BLASTING IMPACT ASSESSMENT
DUFFERIN AGGREGATES ACTON QUARRY
PROPOSED EXTENSION

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1.0 INTRODUCTION

Dufferin Aggregates, a Business Unit of St. Lawrence Cement Inc. is applying to expand its Acton Quarry, in the Town of Halton Hills, Regional Municipality of Halton. The proposed extension is located to the north and south of the existing operation.

1.1 ACTON QUARRY EXTENSION

The Acton Quarry Extension is located in Part of Lots 19, 20, 21, 22, and 24 Concession 3 and Part of Lots 20, 21 and 22, Concession 4, Town of Halton Hills, Regional Municipality of Halton. The total proposed licence area is 124.4 ha (307.4 ac) and the total proposed extraction area is 99 ha (244.6 ac).

The required land use applications include:

1.1.1 Aggregate Resources Act
   - A Class A License, Category 2 – Quarry Below Water

1.1.2 Niagara Escarpment Planning & Development Act
   - An amendment to the Niagara Escarpment Plan (2005) for lands within the Niagara Escarpment Plan boundary.
   - Niagara Escarpment Development Permit for lands within the Niagara Escarpment Development Control Area.

1.1.3 Planning Act
   - A Town of Halton Hills Zoning By-law Amendment for the lands outside of the Niagara Escarpment Development Control Area.

1.2 OVERVIEW OF STUDY

The blasting impact assessment addresses the environmental effects from future blasting operations within the proposed extension areas of the Dufferin Aggregates Acton quarry. The impact assessment specifically addresses whether the applicable Ontario Ministry of Environment guidelines with respect to ground and air vibration effects can be met at the residential properties nearest to the proposed extension. The investigation included monitoring a number of regularly scheduled production blasts at various receptor points around the blast site to assess site-specific
ground and air vibration decay characteristics. Additional blast monitoring data was collected from monitoring stations established at selected residential locations around the current licensed quarry property. Historical blast monitoring results were also reviewed as part of this study.

This report addresses the following topics:

- reviews existing provincial and federal guidelines for the assessment of environmental impacts from blasting,
- provides recommendations for the continued control of ground and air vibration effects,
- evaluates the potential impact of the blasting operations on bedrock strata and adjacent water wells,
- evaluates the long term impact of the blasting operations on surrounding structures, and
- evaluates the impact of ground vibration effects at adjacent Canadian Fisheries waters.

This assessment was carried out by Mr. Marcus van Bers, P.Eng., an Associate with Golder Associates, who has been involved in rock mechanics and blasting engineering for over 20 years. Mr. van Bers provides supervision and technical involvement in all aspects of blasting control, including design, blast optimization, feasibility studies, preparation of specifications, design and implementation of monitoring programs, and assessing the environmental impact of blasting operations on adjacent facilities. Mr. van Bers, whose curriculum vitae is found in Appendix B, has been involved with blasting projects throughout North and South America, Asia, Africa and the Caribbean.

1.3 OVERVIEW OF THE PROPOSED ACTON QUARRY EXTENSION

Dufferin has assembled 301.5 ha (745 ac) generally north and south of its existing Acton Quarry. The Acton Quarry Extension is located in Part of Lots 19, 20, 21, 22, and 24 Concession 3 and Part of Lots 20, 21 and 22, Concession 4, Town of Halton Hills, Regional Municipality of Halton. The total proposed licence area is 124.4 ha (307.4 ac) and the total proposed extraction area is 99 ha (244.6 ac). The remaining two-thirds of Dufferin’s lands will be maintained and protected for conservation uses. Activities in these areas will be limited to monitoring, environmental mitigation and ecological enhancement.

The proposed extension will operate as a continuation to the existing quarry. The proposed quarry will not result in an increase in permitted production levels. Dufferin is applying for a tonnage limit of 4 million tonnes per annum, which is the same as the existing quarry.

Site preparation and extraction in Phase 4 will commence when Phase 3 of the existing quarry is nearing completion. There will be no processing in Phase 4. Blasted aggregate will be
transported by quarry trucks to the existing processing plant. Shipping to market will be status quo as it will utilize the existing entrance/exit and established haul routes.

Phase 5 is a continuation of the existing quarry from Phase 2 and 3. Phase 6 is a continuation of Phase 5. Blasted aggregate from Phase 5 will be predominantly transported by quarry trucks to the existing processing plant using the same internal routes in place for Phase 2 and 3 of the existing operations. Shipping to market will be status quo as it will utilize the existing entrance/exit and established haul routes. A portable processing plant is also permitted in Phase 5. If processing occurs the material will be shipped directly from the Phase, and trucks will travel north on 3rd Line and then utilize the existing established haul routes.

