EXPLOTECH

Specialists in Explosives, Blasting and Vibration
Consulting Engineers

Blast Impact Analysis
Law Quarry Extension
Concession 2, Part Lot 6 & 7, Part of Road Allowance Between Lots 5 & 6 Township of Wainfleet, Regional Municipality of Niagara

Submitted to:

Waterford Sand & Gravel Ltd
522 Thompson Road West
Waterford, Ontario
N0E 1Y0

LICENSED PROFESSIONAL ENGINEER
A. M. CAMPBELL
100209604
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
R. J. CYR
PROVINCE OF ONTARIO

Prepared by

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

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EXECUTIVE SUMMARY

Explotech Engineering Ltd. was retained in December 2017 to provide a Blast Impact Analysis for the proposed Waterford Sand & Gravel Limited Law Crushed Stone Extension located on Concession 2, Part of Lots 6 & 7, Part of Road Allowance Between Lots 5 & 6, Township of Wainfleet, Regional Municipality of Niagara.

Vibration levels assessed in this report are based on the Ministry of the Environment, Conservation and Parks Model Municipal Noise Control By-law (NPC 119) with regard to guidelines for blasting in Mines and Quarries. We have assessed the area surrounding the proposed license area with regard to potential damage from blasting operations and compliance with the aforementioned by-law document. In addition, we have completed an attenuation study, and reviewed blast and vibration reports collected at the existing licenced quarry for the 2015-2019 blasting operations.

We have inspected the site and reviewed the available site plans. Explotech Engineering Ltd. is of the opinion that the planned mineral extraction extension on the site can be carried out safely and within Ministry of the Environment, Conservation and Parks 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.

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INTRODUCTION

The proposed Waterford Sand & Gravel Limited Law Crushed Stone Extension operation is located on the West side of the existing licensed and operating Law Quarry (Licence 4464 and 607541). The legal description for the subject extension property is Part of Lots 6 & 7, Part of Road Allowance Between Lots 5 & 6 - Concession 2 – Township of Wainfleet, Regional Municipality of Niagara.

This Blast Impact Analysis is based on the Ministry of the Environment, Conservation and Parks (MECP) Model Municipal Noise Control By-law (NPC 119) with regard to guidelines for blasting in mines and quarries. We have additionally assessed the area surrounding the proposed license with regard to potential damage from blasting operations. It is a recommendation of this report that a vibration monitoring program be continued on the existing licenced site as well as on the proposed Law Crushed Stone Extension lands and that this monitor program be maintained for the duration of all blasting activities to permit timely adjustment to blast parameters as required.

While not specifically required as part of the scope of the Blast Impact Analysis under the Aggregate Resources Act, this report also touches on 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 while specific flyrock control is addressed at the operational level given significant influences related to blast design, geology and field accuracy.

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 current operating licensed area for the Waterford Sand & Gravel Limited Law Quarry (Licence 4464 and 607541) is described as Part of Lots 3 to 6 Concession 2 – Township of Wainfleet, Regional Municipality Niagara. This property is bound by Erie Peat Road to the East, Highway 3 to the South, the Wainfleet Bog Conservation Area, agricultural land and lands owned by the applicant to the North and Biederman Road (the proposed new licence lands) to the West. The lands immediately surrounding the licence are sparsely populated with the areas of most dense development lying to the South.

The proposed Law Crushed Stone Extension is located immediately West of the existing licence on Part of Lots 6 & 7, Part of Road Allowance Between Lots 5 & 6 - Concession 2 – Township of Wainfleet, Regional Municipality of Niagara. The extension lands are bound by the Wainfleet Bog Conservation Area to the North, residences located on Biederman Road and the existing Law Quarry to the East, residential properties located along Highway 3 and agricultural land to the South and residential properties located on Graybiel Road to the West.

The licenced area for the proposed Law Quarry extension lands encompasses a total area of approximately 72.3HA. The associated extraction area is approximately 51.2HA when allowing for setbacks and sterilized areas.

