EXPLOTECH

Specialists in Explosives, Blasting and Vibration
Consulting Engineers

# Blast Impact Analysis
# Reid Road Reservoir Quarry
# Part of Lot 7, Concession 2
# Town of Milton
# Regional Municipality of Halton



Submitted to:

James Dick Construction Ltd.
14442 Regional Road 50
Bolton, ON
L7E 5T4

Prepared by

Explotech Engineering Ltd.
58 Antares Drive, Unit 5
Ottawa, Ontario
K2E 7W6

December 3, 2019

## EXECUTIVE SUMMARY

Explotech Engineering Ltd. was retained in January 2017 to provide a Blast Impact Analysis for the proposed Reid Road Reservoir Quarry located on Part of Lot 7, Concession 2 (former Geographic Township of Nassagaweya), Town of Milton, Regional Municipality of Halton.

Vibration levels assessed in this report are based on the Ministry of the Environment, Conservation, and Parks Model Municipal Noise Control By-law (NPC119) with regard to Guidelines for Blasting in Mines and Quarries. We have assessed the area surrounding the proposed Aggregate Resources Act licence with regard to potential damage from blasting operations and compliance with the aforementioned by-law document.

We have inspected the property and reviewed the available site plans. Explotech is of the opinion that the planned aggregate extraction on the proposed property can be carried out safely and within MECP guidelines as set out in NPC 119 of the By-Law.

Recommendations are included in this report to advocate for blasting operations which are carried out in a safe and productive manner and to suitably manage and mitigate the possibility of damage to any buildings, structures or residences surrounding the property.

***TABLE OF CONTENTS***

## INTRODUCTION

James Dick Construction Ltd. has applied for a Class A, Category 2 Licence and Category 1 Licence for the property legally described as Part of Lot 7, Concession 2 (former Geographic Township of Nassagaweya), Town of Milton, Regional Municipality of Halton. The proposed name for the operation is the Reid Road Reservoir Quarry. This Blast Impact Analysis assesses the ability of the proposed licence to operate within the prescribed blast guideline limits as required by the Ontario Ministry of the Environment, Conservation, and Parks (MECP).

While not specifically required as part of the scope of the Blast Impact Analysis under the Aggregate Resources Act, this report also covers the topics of flyrock and residential water wells for general informational purposes only. Exhaustive details related to residential water wells are addressed in the hydrogeological report prepared by Harden Environmental Services Ltd. while specific flyrock control is addressed at the operational level given significant influences related to blast design, geology, and field accuracy. Additionally, potential impacts on the nearby waterbodies is discussed to confirm compliance with applicable guidelines as well as potential impacts and recommended controls on the Guelph Junction Railway.

The land surrounding the proposed Reid Road Reservoir Quarry is a mixture of rural, industrial, wetland, and woodlot land use areas. The site is currently zoned as an extractive industrial zone.The proposed Reid Road Reservoir Quarry operation is bound by wetland, woodlots and properties fronting onto First Line Nassagaweya to the Southwest, Highway 401, wetlands, and woodlots to the Northwest, properties fronting onto Twiss Road to the Northeast and commercial properties and woodlots fronting onto Campbellville Road to the Southeast. The property is accessed via an existing haulage road off of Twiss Road.

This Blast Impact Analysis has been prepared based on the Ministry of the Environment, Conservation, and Parks (MECP) Model Municipal Noise Control By-law with regard to Guidelines for Blasting in Mines and Quarries (NPC 119). We have additionally assessed the area surrounding the proposed licence with regard to potential damage from blasting operations.

While excavation operations have taken place on site in the past, blasting operations have not been undertaken and as such, site-specific blast monitoring data is not available. We have therefore applied data generated across a spectrum of quarries and construction projects which provides a conservative approximation of anticipated vibration levels from the operation. It has been our experience that this data represents a conservative starting point for blasting operations. It is a recommendation of this report that a vibration monitoring program be initiated on-site upon the commencement of blasting operations and maintained for the duration of all blasting activities to permit timely adjustment to blast parameters as required. Ultimately, the quarry will be required to operate to the MECP guideline limits for ground vibration and overpressure based on actual measurements taken during blast times.

Recommendations are included in this report to advocate for blasting operations which are carried out in a safe and productive manner and to suitably manage and mitigate the possibility of damage to any buildings, structures or residences surrounding the property.

## EXISTING CONDITIONS

The licence area for the proposed James Dick Construction Ltd. Reid Road Reservoir Quarry encompasses a total area of approximately 29.4HA and an extraction area of approximately 25.7HA when allowing for setbacks and sterilized areas. The site is broken into five (5) distinct extraction phases (Refer to Appendix A Operational Plan). The Phase 1 extraction area of the licence area involves excavation of the South quadrant of the proposed licence. The Phase 2 area of the licence area involves excavation of the West quadrant of the proposed licence. The Phase 3 area lies at the North quadrant of the proposed licence area. The Phase 4 area of the licence is split in two sections involving excavation of a central portion directly South of the rail line and a central portion located South of Phase 2. The Phase 5 area of the licence involves excavation of the central portion located directly North of the rail line. All phases of the licence involve excavation to a proposed maximum extraction depth of 262masl.

The topography of the proposed licence area is generally lowest in the Northwest portion of the site at an elevation in the order of 284masl underwater rising towards the Southwest with the highest elevations (297masl) lying in the Southern portion of the proposed Phase 3 area. The groundwater table elevation is at approximately 291masl.

The lands surrounding the proposed licence area are largely characterized by woodlots, industrial commercial operations and rural residential properties with the closest sensitive receptors lying to the Northeast of the limits of extraction along Twiss Road, to the West and Southwest along First Line Nassagaweya, and to the North along Mohawk Trail. The closest separation distance between sensitive receptor and blast location over the life of the operations is listed in Table 1 below.