Phase 6 east of 3rd Line is located south of the pillar. A sinking cut/access ramp will be required. Phase 6 west is a continuation of Phase 5 west and no sinking cut is required. Blasted aggregate will be predominantly transported by quarry truck to the existing processing plant. Phase 6 east quarry trucks will travel up and over the rock pillar, north through Phase 2 to the at-grade crossing at 22nd Sideroad and through Phase 1 to the processing area. A portable processing plant is also permitted in Phase 6. If processing occurs the material will be shipped directly from the phase, and trucks will travel north on 3rd Line and then utilize the existing established haul routes.

Phase 7 is the southern most cell and a sinking cut/access ramp is required. Phase 7 includes a portable processing plant and shipping will occur directly from this Phase. Due to its size and configuration Phase 7 can only produce and ship approximately one million tonnes annually.

Current extraction of any two phases is permitted to occur to allow for efficient operations and maximize progressive rehabilitation of the site.
2.0 EXISTING CONDITIONS

2.1 Site Description

The Dufferin Aggregates Acton Quarry is situated immediately south of the town of Acton between Regional Road 25 to the west and Fourth Line to the east, as seen in Figure 1. The proposed extension consists of four phases. Phase 4 is located immediately northwest of the existing quarry, and Phases 5 to 7 are situated immediately south of the existing quarry, as seen in Figure 2.

As shown in Figure 2, the closest receptors to the north extension would be those to the west and northeast, which are in excess of 500 m from the proposed Phase 4 extraction limit. The closest receptor to the south extension would be the residence immediately west of the Phase 5 West extraction area, at a minimum distance of 220 m from the proposed extraction limit. Four receptors on the east side of 3rd Line are also situated approximately 240 m east of the Phase 7 extraction area. The topography of the area consists of gently rolling hills.

2.2 Quarry Blasting Operations

The Dufferin Acton quarry currently operates a single bench in Phase 2 to a maximum height of 25 m and two benches in Phase 3 which vary in height from 13 to 17 m. Typical blast design details for the Acton quarry are given in Table 1 while common quarry blasting terms and procedures are illustrated in Figure 3.

All blasting at the Acton quarry is monitored for ground and air vibration effects. Golder Associates has been monitoring blasting operations at various sites around the Acton quarry since 1996. Monitoring is currently being carried out at the following five locations:

- 11967 Hwy 25
- 11978 Third Line
- 10046 22nd Sideroad
- 12060 Fourth Line
- South side of 22nd Sideroad in northwest corner of Phase III extraction of existing quarry

Monitoring has also been carried out for differing periods of time at various other residential properties around the Acton quarry.
Blasting procedures within the proposed extension would be carried out in a manner similar to those currently being carried out within the existing quarry as summarized in Table 1. The proposed extension would not result in an increase in permitted production levels.
3.0 PROPOSED EXTRACTION OF EXTENSION AREA

During the final extraction of Phase 3, extraction of Phase 4 would commence with a sinking cut in the south east corner. The majority of the Phase 4 area would be extracted in two benches with only the northeast corner being extracted in a single bench. Single bench extraction would be carried out when ever the depth of extraction was less than 25 m, in the same manner that extraction occurs within the existing quarry. The direction of extraction in Phase 4 is shown on Figure 2.

Phase 5 would be extracted in a southerly direction from Phases 2 and 3. Extraction on either side of 3rd Line would occur concurrently. West of 3rd Line, extraction of Phase 6 would continue south. Phase 6 on the east side of 3rd Line would commence with a sinking cut in the northeast corner, immediately south of the 30 m wide rock pillar separating Phases 5 and 6. Extraction in Phases 5 and 6 would be carried out primarily in two benches. Only the eastern half of Phases 5 and 6, east of 3rd Line, would be extracted in a single bench.

Extraction of Phase 7 would commence with a sinking cut in the northeast corner. Two benches would be extracted in a south and south easterly direction, as shown on Figure 2. Extraction of Phase 7 would occur concurrently with Phases 5 and 6, with only two phases being active at any time.
4.0 IMPACT IDENTIFICATION

The effects most often associated with blasting operations are ground vibrations and air concussion.

The intensity of ground vibrations, which is an elastic effect measured in units of peak particle velocity, is defined as the speed of excitation of particles within the ground resulting from vibratory motion. For the purposes of this report, peak particle velocity is measured in mm/s.

While ground vibration is an elastic effect, one must also consider the plastic or non-elastic effect produced locally by each detonation when assessing the effects on the bedrock strata and local water wells. The detonation of an explosive produces a very rapid and dramatic increase in volume due to the conversion of the explosive from a solid to a gaseous state. When this occurs within the confines of a borehole it has the following effect:

- The bedrock in the area immediately adjacent to the explosive product is crushed.
- As the energy from the detonation radiates outward from the borehole, the bedrock between the borehole and quarried face becomes fragmented and is displaced while there is minimal fracturing of the bedrock behind the borehole.
- Energy not used in the fracturing and displacement of the bedrock dissipates in the form of ground vibrations, sound and airblast. This energy attenuates rapidly from the blast site due to geometric spreading and natural damping.