The closest sensitive receptors located to the existing Law Quarry licence boundary and the proposed Law Quarry Extension licence boundaries are listed in Table 1 below as well as on the Sensitive Receptor Overviews contained in Appendix A:

TABLE 1 Sensitive Receptors In the Vicinity of the Law Quarry Expansion			
Sensitive Receptor	**Straight Line Distance from Law Quarry Boundary to Receptor (m)**	**Straight Line Distance from proposed Law Quarry Extension Boundary to Receptor (m)**	**Direction from Quarry Extension**
20804 Graybiel Road	937	100	West
20808 Graybiel Road	938	57	West
20816 Graybiel Road	871	87	West
20824 Graybiel Road	877	68	West
20834 Graybiel Road	881	90	West
10855 Rathron Road	933	500	South
10857 Rathron Road	698	522	South
10858 Rathfon Road	956	475	South
10861 Rathfon Road	859	390	South
10868 Rathfon Road	851	245	South
10870 Rathfon Road	851	217	South
10595 Highway 3	141	149	South
10611 Highway 3	80	101	South
10613 Highway 3	127	76	South
10615 Highway 3	148	78	South
10617 Highway 3	164	65	South
10621 Highway 3	182	59	South
10625 Highway 3	241	63	South
10629 Highway 3	262	61	South
10641 Highway 3	384	77	South
10745 Highway 3	409	83	South
10822 Highway 3	961	165	West
10825 Highway 3	987	220	Southwest
10830 Highway 3	1024	235	West
10834 Highway 3	1092	305	West
10942 Highway 3	1202	400	West
10945 Highway 3	1234	460	Southwest
10946 Highway 3	1270	427	Southwest
10949 Highway 3	1266	485	Southwest
10950 Highway 3	1376	572	West

TABLE 1 Sensitive Receptors In the Vicinity of the Law Quarry Expansion			
Sensitive Receptor	**Straight Line Distance from Law Quarry Boundary to Receptor (m)**	**Straight Line Distance from proposed Law Quarry Extension Boundary to Receptor (m)**	**Direction from Quarry Extension**
10646 Quarry Road	488	430	South
10650 Quarry Road	323	373	South
10652 Quarry Road	296	332	South
10654 Quarry Road	236	281	South
10656 Quarry Road	197	245	South
10658 Quarry Road	137	184	South
10660 Quarry Road	115	158	South
20650 Biederman Road	217	35	Northeast

PROPOSED MINERAL EXTRACTION

The proposed quarry extension extraction will begin at the existing Law quarry West face (upon agreement with the Township of Wainfleet) thereby eliminating the need for a sinking cut. The extraction will be completed in five (5) phases. Table 2 denotes relevant extraction details as they pertain to each individual phase.

TABLE 2 Details for Extraction for Each Individual Phase of the Law Quarry Extension	
Phase 1a	• Phase 1a will leverage the existing West face of the existing Law Quarry therefore eliminating the need for a sinking cut. • Extracted to a depth between 166MASL and 167MASL. • Retreat in a Westerly direction. • Likely extracted in 1-2 benches given the existing elevation of approximately 183MASL.
Phase 1b	• Phase 1b will leverage the existing West face of the existing Law Quarry therefore eliminating the need for a sinking cut. • Extracted to a depth between 164MASL and 165MASL. • Retreat in a Westerly direction. • Likely extracted in 1-2 benches given existing elevations in the 185MASL – 186MASL range.
Phase 2	• Initial operations for Phase 2 will leverage the existing West faces of Phase 1a thereby eliminating the need for a sinking cut. • Extracted to a depth between 166MASL and 168MASL • Retreat in a Westerly direction to the West extraction boundary • Likely extracted in 1-2 benches given existing elevations in the 182MASL – 183MASL range.
Phase 3	• Initial operations for Phase 3 will leverage the existing South face of Phase 2 thereby eliminating the need for a sinking cut. • Extracted to a depth between 165MASL and 167MASL • Retreat in a Western direction to the Western extraction boundary • Likely extracted in 1-2 benches given the existing elevation of approximately 183MASL.

Phase 4	• Initial operations of Phase 4 will leverage the existing South face of Phase 3 thereby eliminating the need for a sinking cut. • Extracted to a depth between 164MASL and 165MASL • Retreat in a general Southern direction to the South extraction boundary • Likely extracted in 1-2 benches given existing elevations in the 183MASL - 184MASL range.
Phase 5	• Initial operations of Phase 5 will leverage the existing South face of Phase 1b thereby eliminating the need for a sinking cut. • Extracted to a depth of 163MASL • Retreat in a general Southern direction to the South extraction boundary • Likely extracted in 1-2 benches given the existing elevation of approximately 185MASL.

