Any uncharged holes in the pattern (e.g. blocked holes) are back-filled so that fragment projections cannot occur.

The high degree of control over flyrock is seen in the photographs of Appendix B which shows a series of frames taken from video records which are routinely taken of blasts at the Boral West Burleigh quarry.

7. IMPACT ASSESSMENT

The blasting impacts which have been modelled and predicted in this report relate to ground vibration and air overpressure. Both are unavoidable side effects from blasting, though best practices can minimise the two separate and largely-independent impacts.

When determining environmental blasting impacts, it must be remembered that the impacts will vary over time, according to the location of blasting activities. Therefore, at any particular time, the area affected by blasting is relatively small. To assist in understanding the impacts and how they vary over time, the modelling has been conducted for the nearest property in each of seven nearest communities which surround the proposed quarry site, for each phase of the quarry development, as well as over the full life of the project. The results are summarised in Table 3 (vibration) and Table 4 (overpressure), and detailed graphs are presented in Appendix A. The results are presented in a form consistent with both AS 2187.2: 2006 and the Ecoaccess 2006 Guideline – i.e. the table reports the 95 percentile vibration and overpressure levels. At no stage will peak vibration or peak overpressures levels exceed 10 mm/s and 120 dBL respectively at any private property boundary.

Table 3 shows that the proposed quarry can comply with the expected 95 percentile vibration limit of 5 mm/s at all phases of development of the proposed pit. It also shows a significant change in impacts at all receivers as the development works are terminated and the pit extraction (Quarry Stage) commences. This is to be expected due to the separation of the Processing Plant pad and the pit.
Table 3. Vibration impacts from blasting in different stages of development of the proposed Boral Gold Coast Quarry.

<table>
<thead>
<tr>
<th>Receiver</th>
<th>95 Percentile Vibration (mm/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Development</td>
</tr>
<tr>
<td>A</td>
<td>1.3</td>
</tr>
<tr>
<td>B</td>
<td>2.3</td>
</tr>
<tr>
<td>C</td>
<td>1.3</td>
</tr>
<tr>
<td>D1</td>
<td>2.9</td>
</tr>
<tr>
<td>D2</td>
<td>1.1</td>
</tr>
<tr>
<td>E</td>
<td>0.6</td>
</tr>
<tr>
<td>F</td>
<td>0.4</td>
</tr>
<tr>
<td>I</td>
<td>1.1</td>
</tr>
</tbody>
</table>

Receiver A = A385, Kingsmore Estate, B = B213, Old Burleigh Town (NW), C = C01, Old Burleigh Town (SE), D1 = D01, Tallebudgera Creek Road, D2 = D13 (Maryville), Talbudgera Creek Rd, E = E01, Tuesday Drive, F = F05, Stockland Observatory Estate, I = I01, Stage 20 at the Observatory.

Table 4 shows that the proposed quarry can comply with the expected 95 percentile overpressure limit of 115 dBL at all stages of development of the proposed pit. Special care will be required to ensure that levels of overpressure induced in Area H (Stage 20 at the Observatory) remain compliant, once housing development commences. A factor likely to lead to lower levels of overpressure in the Stage 20 at the Observatory Estate than those estimated using simple regression is that the houses in that estate will be constructed on the north-western side of a rise, while the quarry pit extraction will occur approximately 30 metres lower on the south-eastern side. The topographical barrier is likely to assist in further reducing the peak overpressure levels.

Table 4 also shows a significant change in impacts at most receivers as the development works are terminated and the pit extraction commences. This is to be expected due to the separation of the development pad and the pit.
Figure 8 presents the impact contours for the proposed Gold Coast Quarry during the Development Stage, i.e. the formation of the Processing Plant Pad. Figure 9 presents the same contour for the Quarry Stage, including Phase Q1 through to the end of the pit life, Q5. The contours represent the maximum impacts from all blasts fired over the life of the quarry, and does not indicate the impact for any particular blast. The impacts from individual blasts will be much smaller, and will be centred around the mid-point of each blast. Since vibration and overpressure distances to achieve compliance are essentially the same, the displayed contours can be considered to apply to both impacts.