**Table 1: Closest Sensitive Receptors within 500m**

| Receptor Label | Address | Closest Straight Line Distance to Receptor (m) | Direction from Quarry |
|---|---|---|---|
| R1 | 9096 First Line Nassagaweya | 420 | South |
| R2 | 9108 First Line Nassagaweya | 370 | South |
| R3 | 9114 First Line Nassagaweya | 330 | South |
| R4 | 9130 First Line Nassagaweya | 300 | South |
| R5 | 9228 First Line Nassagaweya | 170 | South |
| R6 | 9240 First Line Nassagaweya | 210 | South |
| R7 | 9256 First Line Nassagaweya | 235 | Southwest |

| Table 1: Closest Sensitive Receptors within 500m | | | |
|---|---|---|---|
| **Receptor Label** | **Address** | **Closest Straight Line Distance to Receptor (m)** | **Direction from Quarry** |
| R8 | 9280 First Line Nassagaweya | 440 | Southwest |
| R9 | 9283 First Line Nassagaweya | 160 | Southwest |
| R10 | 9300 First Line Nassagaweya | 220 | Southwest |
| R11 | 9414 First Line Nassagaweya | 440 | West |
| R12 | 9416 First Line Nassagaweya | 420 | West |
| R13 | 9455 First Line Nassagaweya | 410 | West |
| R14 | 9457 First Line Nassagaweya | 390 | West |
| R15 | 2250 Mohawk Trail | 460 | Northwest |
| R16 | 2270 Mohawk Trail | 450 | Northwest |
| R17 | 2290 Mohawk Trail | 410 | Northwest |
| R18 | 2310 Mohawk Trail | 360 | Northwest |
| R19 | 2315 Mohawk Trail | 460 | Northwest |
| R20 | 2330 Mohawk Trail | 300 | Northwest |
| R21 | 2345 Mohawk Trail | 460 | Northwest |
| R22 | 2350 Mohawk Trail | 310 | Northwest |
| R23 | 2380 Mohawk Trail | 370 | West |
| R24 | 2388 Mohawk Trail | 360 | West |
| R25 | 2400 Mohawk Trail | 470 | West |
| R26 | 9301 Second Line Nassagaweya | 300 | North |
| R27 | 9150 Twiss Road | 450 | East |
| R28 | 9256 Twiss Road | 170 | North |
| R29 | 9261 Twiss Road | 300 | North |

## PROPOSED AGGREGATE EXTRACTION

The proposed initial quarry operations will commence with a sinking cut at the North limit of the Phase 1 extraction area. The sinking cut is denoted in Appendix A as Phase 1A. Initial blasting will be located approximately 310m from the closest sensitive receptor behind the blast, namely 9228 First Line Nassagaweya, and approximately 950m from the closest sensitive receptor in front of the blast, 2388 Mohawk Trail. Extraction will retreat from the sinking cut in a general Southern direction to a proposed maximum extraction depth of 262masl.

Extraction in Phase 2 will commence with a sinking cut at the Northeast limit of the Phase 2 extraction area. This sinking cut will be used to blast a slot along the Northern limit of the Phase 2 extraction area denoted in Appendix A as Phase 2A. Phase 2B will then retreat in a Southwest direction to a proposed maximum extraction depth of 262masl.

Extraction in Phase 3 will commence with a sinking cut at the Southwest limit of the Phase 3 extraction area. The sinking cut will be used to blast a slot along the Southern limit of the Phase 3 extraction area denoted in Appendix A as Phase 3A. Phase 3B will then retreat to the Northeast to reduce air overpressure at the closest sensitive receptors for Phase 3. Phase 3 extraction will take place to a proposed maximum extraction depth of 262masl.

Extraction in Phase 4 will leverage the existing Phase 2 boundary face. Blasting shall commence at the Phase 2 / Phase 4 interface thereby eliminating the need for a sinking cut. Extraction will retreat in a general Eastern and Southwest direction to a proposed maximum extraction depth of 262masl.

Extraction in Phase 5 will leverage the existing Phase 3 Southwest boundary face. Blasting shall commence at the Phase 3 / Phase 5 interface thereby eliminating the need for a sinking cut. Extraction will retreat in a general West direction to a proposed maximum extraction depth of 262masl.

The quarry will not be dewatered and as such, the majority of rock will be blasted underwater. Given existing average top of bedrock elevations in the range of 283 – 297masl, and the groundwater table elevation of 291masl, at most only the top 6m of rock to be blasted will be exposed. This condition will affect overpressure and vibration levels as described later in this report.

As quarry operations migrate across the property, the closest sensitive receptors to the required blasting operations will vary with the governing structures and approximate closest separation distances being as follows:

Northeast corner: 9256 Twiss Road – R28 – 170m
Eastern corner: 9150 Twiss Road – R27 – 450m
Southeast corner: 9228 First Line Nassagaweya – R5 – 170m
South central corner: 9283 First Line Nassagaweya – R9 – 160m
West central corner: 2388 Mohawk Trail – R24 – 360m
Northwest corner: 2350 Mohawk Trail – R22 – 310m

The above distances incorporate maintenance of a minimum 15m extraction setback to adjacent property boundaries and 30m setback to adjacent roadways as well as allowance for sterilized areas to account for the intermittent stream, pond and sensitive receptor offsets.

The closest separation distance between a sensitive receptor and any blast over the life of the quarry is 160m. Blasting at this separation distance can be achieved through the decking of the bench as the blasting approaches the sensitive receptor. The on-site monitoring program will govern the number of decks implemented as the blasting approaches the sensitive receptors. Market economics may dictate that rock extraction be terminated prior to reaching the licence extraction limits.