As quarry operations migrate across the property, the closest sensitive receptors to the required blasting operations will vary. While initial mineral extraction in the proposed extension licence area will take place approximately 275m from the closest sensitive receptor, (namely 20650 Beiderman Road) quarry faces along the West limits of extraction will come as close as 57m removed from the properties located along Graybiel Road.

Current practice at the Waterford Sand & Gravel Limited Law Quarry employs between 89 and 102mm diameter blast holes with a typical load per delay of between 10kg and 160kg per period. Calculations contained within this report suggest modifications to current blast designs will be necessary as operations progress towards adjacent receptors.

It is a recommendation of this report that all blasts shall, as a minimum, be monitored at the nearest sensitive receptors, or closer, in front and behind any given blast in order to ensure constant compliance with MECP guideline limits and to permit timely adjustment to blast designs as required.

BLAST VIBRATION AND OVERPRESSURE LIMITS

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

Recent 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/s Peak Particle Velocity (PPV)

Overpressure________128dB 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 receptor behind the blast, or closer, and one installed at the closest receptor in front of the blast, or closer.

BLAST MECHANICS AND DERIVATIVES

The detonation of explosives within a blast hole 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 of 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 through the air, measured in linear decibels (or dBL) 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 vibration 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 towards receptors, and blast vibrations are greatest when retreating towards the receptors.

GROUND VIBRATION AND OVERPRESSURE ATTENUATION STUDY

A comprehensive network of seismographs was installed by Explotech to measure ground vibration and air overpressure intensities for four (4) blasts conducted in July 2020 and September 2020 at the existing Waterford Sand & Gravel Limited Law Quarry in Wainfleet, Ontario. Monitor locations were established in linear arrays emanating from the blast site to assess the rate of decay of the ground vibration and overpressure. All ground vibration data was plotted using square root scaling from blast vibration data collected (refer to Appendix C). Overpressure data was plotted employing cube root scaling (refer to Appendix C).

It should again be noted that given the high dependence on local environmental conditions, overpressure prediction is far less reliable as a means of blast control.

VIBRATION LEVELS AT THE NEAREST SENSITIVE RECEPTOR

The most commonly used formula for predicting PPV is known as the 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 predicted peak particle velocity (mm/s)

K, e = site factors

d = distance from receptor (m)

w = maximum explosive charge per delay (kg)

The value of K and e are variable and 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.

Based on the vibration data collected from the July 2020 and September 2020 attenuation study, the values for “e” and “K” have been established at -1.366 and 1571.5 respectively for receptors falling behind the blast at the Waterford Sand & Gravel Limited Law Quarry site.

For a distance of 275m (the standoff distance to the closest sensitive receptor behind the initial Phase 1a blasting, namely 20650 Beiderman Road) and a maximum explosive load per delay of 56kg (89mm diameter hole, 10m deep, 2.5m surface collar and 1 hole per delay), we can calculate the maximum PPV as follows:

$$PPV = 1571.5\left(\frac{275}{\sqrt{56}}\right)^{-1.366} = 11.4 mm/s$$

The calculated PPV based on the blast discussed above would be 11.4mm/s.

As discussed in previous sections, the MECP guideline for blast-induced vibration is 12.5 mm/s (0.5 in/s). The calculated 95% predicted PPV (based on the standoff distance to the closest sensitive receptor for the initial Phase 1a blasting) would be 11.4mm/s, below the MECP guideline limit. It is understood that as separation distance to the receptors decreases, adjustments to blast designs may be necessary to maintain compliance with the guideline limits.

