EXPLOTECH

Specialists in Explosives, Blasting and Vibration
Consulting Engineers

Blast Impact Analysis
McClintock Quarry
Part Lot 11 and 12, Concession 2
MNR District of Bracebridge
County of Halliburton

Submitted to:

Timber Craft Consultation Inc.
1629 Jocko Point
North Bay, ON

Prepared by

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

July 27, 2017

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<u>EXECUTIVE SUMMARY</u>

Explotech Engineering Ltd. was retained in November 2016 to provide a Blast Impact Analysis for the proposed McClintock Quarry located on Part Lot 11 and 12, Concession 2, MNR District of Bracebridge, County of Haliburton.

Vibration levels assessed in this report are based on the Ministry of Environment and Climate Change (MOECC) 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 license 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 MOECC guidelines as set out in NPC 119 of the By-Law.

Recommendations are included in this report to ensure that blasting operations in all phases of this project are carried out in a safe and productive manner to ensure that no possibility of damage exists to any buildings, roadways, structures or facilities surrounding the property.

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INTRODUCTION

Bacher Construction Ltd., intends to apply for a Class A, Category 2 Licence for the property legally described as Part Lot 11 and 12, Concession 2, MNR District of Bracebridge, County of Halliburton. 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 Environment and Climate Change (MOECC).

The land immediately surrounding the proposed McClintock Quarry is a mixture of residential and uncultivated land uses.

The proposed McClintock Quarry operation is bounded to the Northeast by uncultivated rural land and a residence designated as 1759 McClintock Road approximately 1550m from the limits of extraction. The quarry is bounded to the Northwest by uncultivated rural land and cottages along Livingstone Lake Road approximately 1250m from the limits of extraction. To the Southeast the quarry is bounded by a cottage on Harvey Lake Road approximately 240m from the limits of extraction. Finally, to the Southwest the quarry is bounded by uncultivated rural land with no sensitive receptors within 1600m of the limits of extraction.

This Blast Impact Analysis has been prepared based on the Ministry of the Environment and Climate Change (MOECC) 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 license with regard to potential damage from blasting operations.

Given that blasting operations have not been undertaken in the past on this property, site-specific blast monitoring data is not available. We have therefore applied data generated at a variety of quarries across Ontario which present similar material characteristics. 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. We note that blast monitoring is a prescribed condition to any licence issued for the proposed quarry under the Aggregate Resources Act.

Recommendations are included in this report to ensure that the blasting operations are carried out in a safe and productive manner and to ensure that no possibility of damage exists to any buildings, roads, structures or residences surrounding the property.

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EXISTING CONDITIONS

The licenced area for the proposed McClintock Quarry encompasses a total area of approximately 21.85HA. The extraction area is approximately 14.85HA when allowing for setbacks and sterilized areas.

The topography of the proposed licence area is generally lowest in the Centre portion of the site at an elevation in the order of 372.0masl rising in both directions outwards towards the West and East with the highest elevations (389.0masl) lying at the Northern edge of the site. The design final quarry floor elevation is 372.0masl leading to the execution of 1 to 3 benches.

The lands surrounding the proposed licence area are largely characterized by uncultivated rural land / forested areas with a limited number of residential structures. The sensitive receptors located within 1600m of the extraction limits over the life of the operation are as follows:

Sensitive Receptor	Distance to Receptor	Direction from Extraction Limits
1759 McClintock Road	1550m	Northeast
Livingston Lake Road Cottage	1250m	Northwest
Harvey Lake Road Cottage	240m	Southeast

PROPOSED AGGREGATE EXTRACTION

The extraction operations will be initiated in the Northern area closest the existing pit. Extraction will proceed in a general North to South retreat along the extraction area boundary to a final floor elevation of 372.0masl. Given existing topography, it is anticipated that Phase 1 extraction will take place in 1 bench.

Quarries in Ontario normally employ 76 to 152 mm diameter blast holes which, for a 7m typical bench, would employ 40kg to 162kg of explosive load per hole. The choice of hole diameter and bench height will govern the maximum number of holes to be fired per period for the sinking cut. As extraction retreats towards the South, it will be possible to vary operational aspects of the drilling and blasting program in response to monitoring program results and observed outcomes in order to maintain compliance and maximize operational efficiency.

BLAST VIBRATION AND OVERPRESSURE LIMITS

The Ontario MOECC 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 MOE. The limits suggested by the MOE are as follows.