Air concussion, or air vibrations, is a pressure wave traveling through the air produced by the direct action of the explosive on air or the indirect action of a confining material subjected to explosive loading. Air vibrations from surface blasting operations consist primarily of acoustic energy below 20 Hz, where human hearing is less acute (Siskind et al., 1980), while noise is that portion of the spectrum of the air vibration lying within the audible range from 20 to 2000 Hz. It is the lower frequency component (below 20 Hz) of air concussion, which is less audible, that is of interest as it is often the source of secondary rattling and shaking within a structure. For the purposes of this report, air vibration is measured as decibels in the Linear or Unweighted mode (dBL). This differs from noise (above 20 Hz) which is measured in dBA.

Both ground and air vibration effects produced at private structures adjacent to quarries are subject to guidelines contained in Noise Pollution Control (NPC) publication 119 of the Model Municipal Noise Control By-Law, dated August, 1978, published by the Ontario Ministry of Environment. Under conditions where monitoring of the blasting operations is routinely carried out, as it is at the Dufferin Acton quarry, the ground and air vibration limitations at the nearest structure off the quarry property are 12.5 mm/s and 128 dBL respectively. Publication NPC 119 is reproduced in Appendix A.
The Department of Fisheries and Oceans (DFO) has established a set of guidelines for the use of explosives in or near Canadian fisheries waters (1998). These guidelines set out that “No explosive may be used that produces or is likely to produce, a peak particle velocity greater than 13 mm/s in a spawning bed during egg incubation”. Under conditions where this guideline could not be met the proponent would be required to prepare a mitigative plan outlining additional procedures for protecting fish, marine mammals and their habitat. As discussed in Section 6.4 following, compliance with the DFO guidelines will be maintained.
5.0 QUARRY BLAST MONITORING

As part of this study, peak ground and air vibration levels were monitored during several typical quarry production blasts at progressively increasing distances from the blast site. The blasts occurred both on the south and west faces in Phase 3 of the quarry. Instrumentation consisted of Instantel DS-077 Minimates, Minimate Pluses and DS-477 Blastmates. These instruments measure and record ground vibration velocities in each of three orthogonal directions, as well as simultaneously recording air vibration levels. Instrumentation was generally set up in a line at distances ranging from about 100 to 900 m from the blast site. Specific instrument and blast locations were established using a Garmin GPS electronic navigation aid (NAVAID) to determine accurate distances between the blast and receptors.

The monitoring results were also reviewed from the permanent monitoring stations around the quarry property and where applicable were included in the assessment of ground and air vibration attenuation rates.

5.1 Attenuation Characteristics

The rate at which ground vibrations attenuate or decrease with increased distance from a blast source depends on a variety of conditions, including the type and condition of the bedrock being blasted, depth and composition of the earth covering deposits (soil), and the general topography. Air vibration effects are less affected by these factors, being more influenced by the prevailing weather conditions at the time of the blast.

The following relationships were established from the blast monitoring results.

5.1.1 Ground Vibrations

The ground vibration attenuation characteristics established for the Dufferin Acton quarry is presented in Figure 4 as a plot of the peak particle velocity against the Scaled Distance. Scaled Distance is defined as:

\[
\text{Scaled Distance (SD)} = \frac{D}{\sqrt{W}}
\]

where \( D \) = distance (m) between the blast and receptor

\( W \) = maximum weight of explosive (kg) detonated per delay period

As seen in Figure 4 the collection of points defining the rate of decay for the ground vibrations exhibits a degree of scatter that is inherent in all Scaled Distance plots. Factors responsible for these variations include the geologic conditions of the bedrock (type and structure), different wave types, errors in blast initiation timing, differences between types of explosives, degree of confinement, and differences in blast efficiencies.
The equation for the 95% regression line developed in Figure 4 can be expressed as:

$$PPV = 4580(SD)^{1.69}$$

where PPV = Peak Particle Velocity (mm/s)  
SD = Scaled Distance (m/(kg^{0.5}))

The calculated Scaled Distance for a peak ground vibration level of 12.5 mm/s would equal 33.1 m/(kg^{0.5}). The purpose of this equation is not so much to predict what a given vibration level would be at a particular location for a given blast, but to indicate the probability that the peak vibration would fall below the level indicated by the equation for a given distance and maximum explosive weight. The equation is therefore a useful blast design tool in establishing maximum explosive charge weights per delay for various distances from a blast site for a given maximum ground vibration level.

### 5.1.2 Air Vibrations

Cube root scaling was used in establishing the air vibration decay characteristics as given in the following relationship:

$$\text{Scaled Distance (SD)} = \frac{D}{3\sqrt{W}},$$

where D and W are defined as previously described.

Figure 5 shows the Scaled Distance air vibration plot which incorporates monitoring results obtained from in front of the blast where air vibration effects tend to be greatest. Air vibration attenuation plots typically exhibit considerably more scatter and have a typically poorer correlation than that seen with the ground vibration results. This is primarily due to variable weather conditions during each blast, which are entirely independent of the blasting operations. Other factors influencing air vibration distribution from a blast include the length of collar and type of stemming material used, differences in explosive types and variations in burden distance.