Similarly, the above equation used to calculate PPV can be reformatted to find an approximation of the distance at which a vibration velocity of 12.5mm/s would occur at a receptor behind the blast if all blasting parameters are kept the same as used in the example above:

$$12.5 = 1571.5\left(\frac{d}{\sqrt{75}}\right)^{-1.366} = 257.6m$$

The above result suggests that design modifications to the above preliminary design would be required once blasting operations encroach to within 257.6m of sensitive receptors surrounding the quarry extraction operations. Fortunately, vibration data will be continually collected and analyzed as part of the Compliance Monitoring Program as the sensitive receptors are approached in order to confirm the requirement for any design modifications. An abundance of design modifications are available which would readily maintain vibration intensities below guideline limits.

Given the separation distances that will be involved at the Law Quarry Extension, Table 3 below provides initial guidance on maximum loads per delay based on various separation distances. The following maximum loads per delay were derived from the equation developed through the July 2020 and September 2020 attenuation study and are based on a maximum intensity of 12.5mm/s:

TABLE 3
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	211
450	171
400	135
350	103
300	76
250	53
200	34
150	19
100	8
50	2

It is noteworthy that the above values are typically conservative and are intended as a guideline only as the ground vibration 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 and adjusted as necessary.

The closest separation distance between a sensitive receptor and any blast over the life of the license is 57m. While blasting at this separation distance is feasible from a technical 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 typically 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 were 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 (dBL)
K, e = site factors
d = distance from receptor (m)
w = maximum explosive charge per delay (kg)

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

Based on the overpressure data collected from the July 2020 and September 2020 attenuation study, the values for “e” and “K” have been established at -0.108 and 207.9 respectively for receptors falling in front of the blast at the Waterford Sand & Gravel Limited Law Quarry site.

As discussed in previous sections, the MECP guideline for blast-induced overpressure is 128dBL. For a distance of 920m (i.e. the standoff distance to the closest sensitive receptor in front of the initial Phase 1 blasting, (namely 20451 Erie Peat Road) and a maximum explosive load of 56kg (89mm diameter hole, 10m deep, 2.5m surface collar and 1 hole per delay), we can calculate the maximum overpressure at the nearest receptor in front of the blast as follows:

$$P = 207.9\left(\frac{920}{\sqrt[3]{56}}\right)^{-0.108} = 115.0dB(L)$$

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.

Similarly, the above equation used to calculate PSPL can be reformatted to find an approximation of the distance at which an overpressure of 128 dB(L) would occur. If all blasting parameters are kept the same as the example above, a distance of 350m from the closest sensitive receptor in front of the blast would have a calculated overpressure of 128db(L). Once again, the on-site monitoring program will accurately delineate the overpressure intensities and provide guidance for the timing for any design changes.

Given the intimate correlation between overpressure and environmental conditions as stated previously, 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 4 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 and are based on a peak overpressure level of 128dB(L):

TABLE 4
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	175
450	125
400	90
350	60
300	38
250	22

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 ensure compliance with MECP NPC-119 guidelines. The hydrogeological study prepared by WSP as part of the licence application will address 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.

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 a 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 a quarry property. The regulations regarding flyrock are enforced by the Ministries of Natural Resources and Forestry, 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

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)

θ_0 = launch angle (degrees)

g = gravitational constant (9.8 m/s^2)

The theoretical maximum horizontal distance fly rock will travel occurs when θ_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 flyrock calculation purposes, we have applied the current blasting parameters used in the Law Quarry which utilize 102mm (4”) diameter holes on a 4m x 4m (13’x 13’) pattern, with total depths of up to 24m (80’) and a collar length of 2m (6.5’).

The range for the constant k is 13.5 for soft rocks and 27 for hard rocks. Given the proposed licence area is predominantly limestone, we have applied a k value of 21. The explosive density is assigned to be 1.2 g/cc for emulsion products and the drill hole angles are assumed to be 90 degrees (i.e. vertical).

The following does not apply to sinking cuts (if ever required) which will require highly specialized designs and additional considerations for flyrock. Based on a free face blast, maximum anticipated horizontal flyrock projection distances are calculated as follows in Table 5:

TABLE 5 **Maximum Flyrock Horizontal**		
***Collar* Lengths** (m)	**Maximum Throw Face Burst** (m)	**Maximum Throw Cratering and Stemming Ejection** (m)
1.5	24	302
2.0	24	143
2.5	24	80
3.0	24	50
3.5	24	33

Different collar lengths are displayed in the table above to account for over or under loaded holes. As demonstrated with these various collar lengths, any deviation, no matter how slight, can greatly affect these maximum values. Blast mats or sand can be placed on top of the shot to further reduce the distance for potential flyrock.