As noted above, the closest sensitive receptor for the initial blasting operations behind the blast is located approximately 310m from the blast (9228 First Line Nassagaweya – R5). Our calculations using the equations listed in the section *Ground Vibration Levels at the Nearest Sensitive Receptor* suggests that a maximum explosive load of approximately 64kg per period can be employed at a distance of 310m to remain compliant with MECP guidelines for ground vibrations. The closest sensitive receptor in front of the blast is located some 950m removed (2388 Mohawk Trail – R24), a distance which our calculations using the equation listed in the section *Overpressure Levels at the Nearest Sensitive Receptor* suggests that a maximum explosive load of 500kg per period can be employed to remain compliant with MECP guidelines for overpressure. We note that overpressures will be dramatically reduced as a result of the water remaining in the quarry during blasting.

Quarries in Ontario normally employ 76 to 152mm diameter blast holes which, for a maximum 32m bench, would employ 180kg to 720kg of explosive load per hole. Given the configuration of the proposed quarry relative to the surrounding receptors and the plan not to dewater, decking of blast holes will be necessary. With decking being required underwater, an enhanced level of diligence will be required in all stages of the drill blast process. The utilization of decks will ensure the maximum load per period is reduced to a level at which the blast will remain compliant with MECP guidelines as blasting operations migrate across the quarry. The distance to the closest sensitive receptor will determine the number of decks required per hole.

At the time of preparation of this report, the intent is to use top hammer drills to drill all blast holes on site. Drill deviation is a concern given that blast hole depths will reach a maximum 35m bench, however, we can cite numerous examples where blast holes were successfully drilled to these depths with minimal drill deviation using top hammers. Should drill deviation prove to be an issue, there are several options available to efficiently eliminate the concern. These include the implementation of down-the-hole (DTH) hammer drills which have been proven to significantly mitigate drill deviation and are currently available to diameters below 76mm allowing for an abundance of blast design modifications to meet MECP guidelines and operational constraints. Additionally, the option exists to drill larger diameter holes and sleeve the hole to a smaller diameter using rigid water resistant blast hole casing if reduction in explosive loads per delay is necessary. Sleeves would also be utilized in the event of voids in the rock mass in order to prevent bulk explosive product migration.

Given that the quarry will not be dewatered, varying blasting techniques will be utilized due to the complexity associated with underwater quarry blasting. Drilling and loading holes will be more demanding than a dry quarry, although this work will not prove to be unfamiliar for a competent blaster.

Special consideration must be made to ensure suitable explosive products are employed. It is the intent to use both bulk emulsion and cartridge explosive products. Explosive products must be resistant to deadpress and sympathetic detonation as well as display excellent sleep times in case of delays between loading and detonation. Fortunately, the appearance of wet holes at quarries in Ontario is extremely common such that blasters are familiar with best practices required to address the condition and a variety of explosive products are readily available which are formulated for these conditions. Additionally, detonators employed shall be restricted exclusively to electronic detonators or similar type products that may be developed in the future which can conclusively assess product performance post-blast to ensure that all holes are detonated as designed. In a properly designed and executed blast, all explosive products are consumed in the process with over 97% of the byproducts being $N_2$ (nitrogen), $H_2O$ (water), and $CO_2$ (carbon dioxide).

While the foregoing product selection will immensely mitigate the risks associated with remnant explosive dissolution into the water, such a possibility cannot be completely eliminated and is addressed in the Hydrogeological Report prepared by Harden Environmental Services Ltd.

## BLAST VIBRATION AND OVERPRESSURE LIMITS

The Ontario MECP guidelines for blasting in quarries are among the most stringent in North America.

Studies by the U.S. Bureau of Mines have shown that normal temperature and humidity changes can cause more damage to residences than blast vibrations and overpressure in the range permitted by the MECP. The limits suggested by the MECP are as follows.

| | | |
|---|---|---|
| ***Vibration*** | 12.5mm/sec | Peak Particle Velocity (PPV) |
| ***Overpressure*** | 128 dB | Peak Sound Pressure Level (PSPL) |

The above guidelines apply when blasts are being monitored. Cautionary levels are slightly lower and apply when blasts are not monitored on a routine basis. It is a recommendation of this report that all blasts at the operation be monitored to quantify and record ground vibration and overpressure levels employing a minimum of two (2) digital seismographs, one installed at the closest sensitive receptor in front of the blast, or closer, and one installed at the closest sensitive receptor behind the blast, or closer.

## BLAST MECHANICS AND DERIVATIVES

The detonation of explosives within a borehole results in the development of very high gas and shock pressures. This energy is transmitted to the surrounding rock mass, crushing the rock immediately surrounding the borehole (approximately 1 borehole radius) and permanently distorts the rock to several borehole diameters (5-25, depending on the rock type, prevalence of joint sets, etc).

The intensity of this stress wave decays quickly so that there is no further permanent deformation of the rock mass. The remaining energy from the detonation travels through the unbroken material in the form of a pressure wave or shock front which, although it causes no plastic deformation of the rock mass, is transmitted in the form of vibrations.

Particle velocity is the descriptor of choice when dealing with vibrations because of its superior correlation with the appearance of cosmetic cracking. As such, for the purposes this report, ground vibration units have been listed in mm/s.

In addition to the ground vibrations, overpressure, or air vibrations are generated through the direct action of the explosive venting through cracks in the rock or through the indirect action of the rock movement. In either case, the result is a pressure wave which travels though the air, measured in decibels (or dB) for the purposes of this report.

## VIBRATION AND OVERPRESSURE THEORY

Transmission and decay of vibrations and overpressure can be estimated by the development of attenuation relations. These relations utilize empirical data relating measured velocities at specific separation distances from the vibration source to predict particle velocities at variable distances from the source. While the resultant prediction equations are reliable, divergence of data occurs as a result of a wide variety of variables, most notably site-specific geological conditions and blast geometry and design for ground vibrations and local prevailing climatic conditions for overpressure.

In order to circumvent this scatter and improve confidence in forecast vibration levels, probabilistic and statistical modeling is employed to increase conservatism built into prediction models, usually by the application of 95% confidence lines to attenuation data.