The 95% regression curve given in Figure 5 can be expressed as:

$$\text{APL} = 260(\text{SD})^{-0.157}$$

Where SD = as defined above  
APL = air pressure level (dBL)

The calculated Scaled Distance for a peak air vibration level of 128 dBL would equal 92 m/(kg^{0.33}). The variability in the plot due to weather influences suggests that it is less reliable as a tool for guiding blast design.
Site specific Scaled Distance plots are commonly used as a blast design tool since peak vibration levels can be reasonably predicted at specified distances from a blast site. Based on the 95% regression equations given in Figures 4 and 5, Table 2 shows the maximum suggested explosive loads for various distances from the blast site based on the provincial guideline limits of 12.5 mm/s and 128 dBL discussed previously.
6.0 IMPACT ASSESSMENT

6.1 Compliance with NPC 119

It is evident from the regression equations discussed in Section 5 that the distance from the blast and the amount of explosive detonated per delay period are the critical parameters in controlling ground and air vibration effects. Based on the blast details given in Table 1 and the maximum explosive loads given in Table 2 for limiting peak ground and air vibration levels to 12.5 mm/s and 128 dBL respectively, it is evident that the provincial guidelines will be complied with for all blasting beyond a distance of about 300 to 400 m from adjacent private residential properties. Residences within 400 m of the proposed extension would include those along Third Line east of the Phase 7 extraction areas and those residences east of Regional Road 25 west of the Phase 5 extraction area, as seen in Figure 2. When blasting approaches to within 400 m of adjacent residences, depending on bench height and the monitoring results, it is anticipated that a reduction in the maximum explosive weight detonated per delay period within the blast would be required. Any one or combination of the following operations would reduce the maximum charge weight per delay:

1. Reducing the borehole diameter with a corresponding reduction in the drill pattern.

2. Introduce decked charges within each borehole, as illustrated on Figure 3.

3. Reduce the borehole length (depth) by reducing the bench height.

For example, a reduction in the borehole diameter from 114 mm to 76 mm would reduce the explosive weight per hole by approximately 55%. Decking the explosive column, as shown in Figure 3, could further reduce the maximum explosive weight per hole by an additional 50%. Additional decking or reductions in the bench height, as identified above, could achieve further reductions in maximum explosive weights per delay.

It is a requirement for Dufferin to monitor blasts at the proposed extension. The attenuation curves discussed previously would be used in conjunction with the monitoring data collected at adjacent properties to dictate when changes to the blast procedure become necessary within the proposed extension. Although a reduction in the maximum charge weight per delay is anticipated, the ground and air vibration guideline limits as discussed in this report would continue to be maintained. A review of the historical monitoring results at the Acton quarry, during extraction within Phases 2 and 3, show that the ground and air vibration levels generated by the blasting operations have consistently remained within the MOE guideline limits at adjacent residences.
6.2 Repeated Vibration Effects on Structures

Blast vibrations characteristically produce temporary transient strains within the various materials that makeup a residential structure. These strains would typically have durations of no more than one or two seconds for each blast as the vibration passed the structure. In addition to these temporary strains, Table 3 shows the strain levels produced in a household by changes in temperature and humidity (environmental changes), as well as those produced by regular household activities (Dowding, 1985), which occur on a recurring and often frequent basis. These strain levels are compared to equivalent levels of ground vibration produced from blasting operations. It is evident from Table 3 that routine household activities and environmental changes can at times produce strains within a structure that are well in excess of those produced by blasting.

Several studies have also been carried out to look at the long-term effects of repeated blasting on structures (Stagg et al, 1984, Siskind et al, 1980). These studies concluded that repeated blasting over several decades, producing peak vibration levels well in excess of the provincial guideline limit, were required to cause cosmetic threshold cracking to occur. By ensuring that blasting continues to remain within the provincial guideline limits, there would not be any noticeable cumulative effect associated with the blasting operations within the extension area.

6.3 Effects on Bedrock and Water Wells

As discussed previously, under typical blasting conditions stresses introduced into the bedrock by the explosive detonation and the accompanying gas pressures create and extend fractures within the bedrock around each borehole. Fracture development is usually limited to the equivalent distance of about 20 times the borehole diameter. In the case of the blast procedures expected for the proposed extension, this would equate to about two to three metres for a 114 mm diameter hole. The gas pressures within the hole may extend micro-cracks or existing natural discontinuities within the bedrock, such as joints or bedding planes, beyond this distance.

Studies on crack development within bedrock from blast detonations (Keil et al., 1977) indicate that peak ground vibration levels of 300 to 600 mm/s are required to create micro-cracks or open existing discontinuities. Our own experience within the limestone of Southern Ontario indicates that such values would not be anticipated beyond a distance of about 10 to 20 m from the blast site, depending on such parameters as drill hole diameter and the type of explosive product. It is evident therefore that the creation or extension of fractures within the bedrock would remain confined to an area immediately around the blast site.