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 and adjust designs accordingly when blasting along the perimeter to accommodate the reduced distance to receptors and to ensure flyrock remains within the property limit.

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. Unfortunately, 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 ensure results could be readily extrapolated to all 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 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 Tomlinson Brickyards Quarry will induce no permanent adverse impacts on the residential water wells on properties surrounding the site.

REVIEW OF HISTORICAL LAW QUARRY DATA

A vibration and overpressure monitoring program has been in place for all blasts conducted at the Waterford Sand & Gravel Limited Law Quarry in recent years. As part of this analysis, Waterford Sand & Gravel Limited has provided copies of vibration data summaries collected for 2015 through 2019 inclusive. For continuity, summaries of the historical data collected and supplied by Waterford Sand & Gravel Limited are included in Appendix C to this report.

2015-2019 DATA

Vibration monitoring conducted over the course of the 2015 – 2019 blasting campaigns have included the installation of seismographs at the following locations:

- 20455 Erie Peat Road, Behind the Quarry
- First Pole on Erie Peat
- Beside Youngs Road Water Well
- Youngs Street Test Well
- 17 First Avenue
- 678 Barrick Road
- 40 Townline Road
- 2035 Youngs Road
- Corner of Highway 3 and Erie Peat Road
- Southwest Corner of Kwik Mix Building
- Erie Peat Road North End
- 10423 Lakeshore Road
- Erie Peat Road
- 533 Clarence Street
- B/W 201 & 207 West Side Road
- 10611 Highway 3 on Road
- 20804 Graybiel Road

All vibration monitoring was performed by either the blasting contractor or the quarry owner. A review of the data supplied confirms that for the five year period from 2015 through 2019 inclusive, two (2) blasts exceeded the MECP guideline limit of 12.5mm/s set for ground vibrations, while all blasts remained compliant with the MECP guideline limit of 128dB for overpressure. Table 6 below lists the blasts that exceeded these limits:

EXPLOTECH

TABLE 6 Exceedances of NPC 119 Recorded During 2015-2019 Blasting Operations				
Date	**Time**	**Location**	**Limit Exceeded**	**Value of Exceedance**
August 22, 2017	10:16	Corner of Erie Peat Road and Highway 3 Telephone Pole	**>12.5mm/s**	15.1mm/s
September 20, 2017	10:19	Southwest Corner of Kwik Mix Building	**>12.5mm/s**	13.1mm/s

It is noteworthy that while these monitor locations exceeded the MECP guidelines, the structures located at the selected monitor locations are not considered sensitive receptors and are thereby not subject to the 12.5mm/s. Accordingly, the two noted events are not true exceedances of MECP guidelines for ground vibration.

RECOMMENDATIONS

It is recommended that the following conditions be applied for all blasting operations at the proposed Waterford Sand & Gravel Limited – Law Quarry Extension areas:

1. All blasts shall be monitored for both ground vibration and overpressure by an independent Blast Consultant at the closest privately owned sensitive receptors adjacent the site, or closer, with a minimum of two (2) instruments – one installed in front of the blast and one installed behind the blast.

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

3. In the event of an exceedance of NPC 119 limits or any such document, regulation or guideline which supersedes this standard, blast designs and protocol shall be reviewed prior to any subsequent blasts and revised accordingly in order to return the operations to compliant levels.

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

5. Blast designs shall be continually reviewed with respect to fragmentation, ground vibration and overpressure. Blast designs shall be modified as required to ensure compliance with current applicable guidelines and regulations.

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

7. Detailed blast records shall be maintained in accordance with current industry best practices

The blast parameters described within this report are supported by the modeling in the attached appendices. As the quarry progresses and as site-specific data is collected from the on-going operation, the blast parameters can be refined, as necessary, to ensure continual compliance with MECP Guidelines.

CONCLUSION

Blasting operations required for mineral extraction at the proposed Waterford Sand and Gravel – Law Quarry Extension lands can be carried out safely and within governing guidelines set by the Ministry of the Environment, Conservation and Parks.

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.