The attenuation relations are not designed to conclusively predict vibrations levels at a specific location as a result of a specific blast design, application of this probabilistic model creates confidence that for any given scaled distance, 95% of the resultant velocities will fall below the calculated 95% regression line.

While the data still provides insight into probable vibration intensities, attenuation relations for overpressure tends to be less reliable and precise than results for ground vibrations. This is due primarily to wider variations in variables outside of the influence of the blast design which impact propagation of the vibrations. Atmospheric factors such as temperature gradients and prevailing winds (refer to Appendix B) as well as local topography can all serve to significantly alter overpressure attenuation characteristics.

Our experience and analysis demonstrates that blast overpressure is greatest when blasting toward receptors, and blast vibrations are greatest when retreating in the direction of the receptor.

## GROUND VIBRATION LEVELS AT THE NEAREST SENSITIVE RECEPTOR

The most commonly used formula for predicting PPV is known as Bureau of Mines (BOM) prediction formula or Propagation Law. We have used this formula to predict the PPV's at the closest house for the initial operations.

$$PPV = k\left(\frac{d}{\sqrt{w}}\right)^{e}$$

Where, PPV = the calculated peak particle velocity (in/s-imperial, mm/s-metric)

K, e = site factors

d = distance from receptor (ft-imperial, m-metric)

w = maximum explosive charge per delay (lbs-imperial, kg-metric)

The value of K is variable and is influenced by many factors (i.e. rock type, geology, thickness of overburden, etc.). As such, these site factors are developed empirically through the measurement of vibration characteristics at the specific operations of interest.

The portion of the BOM prediction formula contained within the parentheses is referred to as the Scaled Distance and represents another important PPV relation. It correlates the separation distance between a blast and receptor to the energy (usually expressed as explosive weight) released at any given instant in time. The two most popular approaches are square root scaling and cube root scaling:

$$(SDSR = \frac{R}{\sqrt{W}}) \qquad (SDCR = \frac{R}{\sqrt[3]{W}})$$

Where, SDSR = Scaled distance square root method
SDCR = Scaled distance cube root method
R = Separation distance between receptor site and blast (ft, m)
W = Maximum explosive load per delay period (lbs, kg)

Historically, square root scaling is employed in situations whereby the explosive load is distributed in a long column (i.e. blasthole) while cube root scaling is employed for point charges. In accordance with industry standard, square root scaling was adopted for ground vibration analysis for the purposes of this report.

For a distance of 310m (i.e. the standoff distance to the closest existing sensitive receptor behind the blast for the initial blasting) and a maximum explosives load per delay of 75kg (76mm diameter hole on a 2.74m x 2.74m pattern, 31m deep, 2 explosive decks with a column load of 13.7m per deck, 1.5m inert stemming between decks, 2.1m surface collar and 1 deck per delay), we can calculate the maximum PPV at the closest building using the following formulae:

*Imperial Equations:*

| | |
|---|---|
| Oriard 50% bound (2002) | $v = 160(\frac{D}{\sqrt{W}})^{-1.6}$ |
| Oriard 90% Bound (2002) | $v = 242(\frac{D}{\sqrt{W}})^{-1.6}$ |
| Quarry Production Blast (Bulletin 656 – 1971) | $v = 182(\frac{D}{\sqrt{W}})^{-1.82}$ |
| Typical limestone Quarry (Pader report – 1995) | $v = 52.2(\frac{D}{\sqrt{W}})^{-1.38}$ |
| Typical Coal Mine (RI8507 1980) | $v = 133(\frac{D}{\sqrt{W}})^{-1.5}$ |

*Metric Equations:*

| | |
|---|---|
| General Blasting (Dupont) | $v = 1140(\frac{D}{\sqrt{W}})^{-1.6}$ |
| Construction Blasting (Dowding 1998) | $v = 1326(\frac{D}{\sqrt{W}})^{-1.38}$ |
| Agg. Quarry Blasting (Explotech 2005) | $v = 5175(\frac{D}{\sqrt{W}})^{-1.76}$ |

Agg. Quarry blasting
(Explotech 2003)

$$v = 7025\left(\frac{D}{\sqrt{W}}\right)^{-1.85}$$

The equations described above accommodate for a range of geological conditions and blasting methodologies. The proposed parameters were applied to the formulae to estimate a range of the potential vibrations imparted on the closest sensitive receptor behind the blast. As discussed in previous sections, the MECP guideline for blast-induced vibration is 12.5mm/s (0.5 in/s). Appendix C demonstrates that the maximum calculated value for the vibration intensities imparted on the closest sensitive receptor based on all equations is 9.5mm/s for the initial blasting, below the MECP guideline limit. All ground vibration calculations and tables going forward will utilize the formula providing the worst case scenario for all geological conditions. All blasts will be monitored for overpressure and ground vibrations with blast designs adjusted in response to readings on site in order to ensure consistent compliance with established limits.

Given the separation distances to the various sensitive receptors adjacent the proposed Quarry, Table 2 below provides initial guidance on maximum loads per delay based on various separation distances until such time as a site specific equation is developed. The following maximum loads per delay were derived from the equation for ground vibrations listed above (Agg. Quarry Blasting – Explotech 2005) and are based on a maximum intensity of 12.5mm/s:

| **Table 2: Maximum Loads per Delay to Maintain 12.5mm/s at Various Separation Distances** | |
|---|---|
| **Separation distance between sensitive receptor and closest borehole (meters)** | **Maximum recommended explosive load per delay (Kilograms)** |
| 500 | 265 |
| 450 | 215 |
| 400 | 170 |
| 350 | 130 |
| 300 | 96 |
| 250 | 66 |
| 200 | 42 |
| 150 | 24 |
| 100 | 11 |

The quarry will not be dewatered with water surface elevations anticipated at approximately 291masl. While the presence of water will not affect the vibration attenuation behind the blast, it will result in a slower attenuation rate in front of the blast. However, given the direction of retreat and separation to the closest sensitive receptors, vibrations behind the blast will govern blast designs. Ultimately, the results of the monitoring program will guide the blasting operations from a ground vibration perspective.