Several studies have been carried out to investigate the effects of blasting on ground water wells (Froedge, 1983). These studies have concluded that:
1. When blast induced ground vibrations are less than about 25 mm/s maximum resultant particle velocity, the response of the well is limited to a slight temporary variation in water level on the order of 3 to 6 cm either up or down. The specific capacity of the water well is unchanged based on drawdown tests.

2. Vibration measurements made at the surface and at the bottom of the observation wells indicate the vibration levels are always lower at the bottom of the well.

3. All of the data collected indicates that a ground vibration limit of 50 mm/s peak particle velocity is adequate to protect the wells from any significant damage. There is a possibility that temporary turbidity may be caused at lower levels periodically, although not at any constant threshold level.

The research consistently indicates that blast vibrations below 25 mm/s should have no adverse effects on nearby wells. As the maximum provincial guideline vibration limitation at the nearest residence is only half of this value, at 12.5 mm/s, the ground vibrations produced from the quarry’s blasting operations within the proposed extension area would have no effect on the integrity of neighbouring water wells.

6.4 Effects on Canadian Fisheries Waters

The Phase 4 extension lands are located within the CVC’s Black Creek subwatershed. There are no on-site watercourses within Phase 4. The main branch of Black Creek is within 400 m (at its closest point) of Phase 4, draining in a southeasterly direction. These reaches (and downstream) of Black Creek support coldwater habitat, and according to data compiled in CVC’s database, a resident population of brook trout (*Salvelinus fontinalis*).

A brook trout spawning survey conducted by Stantec in November, 2007 identified suitable spawning habitat within the main branch of Black Creek, but no spawning trout or redds were observed. However, in October 2006, one although unconfirmed but likely redd was documented along the reach of Black Creek just downstream of the discharge channel (Dillon Consulting for Halton Region, Technical Brief, March 2007). The spawning survey study was conducted as part of the Acton WWTP assimilation capacity study. A more detailed discussion on the natural environment can be found in the report prepared by Stantec Consulting Ltd, entitled “Acton Quarry Extension Level II Natural Environment Technical Report” dated 2008.

Phase 5, 6 and 7 extension lands are located within CH’s 16 Mile Creek subwatershed. The on-site and downstream drainage features are small headwater tributaries draining southerly toward 16 Mile creek. These features support only ephemeral or intermittent flow, predominantly poorly defined channels and limited connectivity. The only fish use in the vicinity of the extension lands is associated with a few small dug ponds, which support resident communities of tolerant warm water baitfish. Although localized seasonal use of the stream reaches up and/or downstream of some of the ponds by common warmwater bait/forage species does occur, this use is entirely dependent on the on-stream ponds, and direct stream productivity is negligible.)
Based on the ground vibration attenuation rates discussed previously in Section 5, peak ground vibration levels would be expected to fall below the DFO guideline limit of 13 mm/s beyond a distance of about 300 to 400 m from the blasting operations. The closest Black Creek approaches the proposed extension is approximately 400 m northeast of Phase 4. Therefore, regardless if spawning activity occurs along these reaches of Black Creek, maintaining compliance with the DFO guidelines when blasting within Phase 4 can easily be achieved by a consequence of its distance from the blasting.
7.0 CONCLUSIONS

Based on the foregoing considerations, it is our opinion that blasting operations may be readily performed within the limits of the proposed extension of the Dufferin Acton quarry in compliance with the current quarry blasting guidelines published by the Ministry of Environment and Department of Fisheries and Oceans. All blasting and blast monitoring would occur in accordance with the Aggregate Resources Act prescribed conditions in order to ensure compliance with the provincial guidelines, and as such the proposed operation will not result in unacceptable impacts on surrounding receptors.

GOLDER ASSOCIATES LTD.

Andrew Curic, P.Eng.
Senior Engineer

MVVB/AC/co/cg/co

Golder Associates
REFERENCES


Wright, D. G., Hopky, G. E., Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters, Canadian Technical Report of Fisheries and Aquatic Sciences 2107, Fisheries and Oceans Canada, 1998.
TABLES
<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>ACTON QUARRY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bench (face) height (m)</td>
<td>Maximum 25</td>
</tr>
<tr>
<td>Drill hole pattern (m)</td>
<td>3.6 – 4.0 m x 4.7 m</td>
</tr>
<tr>
<td>Drill hole diameter (mm)</td>
<td>114 and 127</td>
</tr>
<tr>
<td>Sub-drill depth (m)</td>
<td>1.5</td>
</tr>
<tr>
<td>Collar length (m)</td>
<td>2.4</td>
</tr>
<tr>
<td>Holes per blast</td>
<td>25 – 80</td>
</tr>
<tr>
<td>Explosive product(s) used</td>
<td>Bulk emulsion</td>
</tr>
<tr>
<td>Initiation system</td>
<td>Non-electric</td>
</tr>
<tr>
<td>Delay timing (ms)</td>
<td>25 between holes</td>
</tr>
<tr>
<td></td>
<td>184 between rows (non-electric)</td>
</tr>
<tr>
<td>Maximum explosive weight per delay period (kg)</td>
<td>90 – 195</td>
</tr>
</tbody>
</table>