Figure 8. Vibration and overpressure contour for the proposed Development Stage (Processing Plant Pad).

Figure 9. Vibration and overpressure contour for the proposed Quarry Stage (Phases Q1 to Q5).
8. MITIGATION MEASURES

Separate mitigation measures will be required for vibration and overpressure compliance, since the two impacts are largely independent. The principal design strategies will be developed early in the Development Stage of the project, where the initial blasts will be used as trial blasts, and fully monitored for both ground vibration and overpressure at multiple locations.

8.1 Vibration Mitigation

The principal factor affecting vibration levels induced by blasting is the maximum weight of explosive loaded into any hole of a pattern. The maximum weight is controlled by the diameter of the blasthole and the length of the charge within the blasthole. When blasting at large distances from sensitive receivers, a single charge column weighing approximately 75 kg will be loaded into each hole. Where this charge produces levels approaching 5 mm/s, the quarry will adopt one or more of the following mitigation actions:

1. Two separate charges, separated by an inert stemming deck with each charge independently delayed, so that the maximum weight of explosive is approximately halved;
2. The bench height can be reduced from 12 metres to 6 metres;
3. The blasthole diameter can be reduced from 89 mm to 76 mm;
4. Delay timing can be adjusted to produce destructive interference of vibration waves from different charges.

Trial blasting will be conducted during the early stages of work on the Processing Plant Pad, initially using small explosive charges monitored at different directions and distances. The small trial blast charges will be at least 430 metres from the nearest property boundary. This will provide an advance opportunity to establish vibration attenuation conditions and to identify possible vibration anomalies. Since all blasts will be monitored at multiple locations, and the data used to update vibration attenuation trends, the blasting contractor will be well-positioned to make adjustments to charge weights on a continuous basis well before production-scale blasting commences.

8.2 Overpressure Mitigation

The principal factors affecting peak overpressure levels induced by blasting are the maximum weight of explosive loaded into any hole of a pattern, the amount of stemming loaded into each hole, and the amount of burden on the holes drilled to the free face. Where the normal charge of approximately 75 kg produces levels approaching 115 dBL, the quarry will adopt one or more of the following mitigation actions:
1. Two separate charges, separated by an inert stemming deck with each charge independently delayed, so that the maximum weight of explosive is reduced from around 75 kg to around 35 kg;

2. The bench height can be reduced from 12 metres to 6 metres;

3. The blasthole diameter can be reduced from 89 mm to 76 mm;

4. Stemming height and front row burdens can be increased to provide greater charge confinement.

9. BLASTING CONTROLS

In order to ensure that blasting operations are 100% compliant with the Ecoaccess Blasting and Noise Guidelines (2006) limits, the following recommendations are made as regards blasting and monitoring practices at the proposed Boral Gold Coast Quarry.

All blasts will be monitored at a minimum of 2 locations simultaneously. The closest residence in the two closest residential areas (Figure 4) should be chosen for monitoring, though monitors should be moved from time to time to ensure that no residences in the area are exposed to impact levels outside Licence Conditions, and at least one roving monitors should also be used to address complaints or other locations of interest. Monitoring at any one location should involve an appropriate number of blasts to establish impact levels. Monitoring will involve trained and experienced personnel, standard blasting seismographs with a calibration certificate less than 12 months old. Monitoring procedures will be according to Australian Standard AS 2187.2: 2006 – for permanent monitoring stations, the triaxial geophone monitor will be firmly mounted onto a cubic concrete block of at least 30 kg mass which has been tamped into the ground with the exposed surface of the block level with the surrounding ground surface. Roving monitors will be firmly mounted using soil spikes.

Monitoring should be both proactive and reactive. In response to complaints, monitors should be deployed to the complaint area and monitoring conducted a sufficient number of times to establish impact levels. Otherwise, monitoring location should be chosen on the basis of the locations with the highest potential impacts.

Where vibration or overpressure sensitivity requires it, Boral should use two smaller explosive charges in each hole, instead of a single charge in order to ensure that impacts remain 100% compliant with Ecoaccess 2006 Guidelines. Alternatively, bench height or hole diameter can be adjusted as indicated in Section 8.