The closest separation distance between a sensitive receptor and any blast over the life of the license is 160m. While blasting at this separation distance is feasible from a technological perspective, given current blasting technology and techniques, market economics will dictate the feasibility of extracting rock at lesser separation distances. Monitoring and changes in blasting designs will be required in order to confirm all blasts are within MECP guidelines when blasting comes closer to adjacent sensitive receptors.

## OVERPRESSURE LEVELS AT THE NEAREST SENSITIVE RECEPTOR

It is unusual for overpressure to reach damaging levels, and when it does, the evidence is immediate and obvious in the form of broken windows in the area. However, overpressure remains of interest due to its ability to travel further distances as well as cause audible sounds and excitation in windows and walls.

Air overpressure decays in a known manner in a uniform atmosphere, however, a uniform atmosphere is not a normal condition. As such, air overpressure attenuation is far more variable due to its intimate relationship with environmental influences. Air vibrations decay slower than ground vibrations with an average decay rate of 6dBL for every doubling of distance.

Air overpressure levels are analyzed using cube root scaling based on the following equation:

$$P = k\left(\frac{d}{\sqrt[3]{w}}\right)^{e}$$

Where, P = the peak overpressure level (psi - imperial, Pa, dB - metric)
K, e = site factors
d = distance from receptor (ft - imperial, m - metric)
w = maximum explosive charge per delay (lbs - imperial, kg - metric)

The value of K and e are variable and are influenced by many factors (i.e. rock type, geology, thickness of overburden, etc.). As such, these site factors are developed empirically through the measurement of overpressure characteristics at the specific operations of interest.

As discussed in previous sections, the MECP guideline for blast-induced overpressure is 128dBL. For a distance of 950m (i.e. the standoff distance to the closest existing structure in front of the blast for the initial blasting) and a maximum explosives load per delay of 75kg (76mm diameter hole on a 2.74m x 2.74m pattern, 31m deep, 2 explosive decks with a column load of 13.7m each, 1.5m stemming between decks, 2.1m surface collar and 1 deck per delay), we can calculate the overpressure at the nearest receptor in front of the blast using the following equations:

*Imperial Equations:*

USBM RI8485 (Behind Blast) $$P = 0.056\left(\frac{D}{\sqrt[3]{W}}\right)^{-0.515}$$

USBM RI8485 (Front of Blast) $$P = 1.317\left(\frac{D}{\sqrt[3]{W}}\right)^{-0.966}$$

USBM RI8485 (Full Confined) $$P = 0.061\left(\frac{D}{\sqrt[3]{W}}\right)^{-0.96}$$

Construction Average (Oriard 2005) $$P = 1\left(\frac{D}{\sqrt[3]{W}}\right)^{-1.1}$$

*Metric Equations:*

Ontario Quarry - dB (Explotech) $$P = 159\left(\frac{D}{\sqrt[3]{W}}\right)^{-0.0456}$$

Limestone - dB (Explotech) $$P = 206\left(\frac{D}{\sqrt[3]{W}}\right)^{-0.1}$$

Ontario Quarry - Pa (Explotech) $$P = 1222\left(\frac{D}{\sqrt[3]{W}}\right)^{-0.669}$$

Appendix C demonstrates that the maximum calculated value for the overpressure intensities imparted on the closest sensitive receptor based on all equations is 124.2dB(L) for the initial blasting, below the MECP guideline limit. All blasts will be monitored for overpressure and ground vibrations with blast designs adjusted in response to readings on site in order to ensure consistent compliance with established limits.

Based on this calculation and the assumed blast parameters, overpressures from blasting operations will remain compliant with the MECP NPC 119 guideline limit of 128dBL. The design method of retreat has been planned so as to direct overpressures generated as much as practicable in the direction of vacant lands. All overpressure calculations and tables going forward will utilize the formula providing the worst case scenario for all geological conditions.

We reiterate that air overpressure attenuation is far more variable due to its intimate relationship with environmental influences and as such, the equation employed is less reliable than that developed for ground vibration. Overpressure monitoring performed on site shall be used to guide blast design as it pertains to the control of blast overpressures. As demonstrated in Appendix B, prevailing winds during quarry operational periods are predominantly out of the West, a condition which will assist in attenuating overpressures at the receptors in front of the majority of the blasts.

Given that the quarry will not be dewatered and the majority of the explosive load will be placed below water, overpressures generated by gas venting at the face and direct movement of the rock will effectively be eliminated. The net effect will be a dramatic reduction in the actual overpressures to levels well below the above calculated levels. As such, compliance with MECP overpressure levels at the operation will be readily achieved.

Given the intimate correlation between overpressure and environmental conditions, care must be taken to avoid blasting on days when weather patterns are less favourable. Extraction directions have been selected so as to minimize overpressure impacts on adjacent receptors.

Table 3 below can be used as an initial guide showing maximum loads per delay based on various separation distances for receptors in front of the blast face. The following maximum loads per delay are derived from the air overpressure equation above (Ontario Quarry – dB – Explotech) and are based on a peak overpressure level of 128dB(L):

**Table 3: Maximum Loads per Delay to Maintain 128dB(L) at Various Separation Distances for Receptors in Front of the Face**

| Separation distance between sensitive receptor and closest blasthole (meters) | Maximum recommended explosive load per delay (Kilograms) |
|---|---|
| 500 | 77 |
| 450 | 56 |
| 400 | 39 |
| 350 | 26 |
| 300 | 16 |
| 250 | 9 |

We note that the above values are conservative and are intended as a guideline only as the air overpressure attenuation equation is based on a calculated 95% regression line. Actual loads employed shall be based on the results of the monitoring program in place.