**Note:** See Figure 3 for a description of blasting terms.
## TABLE 2

**Suggested Maximum Explosive Loads per Delay Period***

| Distance (m) | PPV = 12.5 mm/s**  
|             | SD = 33.1 kg/m^0.5 | INL = 128 dBL**  
|             | SD = 92 kg/m^0.33  |
|-------------|---------------------|---------------------|
| 150         | 21                  | 4                   |
| 200         | 37                  | 10                  |
| 250         | 57                  | 20                  |
| 300         | 82                  | 34                  |
| 400         | 146                 | 81                  |
| 500         | 229                 | 158                 |
| 750         | 514                 | 534                 |

See Section 5 in accompanying report.

** MOE recommended guideline limits when blasting is routinely monitored.
TABLE 3
Strain Levels Induced by Household Activities, Environmental Changes and Blasting

<table>
<thead>
<tr>
<th>Loading Phenomena</th>
<th>Sitea</th>
<th>Microstrain Induced by Phenomena (µin.in.)</th>
<th>Corresponding Blast Vibration Levelb (mm/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily environmental changes</td>
<td>K₁</td>
<td>149</td>
<td>30.0</td>
</tr>
<tr>
<td></td>
<td>K₂</td>
<td>385</td>
<td>76.0</td>
</tr>
<tr>
<td>Household activities:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Walking</td>
<td>S₂</td>
<td>9.1</td>
<td>0.8</td>
</tr>
<tr>
<td>2. Heel drops</td>
<td>S₂</td>
<td>16.0</td>
<td>0.8</td>
</tr>
<tr>
<td>3. Jumping</td>
<td>S₂</td>
<td>37.3</td>
<td>7.1</td>
</tr>
<tr>
<td>4. Door slams</td>
<td>S₁</td>
<td>48.8</td>
<td>12.7</td>
</tr>
<tr>
<td>5. Pounding nails</td>
<td>S₁₂</td>
<td>88.7</td>
<td>22.4</td>
</tr>
</tbody>
</table>

*a K₁ and K₂ were placed across a taped joint between two sheets of gypsum wallboard.

** Blast equivalent based on envelope line of strain vs ground vibration.

Source: Dowding (1985)
FIGURES
REFERENCES:

1. DIGITAL FILE PROVIDED BY MHBC REGIONAL URBAN PLANNING & RESOURCE DEVELOPMENT, FILENAME: PHASING PLAN - Aug 8 2008.DWG.

Legend:
- Proposed Licence Area
- Proposed Extraction Area
- Proposed Setback Area
- Existing Acton Quarry Licence (225.0 ha (565.0 ac))
- Processing Area Outside of Licence
- Internal Access Road (Approximate Location)
- At Grade Crossing
- Highway Truck Entrance / Exit
- General Direction of Extraction
- Buffer Lands (No Extraction / Conservation Uses)

SCALE: 1:20000

METRES

400 0 400 800

SCALE AS SHOWN

DATE: NOV. 2008

DESIGN: MVB

CAD: JFC

CHECK: MVB

REVIEW: MVB

Golder Associates
Mississauga, Ontario, Canada

FILE No.: 06117032AE002.dwg

PROJECT No.: 06-1117-032

REV.: A

PHASING PLAN

DUFFERIN ACTON QUARRY EXTENSION

FIGURE 2
### DESCRIPTION OF BLASTING TERMS

**Table: Numbers Show Short Period Delay**

<table>
<thead>
<tr>
<th>Period</th>
<th>Delay (Milliseconds)</th>
</tr>
</thead>
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</tr>
<tr>
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<td>4</td>
<td>100</td>
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<tr>
<td>5</td>
<td>125</td>
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</tbody>
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**Plan of Drill Hole Pattern**

- **Collar-Crushed Stone Stemming**
- **Hole Depth**
- **Explosive Charge Length**
- **Bench Face**
- **Top Explosive Deck**
- **Deck Separation with Crushed Stone**
- **Bottom Explosive Deck**
- **Subgrade**

**Sections**

- **Full Column Explosive Load**
- **Decked Explosive Load**

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**As Shown**

- **Nov. 2008**

**Title**

**DESIGN OF BLASTING TERMS**

**DUFFERIN ACTON QUARRY EXTENSION**

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**File No.** 06111703AE003.dwg

**Project No.** 06-1117-032

**Rev.** B

**Check** MVB

**Review** MVB

**Design** MVB

**Cad** JFC

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**Scale** AS SHOWN
95% Line Equation: \( V = 4580 \times (SD)^{-1.69} \)
95% Line Equation: \( V = 260 \times (SD)^{-0.157} \)
APPENDIX A
PUBLICATION NPC 119
Publication NPC-119

Blasting

1. Scope

This Publication refers to limits on sound (concussion) and vibration due to blasting operations.