As much as possible, Boral will avoid the firing of multiple small blasts where a single larger blast can be fired. Vibration and overpressure impacts are largely independent of size, and the reduced frequency of blasting achieved by firing larger blasts is expected to reduce public perception and complaint.

Boral will maintain the practice of requiring the Drill & Blast Contractor to adhere to strict blasting protocols, including the practice of surveying bench faces, surveying front row
blastholes, logging the precise charge configuration of every blasthole, and obtaining a video record of every blast fired. Where vibration levels approach maximum permitted limits, the Drill & Blast Contractor will be required to submit to the Quarry Manager a plan to ensure that the induced vibration levels never exceed permitted limits.

10. PRE-CONSTRUCTION CONDITION SURVEYS

The Terms of Reference provided by the Coordinator General for the Gold Coast Quarry Environmental Impact Study include Pre-Construction Condition Surveys to be undertaken on selected residential structures in the vicinity of the proposed quarry.

The EIS should include an outline of the scope and methodology of pre-construction building surveys including a preliminary identification of the type and location of properties that should be surveyed. The proponent should undertake any required pre-construction building surveys in the vicinity of the project prior to commencement of any quarrying operations.

The purpose of such studies is to identify changes in the condition of structures which may be attributable to the new quarrying activities and blasting in particular. Blastechnology considers such studies unnecessary for the following reasons.

1. The quarry will comply with the maximum vibration impact levels presented in the Queensland Government Ecoaccess Guidelines for Noise and Vibration, 2006, which state that vibration levels from blasting must not exceed a peak particle velocity of 5 mm/s for 9 out of any 10 consecutive blasts initiated. The Queensland Government Ecoaccess Guidelines for Noise and Vibration, 2006, are stated to represent human comfort criteria, and further state “People are able to detect vibration at levels much lower than those required to cause even superficial damage to the most susceptible structures.”

2. All field studies conducted to investigate blast-induced damage have demonstrated that normal environmental fluctuations (amount of rainfall, temperature cycling, humidity variability) induce considerably higher stresses in structures than occasional low-level vibrations from blasting. Such findings signify that the contribution of blast-induced vibrations to structural deterioration is very small and probably insignificant.

3. All structures deteriorate with time, commencing with cosmetic cracking and proceeding ultimately to structural failure. Periodic surveys of the condition of structures will therefore always identify some level of deterioration even in well maintained structures.

4. Such surveys are most useful when the duration of the new activity is sufficiently short that changes in condition can unambiguously be attributed to the introduced activity, such as a new tunnel, road cutting or structural foundations. In the case of the proposed Gold Coast Quarry, the duration of the activities is of the order of 40 years.

5. Compliance with the Queensland EcoAccess Guidelines is therefore considered to ensure that blast-induced vibration levels at all surrounding structures will be significantly lower than the levels capable of causing even cosmetic damage (such as paint cracking).
10.1 Vibration Levels and Damage to Structures

Various studies have been conducted into the effect of blasting vibrations on damage (cosmetic through to structural) to residential structures, including in the US, Sweden, UK, Germany and Australia. The studies have included the effects of repeated blasting – in the case of the US study involving more than 500 closely-monitored blast events, and even involving very large shakers to shake a test house for extended periods. The US study, conducted by the government-based United States Bureau of Mines (USBM), was the most detailed of all the studies, but the UK-based BS 7385 may be the most comprehensive in terms of the size of the database reviewed. The following is a summary of the main findings from these sources:

- The UK Department of Environment, Transport and Regions study showed that more than 30% of vibration-related complaints about blasting relate to a fear of damage to the occupants’ structures. The study also concluded that complaints from blasting are likely to commence as soon as the levels of induced vibration become perceptible (typically in the range of 0.5 to 1.0 mm/s).
- Cracking occurs naturally in structures, commencing even before the completion of construction, with typical cracking frequencies of around 0.3 new hairline or cosmetic cracks appearing per week in timber structures, and 12-13 cracks per year in concrete structures. This cracking continues for the life of the structure.
- If structures are exposed to vibration levels of around 1 in/s (25 mm/s), the appearance rate of new cracks increases from 0.3 to around 1.0 hairline or cosmetic cracks per week. Levels lower than 0.5 in/s (12 mm/s) appear to have an insignificant (immeasurably low) effect on the natural rate of appearance of hairline cracks;
- Cosmetic damage such as hairline cracking in paint and plaster joins is not expected to occur for vibration levels lower than 15 mm/s, even at very low frequencies of vibration (e.g. 4 Hz);
- Minor damage is not expected (has not been substantiated) at levels of vibration less than 30 mm/s even for low frequency vibrations, and structural damage is not expected (has not been substantiated) at levels less than 60 mm/s even at very low vibration frequencies (e.g. 4 Hz);
- The British Standard BS 7385-2 advises that the guide values contained in that standard (minimum of 15 mm/s for cosmetic damage) “…… should not be reduced from fatigue considerations since no substantiated cases are known to have arisen from groundbourne vibration.”
- The German Standard DIN 4150 states for cases where induced levels comply with recommended guidelines (minimum level of 5 mm/s for residential structures): “If, however, damage is found, it is to be assumed that other causes are responsible for this damage.”

While there is sometimes a perception that vibration must cause damage, there are no examples where damage from low-level vibrations has been substantiated. With human perception levels for vibration being around 0.5 to 1.0 mm/s, it is clear that humans are very vibration-sensitive, much more so than the residential structures in which they live.
10.2 Recommendations – Condition Surveys

Notwithstanding the rationale of the previous section, the Terms of Reference from the Coordinator General for the Environmental Impact Statement for the proposed Boral Gold Coast Quarry Project stipulate “the EIS should include an outline of the scope and methodology of pre-construction building surveys including a preliminary identification of the type and location of properties that should be surveyed. The proponent should undertake any required pre-construction building surveys in the vicinity of the project prior to commencement of any quarrying operations.”

In accordance with the Coordinator General’s Terms of Reference, Boral therefore proposes to offer building condition surveys to a limited number of houses in the surrounding communities, prior to the commencement of construction activities currently scheduled for 2016. Blastechnology recommends that the condition surveys be offered at the developed properties chosen in this report on the basis of proximity to the quarry’s proposed blasting activities, being:

- Old Burleigh Town NW, B213
- Old Burleigh Town SE, C213
- Tallebudgera Ck Rd, D01
- Tallebudgera Ck Rd, D13
- Tuesday Drive, E01
- Stocklands Observatory Estate, F05
- Kingsmore Estate, A385

The property I01 in Stage 20 at the Observatory has not been included since there are no existing structures in this proposed development area. If residential structures are erected in this site prior to the commencement of construction activities, the nearest structure to the quarry would also be included in the survey offer.

The condition surveys will only be conducted if the property owners provide consent for detailed internal and external surveys to be undertaken on all major structures. The surveys will be undertaken by competent and experienced structural engineers with a focus on identifying, photographing and classifying all obvious cracks and defects (cosmetic and structural) in houses, concrete driveways, swimming pools, and any other important structures which might be sensitive to the effects of vibrations from blasting. The structural surveys will also include an assessment of the soil characteristics in which the structures have been constructed, an assessment of drainage around the structures, and an assessment of structural foundations where possible.

To give effect to this recommendation, the following condition is recommended for inclusion in the Coordinator-General’s recommendation report:

Prior to commencement of blasting operations for the Development Stage of the proposed works, Boral will circulate a letter offering Condition Surveys to selected properties around the site. The same letter will be circulated to a selected property in Stage 20 at the Observatory once houses in this area are constructed and occupied. The Condition Surveys offered to property owners shall include all major structures on the property, detailed internal and external examinations, and
a review of ground conditions around house foundations. The purpose of the Condition Surveys will be to establish the prior structural state of the properties so that future deterioration of the properties can be compared with the normal rates of deterioration, and to assist in identifying possible acceleration of deterioration due to the impacts of quarrying operations.