## ADDITIONAL CONSIDERATIONS OUTSIDE OF THE BLAST IMPACT ANALYSIS SCOPE

The following headings are addressed for general information purposes and are not strictly required as part of the scope of the Blast Impact Analysis as required under the ARA to assess compliance with MECP NPC-119 guidelines. Considerations for aquatic species in the adjacent waterbodies are further addressed in the Natural Environment report prepared by GWS Ecological & Forestry Services Inc. The hydrogeological study prepared by Harden Environmental Services Ltd. as part of the license application addresses residential water wells in detail. Flyrock control is addressed at the operational level given significant influences related to blast design, geology and field accuracy which render concrete recommendations related to control inappropriate at the licencing phase.

## BLAST IMPACT ON ADJACENT FISH HABITATS

The detonation of explosives in or near water can produce compressive shock waves which initiate damage to the internal organs of fish in close proximity, ultimately resulting in the death of the organism. Additionally, ground vibrations imparted on active spawning beds have the ability to adversely impact the incubating eggs and spawning activity. In an effort to alleviate adverse impacts on fish populations as a result of blasting, the Department of Fisheries and Oceans (DFO) developed the Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters (1998). This publication establishes limits for water overpressure and ground vibrations which are intended to mitigate impacts on aquatic organisms while providing sufficient flexibility for blasting to proceed. Specifically, water overpressures are to be limited to 100kPa and, in the presence of active spawning beds, ground vibrations at the bed are to be limited to 13mm/s.

The Natural Environment study prepared for the application indicates that there are fish habitats in watercourses in the vicinity of the required blast locations. The two watercourses in which fish habitats are present are Kilbride Creek, located approximately 50m offset from the Southwest portion of Phase 4, and two ponds located along the access road that drain into a watercourse approximately 300m Southeast of Phase 3. Based on these separation distances, water overpressures generated by the blasting will reside below the DFO 100Kpa guideline limit and will have no impact on the adult fish populations present.

The fish species identified in the Natural Environment study and noted to occupy the adjacent watercourses could be utilizing any of the vegetation that proliferates through the system as spawning beds. The active spawning season for the fish species identified include warmwater fish, specifically Central Mudminnows, Creek Chubs, Brook Sticklebacks, White Suckers, and Bluntnose Minnows, which runs from March 15 – July 15, and a single species of coldwater fish, Brook Trout, which runs from October 1 – May 31. These spawning beds would be subject to the DFO vibration limit of 13mm/s during active periods and blasts shall be designed to adhere to this limit. During active spawning season, vibration monitoring will be required at the shoreline adjacent the closest spawning area, or closer to the blast, in order to ensure compliance with DFO limits for ground vibration.

Table 4 below is presented as initial guidance showing maximum permissible loads per delay based on various separation distances from spawning beds. The following maximum loads per delay are derived from the equation for ground vibrations listed earlier in this report and are based on a maximum vibration intensity of 13.0mm/s as experienced at the active spawning habitat:

| Table 4: Maximum Loads per Delay to Maintain 13.0mm/s at Various Separation Distances | |
|---|---|
| **Separation distance between possible spawning bed and closest borehole (meters)** | **Maximum recommended explosive load per delay (Kilograms)** |
| 500 | 278 |
| 450 | 225 |
| 400 | 178 |
| 350 | 136 |
| 300 | 100 |
| 250 | 70 |
| 200 | 45 |
| 150 | 25 |
| 100 | 11 |

The generation of suspended solids within the watercourse as a result of the blasting activities will be negligible and grossly subordinate to suspended solids generated as a result of spring runoff and rain activity.

RESIDENTIAL WATER WELLS

Possible impacts to the water quality and production capacity of groundwater supply wells is a common concern for residents near blasting operations. Complaints related to changes in water quality often include the appearance of turbidity, water discolouration and changes in water characteristics (including nitrate, e-coli, and coliform contamination). Complaints regarding water production most often involve loss of quantity production, air in water and damage to well screens and casings. A review of research and common causes of these problems indicates that most of these concerns are not related to blasting and can be shown to be the direct impact of environmental factors and poor well construction and maintenance.

There is an intuitive belief that blasting operations have dramatic and disastrous impacts on residential water wells for large distances around such operations; there is no scientific basis for such claims. Outside of the immediate radius of approximately 20-25 blasthole diameters from a loaded hole, there is no permanent ground displacement. As such, barring blasting activity within several meters of an existing well, the probability of damage to residential wells is essentially non-existent.

Despite the scientific support for the above conclusion, numerous studies have been performed to verify the validity of this statement. These studies have investigated the effects of blasting on varied well configurations and in varied geological mediums to permit conclusions to be readily extrapolated to diverse blasting operations. The conclusion of these studies has confirmed that with the exception of possible temporary increases in turbidity, blasting operations did not result in any permanent impact on wells outside of the immediate blast zone (20-25 blasthole diameters) of the blast until vibrations levels reached exceedingly high intensities. Applying universally accepted threshold levels for ground vibrations eliminates the possibility for any long term adverse effects on wells in the vicinity of blasting operations.

In a study by Froedge (1983), blast vibration levels of up to 32.3mm/s were recorded at the bottom of a shallow well located at a distance of 60 meters (200 feet) from an open pit blast. There was no report of visible damage to the well nor was there any change in the water pumping flow rate. This study concluded that the commonly accepted limit of 50mm/s PPV level is adequate to protect wells from any damage. We reiterate, the current guideline limit for vibrations from quarry and mining operations is 12.5mm/s.

Rose et al. (1991) studied the effect of blasting in close proximity to water wells near an open pit mine in Nevada, USA. Blasts of up to 70 kilograms of explosives per delay period were detonated at a distance of 75 meters (245 feet) from a deep water well. There was no reported visible damage to the well. Fluctuations in water level and flow rate were evident immediately after the blast. However, the well water level and flow rate quickly stabilized.