2. Technical Definitions

The technical terms used in this Publication are defined in Publication NPC-101 – Technical Definitions.

3. Measurement Procedures

All measurements of peak pressure level and vibration velocity shall be made in accordance with the “Procedure for Measurement of Sound and Vibration due to Blasting Operations” set out in Publication NPC-103 – Procedures, section 5.

4. Concussion – Cautionary Limit

Subject to section 5 the peak pressure level limit for concussion resulting from blasting operations in a mine or quarry is 120 dB.

5. Concussion – Peak Pressure Level Limit

If the person in charge of a blasting operation carries out routine monitoring of the peak pressure level, the peak pressure level limit for concussion resulting from blasting operations in a mine or quarry is 128 dB.

6. Vibration – Cautionary Limit

Subject to section 7, the peak particle velocity limit for vibration resulting from blasting operations in a mine or quarry is 1.00 cm/s.

7. Vibration – Peak Particle Velocity Limit

If the person in charge of a blasting operation carries out routine monitoring of the vibration the peak particle velocity limit for vibration resulting from blasting operations in a mine or quarry is 1.25 cm/s.
Marcus V. van Bers

Education
B.Sc. (Hons.), Geological Engineering, Queen's University, Ontario, Canada, 1984.

Affiliations
Registered Professional Engineer, Ontario
Member, Canadian Institute of Mining and Metallurgy
Member, International Society of Explosives Engineers

Experience
1991 to Date
Golder Associates Ltd.
Mississauga, Canada

Associate

Supervision and technical involvement in all aspects of blasting control, including design, blast optimization, feasibility studies, preparation of specifications, design and implementation of monitoring programs, and assessing the environmental impact of blasting operations on adjacent facilities, including:

- Assess the viability and potential impact of blasting for the Millennium Pipeline Project on Consolidated Edison high voltage transmission facilities in New York State.

- Assess blasting procedures, existing monitoring program and quarry operations for a large aggregate operation in New Jersey. Provide recommendations to mitigate ground and air vibration effects within the neighbouring residential community.

- Preparation of blasting impact assessments on adjacent structures, services and slopes for the excavation of a 25m rock cut adjacent to Tuen Mun Highway and the extension of the Yau Tong Subway Station in Hong Kong. This included preparation of detailed blasting operations and design, excavation methodology, and recommendations for a monitoring program.

- Review and amend blasting specifications and provide initial on-site assistance for the excavation of 820,000 cu.m of bedrock for two 700 Mw nuclear power plants in Haiyan, China. This included evaluating seismic monitoring procedures, collection and evaluation of structural bedrock data and establishing blast control procedures to ensure the integrity of the bedrock foundation and walls were maintained, and to control water inflows as the excavation proceeded 13m below sea level.

- Established safe blasting criteria and procedures for the excavation of 20,000 cu.m. of bedrock within 5m of the Parliament Buildings, Canada’s most historically sensitive structures. Prepared blasting specifications and established a comprehensive monitoring program, including specifying vibration limitations for the control of all blasting operations during the excavation phase of the project.

- Preparation of blast impact assessments, including design review, for new quarry license applications, quarry expansions, and quarry production increases for numerous operations throughout southern Ontario.

- Assessment of proposed marine blasting operations adjacent to an existing berth at Fremantle Harbour, Australia. This included an appraisal of ground vibration, air blast and underwater overpressure levels at adjacent structures, establishing blasting protocol and monitoring procedures, and reviewing blast specifications.
- Evaluate and provide recommendations on the blast pattern, initiation sequence and methodology for removal of a tailrace tunnel rock plug below the Nagagami River. Assessed impact of blast on the adjacent powerhouse with regard to ground vibrations, and air concussion or water borne overpressures within the tunnel.

- Blast impact and feasibility assessment to excavate a 2.4 m diameter tunnel below a major residential roadway and various services. Included design of the tunnel round and monitoring of ground vibration and air-blast effects.

- Inspection of existing emulsion explosive manufacturing plants at two coal mining operations in British Columbia to assess explosive risk on plant facilities.

- Blast demolition feasibility study for the submerged portion of a bridge substructure crossing the Ottawa River, including blast impact evaluation on new adjacent bridge structure and fish habitat, and preparation of the blasting specifications.

- Blast impact assessment at neighbouring industrial complex as a result of quarry blasting operations in St. Vincent and the Grenadines.

- Establishment of blast design criteria, consultation and monitoring of ground vibration and underwater overpressure levels during the excavation of 45,000 m³ of rock in the Vancouver Harbour. This included design of final excavation walls within 5 m of the jetty support piles.

- Preparation of Non-Standard Special Provision for blasting in and around Canadian Fisheries waters for the Ontario Ministry of Transportation, Thunder Bay District.