The U.S. Bureau of Mines conducted a study (Robertson et al., 1990) to determine the changes in well capacity and water quality. This involved pumping from wells before and after nearby blasting. One experiment with a well in sandstone showed no change in well capacity after blasts induced PPV's at the surface of 84mm/s and there was no change in water level after PPV's of 141mm/s, well above the current guideline limit of 12.5mm/s.

Matheson et al. (1997) brought together available information on the most common complaints, the possible causes of the complaints and the relation between blasting and the complaint causes. This study yet again reaffirmed the fact that the attribution of well problems to blast sources are unfounded.

The MECP vibration limit of 12.5mm/s effectively excludes any possibility of damage to residential water wells. Based on available research and our extensive experience in Ontario quarry blasting, blasting at the Reid Road Reservoir Quarry will induce no permanent adverse impacts on the residential water wells on properties surrounding the site.

## FLYROCK

Flyrock is the term used to define rocks which are propelled from the blast area by the force of the explosion. This action is a predictable and necessary component of the blast and requires that every blast have an exclusion zone established within which no persons or property which may be harmed are permitted.

Government regulations strictly prohibit the ejection of flyrock off of quarry property. The regulations regarding flyrock are enforced by the Ministries of Natural Resources, Environment, Conservation and Parks, and Labour. In the event of an incident where flyrock does leave a site, the punitive measures include suspension / revocation of licences and fines to both the blaster and quarry owner / operator. Fortunately, flyrock incidents are extremely rare due to the possible serious consequences of such an event. It is in the best interest of all, stakeholders and non-stakeholders, to ensure that dangerous flyrock does not occur. Through proper blast planning and design, it is possible to control and mitigate the possibility for flyrock.

## THEORETICAL HORIZONTAL FLYROCK CALCULATIONS

We have analyzed theoretical flyrock projection distances based on a quarry operating in the dry. It is critical to note that the proposed Reid Road Reservoir Quarry intends to operate in a wet environment. It has been our experience that the presence of the water will restrict face burst rock projection when compared to the calculations contained below.

Flyrock occurs when explosives in a hole are poorly confined by the stemming or rock mass and the high pressure gas breaks out of confinement and launches rock fragments into the air. The three primary sources of fly rock are as follows:

- **Face burst:** Lack of confinement by the rock mass in front of the blast hole results in fly rock in front of the face.

- **Cratering:** Insufficient stemming height or weakened collar rock results in a crater being formed around the hole collar with rock projected in any direction.

- **Stemming Ejection:** Poor stemming practice can result in a high angle throw of the stemming material and loose rocks in the blasthole wall and collar.

The horizontal distance flyrock can be thrown ($L_H$) from a blast hole is determined using the expression:

$$L_H = \frac{V_o^{\,2} Sin2\theta_0}{g} \qquad [1]$$

where:

$V_o$ = launch velocity (m/s)
$\theta_0$ = launch angle (degrees)
$g$ = gravitational constant (9.8 m/s$^2$)

The theoretical maximum horizontal distance fly rock will travel occurs when $\theta_0$ = 45 degrees, thereby yielding the equation:

$$L_{H\max} = \frac{V_o^{\,2}}{g} \qquad [2]$$

The normal range of launch velocity for blasting is between 10m/s - 30m/s. To calculate the launch velocity of a blast the following formula is used:

$$V_o = k\left(\frac{\sqrt{m}}{B}\right)^{1.3} \qquad [3]$$

where:

k = a constant
m = charge mass per meter (kg/m)
B = burden (m)

By combining equations 2 and 3 and taking into account the different sources of fly rock, the following equations can be used to calculate the maximum fly rock thrown from a blast:

Face burst:

$$L_{H\max} = \frac{k^2}{g} * \left(\frac{\sqrt{m}}{B}\right)^{2.6}$$

Cratering:

$$L_{H\max} = \frac{k^2}{g} * \left(\frac{\sqrt{m}}{SH}\right)^{2.6}$$

Stemming Ejection:

$$L_{H\max} = \frac{k^2}{g} * \left(\frac{\sqrt{m}}{SH}\right)^{2.6} Sin2\theta$$

where: θ = drill hole angle
$L_{hmax}$ = maximum flyrock throw (m)
m = charge mass per meter (kg/m)
B = burden (m)
SH = stemming height (m)
g = gravitational constant
k = a constant

For calculation purposes, we have utilized the initial blasting parameters: 76mm (3”) diameter holes on a 2.74m x 2.74m (9’ x 9’) pattern, with total depths of up to 35m (115’) and a collar length of 1.4m (4.6’) to 2.2m (7.2’).

The range for the constant k is 13.5 for soft rocks and 27 for hard rocks. Given dolostone bedrock in the area, we have applied a k value of 20. The explosive density is assigned to be 1200 kg/$m^3$ for emulsion products and the drill hole angles are assumed to be 90 degrees (i.e. vertical).

The maximum horizontal throw for the flyrock using a varied collar is shown in Table 5 below.

| **Table 5 – Maximum Flyrock Horizontal** | | |
|---|---|---|
| ***Collar* Lengths** (m) | **Maximum Throw Face Burst** (m) | **Maximum Throw Cratering and Stemming Ejection** (m) |
| 1.4 | 27 | 154 |
| 1.6 | 27 | 108 |
| 1.8 | 27 | 80 |
| 2.0 | 27 | 61 |
| 2.2 | 27 | 47 |

We reiterate that actual observed face burst will be restricted due to the presence of the water. Portions of the rock above the water level would not leverage this same benefit. The design as proposed earlier in this report implemented a 2.1m collar which would result in a calculated horizontal flyrock projection of 54m.

Through proper blast design and diligence in inspecting the geology before every blast, flyrock can readily be maintained within the quarry limits. It may be necessary to increase collars when blasting along the perimeter. The operational plan for the quarry has been designed to retreat towards the closest receptors thereby projecting flyrock and overpressures away from the receptors.

## GUELPH JUNCTION RAILWAY

The Guelph Junction Railway runs through the proposed quarry limits directly adjacent to Phase 2, Phase 4 and Phase 5 of the proposed Operational Plan (refer to Appendix A). The MECP guideline for blast-induced vibration (12.5mm/s) does not apply to railways as they are not classified as sensitive receptors. Railways throughout Canada typically employ a minimum vibration limit of 50mm/s as measured along the centreline of the tracks.

Applying the equation from *Predicated Vibration Limits at the Nearest Sensitive Receptor*, for a distance of 400m (the standoff distance to the railway for the initial blasting) and a maximum explosives load per delay of 75kg (76mm diameter hole on a 2.74m x 2.74m pattern, 31m deep, 2 explosive decks with a column load of 13.7m per deck, 1.5m stemming between decks, 2.1m surface collar and 1 deck per delay, we can calculate the maximum PPV utilizing the equations stated in section ‘Ground Vibration Levels at the Nearest Sensitive Receptor.’

The maximum calculated value for the vibration intensities imparted on the Guelph Junction Railway (based on the proposed blasting data discussed above) is 6.1mm/s utilizing the worst-case equation for the initial blasting, well below the 50mm/s railway standard. As the blasting operations retreat towards the Guelph Junction Railway, blast designs and parameters must be adjusted accordingly to remain compliant with the 50mm/s railway vibration standard.

**RECOMMENDATIONS**

It is recommended that the following conditions be applied for all blasting operations at the proposed Reid Road Reservoir Quarry:

1. An attenuation study shall be undertaken by a competent independent blasting consultant during the first 12 months of operation in order to obtain sufficient quarry data for the development of site specific attenuation relations. This study will be used to confirm the applicability of the initial guideline parameters and assist in developing future blast designs.

2. All blasts shall be monitored for both ground vibration and overpressure at the closest privately owned sensitive receptors adjacent the site, or closer, with a minimum of two (2) digital seismographs – one installed in front of the blast and one installed behind the blast. Monitoring shall be performed by and independent third party engineering firm with specialization in blasting and monitoring.

3. The guideline limits for vibration and overpressure shall adhere to standards as outlined in the Model Municipal Noise Control By-law publication NPC 119 (1978) or any such document, regulation or guideline which supersedes this standard.

4. In the event that calculations suggest the vibrations at the closest portion of the rail line will exceed 2/3 of the applicable limit, an additional vibrations monitor shall be installed at the closest portion of the rail line.

5. Vibrations imparted on the rail line shall be maintained below industry best practices for structures of this nature or railway owner corporate policy.

6. When blasting on site is to take place employing blast parameters which suggest vibration in excess of 10mm/s (75% of DFO 13mm/s limit) imparted on an active spawning bed, an additional seismograph shall be installed at the location of the closest spawning bed, or closer to the blast, to confirm compliance with DFO guideline limit for ground vibration of 13mm/s.

7. Explosive products employed shall be suitable for wet conditions including formulations which take into consideration deadpress, sympathetic detonation, sleep times and product leaching as necessary. Detonators employed shall be restricted exclusively to electronic detonators or similar

type products that may be developed in the future which can conclusively assess product performance post-blast to ensure that all holes detonated as designed. Loading protocol will follow industry standard best practices which may include the use of sleeves or decking at locations of voids.

8. Drilling accuracy and deviation will be monitored and addressed as necessary to ensure safety of site personnel and compliance with applicable regulations and guidelines.

9. Orientation of the aggregate extraction operation and will be designed and maintained so that the direction of the overpressure propagation and flyrock from the face will be away from structures as much as possible.

10. Blast designs will be continually reviewed with respect to fragmentation, ground vibration and overpressure. Blast designs shall be modified as required to ensure compliance with applicable guidelines and regulations. Decking reduced hole diameters and sequential blasting techniques will be used to ensure minimal explosives per delay period initiated.

11. Once blasting progress encroaches to within 250m of any offsite sensitive receptor, a formal review of accumulated blast records including vibration data and blast designs shall be undertaken. This review will identify what modifications to blasting protocol and procedures are required to address the reduced separation distance.

12. Clear crushed stone will be used for stemming.

13. Blasting procedures such as drilling and loading shall be reviewed on a yearly basis and modified as required to ensure compliance with industry standards.

14. Detailed blast records shall be maintained. The MECP (1985) recommends that the body of blast reports should include the following information:

    - Location, date and time of the blast.
    - Dimensional sketch including photographs, if necessary, of the location of the blasting operation, and the nearest point of reception.
    - Physical and topographical description of the ground between the source and the receptor location.
    - Type of material being blasted.

- Sub-soil conditions, if known.
- Prevailing meteorological conditions including wind speed in m/s, wind direction, air temperature in $^{o}C$, relative humidity, degree of cloud cover and ground moisture content.
- Number of drill holes.
- Pattern and pitch of drill holes.
- Size of holes.
- Depth of drilling.
- Depth of collar (or stemming).
- Depth of toe-load.
- Weight of charge per delay.
- Number and time of delays.
- The result and calculated value of Peak Pressure Level in dB and Peak Particle Velocity in mm/s.
- Applicable limits and any exceedances.

## CONCLUSION

The blast parameters described within this report will provide a good basis for the initial blasting operations at this location. As site specific blast vibration and overpressure data becomes available, it will be possible to refine these parameters on an on-going basis.

Blasting operations required for operations at the proposed James Dick Construction Ltd. Reid Road Reservoir Quarry site can be carried out safely and within governing guidelines set by the Ministry of the Environment, Conservation and Parks (MECP).

Modern blasting techniques will permit blasting to take place with explosives charges below allowable charge weights ensuring that blast vibrations and overpressure will remain minimal at the nearest receptors and compliant with applicable guideline limits.