- Evaluation of all blasting operations adjacent to Union Gas high pressure gas facilities throughout Southern Ontario.

- Blast design, consultation and monitoring for shaft and tunnel excavations adjacent to Bronte Creek in a residential area of Oakville, Ontario.

- Evaluation of blasting procedures and blast monitoring for a tunnel excavation beneath a major highway and residential subdivision in Brampton, Ontario.

- Blast vibration and impact noise evaluation for various new quarry applications and expansions in Southern Ontario.

- Evaluation of blasting procedures and recommending means to improve blasting efficiency, and reduce ground vibration and air-blast effects at adjacent residential properties, Global Stone (Ingersoll) Quarry, Ontario.

- Blast vibration and impact noise level monitoring for various demolition projects within Canada and the United States.

- Review of blasting procedures, blast monitoring and control during installation of a new 1.07 m diameter gas pipeline adjacent to existing gas lines for TransCanada PipeLines in Manitoba and Ontario.

- Vibration and noise monitoring, and consultation during installation of a geomembrane within a residential neighbourhood in Mississauga, Ontario.

- Instructor in Blasting Control, Technique and Safety, Ontario Ministry of Environment and Energy inspectors course.
Marcus V. van Bers

- Review blast designs for various construction projects, including:
  - highway rockcut in Newfoundland,
  - excavation of bridge footings for a transit terminal in Ottawa,
  - removal of a major rockfall within a tailrace tunnel,
  - ditch and right-of-way rock adjacent to high pressure gas lines throughout Ontario,
  - shaft excavations for collector sewers in Ottawa,
  - service trenches and building foundations adjacent to historic, residential, commercial and industrial structures.
- Blast vibration and noise consultation for numerous quarry operations across Southern Ontario.

Golder Associates Ltd.  
Geological Engineer  
Toronto, Canada

1987-1991

Technical involvement in rock mechanics for numerous civil and mining engineering projects, including:
- Mine/Stope stability analysis using empirical and numerical methods for a proposed open stope mine geometry at a new mine property in North-western Quebec.
- Preparation of preliminary specifications and construction drawings for a large open cut excavation adjacent to, and beneath, the Parliament Buildings in Ottawa, Ontario. This included a geological assessment and stability analysis of the slopes around the rock promontory, development of excavation sequencing and support design, and outlining the blasting restraints and excavation limits on the existing structures and services.
- Optimizing recommendations, including blast vibration limits, excavation methodology and sequencing, and final excavation support procedures, for a proposed transitway rock cut in Ottawa, Ontario.
- Preparation of contract specifications and construction drawings for a pipeline tunnel through a rock bluff in Hope, British Columbia, including geological mapping, analysis and support design.
- Site engineer for P.E.B. Replacement Project in Niagara Falls, Ontario; involved with site investigation; support design; quality control of blasting, support installation, instrumentation and data collection; and preparation of as-built reports and drawings for the bench excavation, underground elevator shaft and tunnel.
- Technical supervision of foundation bedrock grouting programme for an earthfill tailings dam at the Holt McDermott Mine, Kirkland Lake, Ontario, including detailed bedrock foundation mapping and grouting, foundation preparation, quality control and materials testing, and preparation of as-built reports and drawings.
- Other projects have included: feasibility studies and capital cost estimates for two aggregate quarries in Newfoundland; feasibility study for increasing the existing mining limits for a brick shale quarry in Southern Ontario; involved with geotechnical aspects of planning for underground mining development and with rock cut stabilization.

Western Deep Levels South  
Rock Mechanics Engineer  
South Africa

1986-1987

1987-1991
Marcus V. van Bers

In addition to those activities described below, also involved with ground investigation, insitu stress measurements, design of alternate stope support for thin tabular deposits, and investigating mining sequence and instrumentation for shaft/reef pillar extraction.

1984-1986  
**Doornfontein Gold Mining Co. Ltd.**  
*South Africa*  
*Rock Mechanics Engineer*

Responsibilities included advising and recommending optimal mining strategies for long and short term mine planning, design of major excavations and their support at great depths, stope and haulage support design, stress analysis by computer simulation and instruction/training of mining and supervisory personnel in basic rock mechanics principles.

1984  
**Giant Yellowknife Mines Ltd.**  
*Yellowknife, Canada*  
*Exploration Geologist*

Involved with siting of surface and underground exploratory drills, supervision of drilling crews, logging and geotechnical evaluation of core, surface and underground mapping and detailing geological sections and plans.
Publications

Bench Excavation, Shaft and Tunnel Construction for the Maid of the Mist Facility, Niagara Falls, Ontario (with C.M.K. Yuen, J.M. Harris), Tunnelling in the 90’s, TAC, Eighth Annual General Meeting, 1990.


How Do Your Quarry Blasts Rate (with A.L. McAnuff, A. Cameron), Canadian Aggregates & Roadbuilding Contractor, May, 1994.