Vibration_____12.5mm/sec   Peak Particle Velocity (PPV)

Overpressure_____128 dBL   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 <u>minimum</u> of two (2) digital seismographs.

BLAST VIBRATION AND OVERPRESSURE DATA

Blast vibration and overpressure data used in this report was collected from an amalgamation of quarries and mines throughout Ontario.

All ground vibration data was plotted using square root scaling from blast vibrations (Refer to Appendix C for a sample plot of data). The composite data employed has been proven to be very conservative and has been used as a start-up guideline for many aggregate extraction operations.

Overpressure data was plotted employing cube root scaling (Refer to Appendix C for a plot of data). 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.

Our experience and analysis demonstrates that blast overpressure is greatest when blasting toward residences, and blast vibrations are greatest when retreating towards the residences. Based on our complete data set from other Ontario quarries, we present the following initial guidelines for blasting operations at the proposed McClintock Quarry:

INITIAL BLASTING PARAMETERS

Blast Pattern:	2100 x 2100 to 3300 x 3300 mm
Number of holes:	Varies
Hole depth:	5 – 25m
Hole Diameter:	76 to 152mm
Stemming:	Clearstone
Toe Load:	Cast Booster / Cartridge
Column Load:	ANFO / ANFO WR / Emulsion
Maximum Charge per hole:	Varies with cut depth
Total Explosives per blast:	Varies with blast size
Material being blasted:	Granite
Tonnage per blast:	Varies
Number of blasts per year	Varies with production required

The above parameters provide initial guidance to direct blasting operations. Upon the commencement of blasting on site, these parameters will require revision based on site-specific data obtained and attenuation equations developed required as a recommendation of this report.

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 towards the receptor.

PREDICTED 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 (mm/s)

K, e = site factors

d   = distance from receptor (m)

w   = maximum explosive charge per delay (kg)

The value of K is highly variable and is influenced by many factors (i.e. rock type, geology, thickness of overburden, etc.). Based on monitoring performed in Ontario quarries with similar material characteristics, our initial estimates for "e" will be set at -1.85 and "K" will be set at 7025 (refer to Appendix C). In the absence of data for the proposed aggregate extraction operation, these are used for initial prediction purposes.

An ***example*** of this calculation is as follows:

For an initial distance of approximately 765m (the standoff distance to the closest sensitive receptor for the initial blasting) and a maximum explosives load per delay of 138.46 kg (76mm diameter hole, 7m deep including 1m sub-drill and 2m surface collar, and 1 holes per delay), we can calculate the maximum PPV at the closest building as follows:

$$ppv = 7025\left(\frac{765}{\sqrt{138.46}}\right)^{-1.85} = 4.17mm/s$$

As discussed in previous sections, the MOECC guideline for blast-induced vibration is 12.5 mm/s (0.5 in/s). For the initial blasting conducted onsite the calculated 95% predicted PPV (based on the proposed blasting data discussed above) would be 4.17mm/s, well below the MOECC guideline limit.

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:

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

Where, PSPL = the peak sound pressure level particle velocity (dBL)

        K, e   = site factors

        d   = distance from receptor (m)

        w   = maximum explosive charge per delay (kg)

Data collected at various Ontario quarry was used to develop the following 95% regression equation (refer to Appendix C). The values for "e" and "K" have been established at -0.0456 and 159 respectively based on the collected empirical data.

$$PSPL = 159\left(\frac{D}{\sqrt[3]{W}}\right)^{-0.0456}$$

As discussed in previous sections, the MOE guideline for blast-induced overpressure is 128dBL. For an initial distance of approximately 765m (i.e. the standoff distance to the closest sensitive receptor for the initial blasting) and a maximum explosive weight of 138.46kg (76mm diameter hole, 7m deep including 1m sub-drill and 2m surface collar, and 1 hole per delay), we can calculate the PSPL at the nearest receptor as follows:

$$PSPL = 159 \left(\frac{765}{\sqrt[3]{138.46}} \right)^{-0.0456} = 126.60 dB(L)$$

Based on this calculation and the assumed initial blast parameters, blasting from the initial operations will remain compliant to the MOECC NPC 119 guideline limit of 128dBL.

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.

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BLAST IMPACTS ON ADJACENT WATERCOURSES

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 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.

We have been advised that there are no fish populations on the proposed licence site or within the immediate vicinity of the site. As such, water overpressure impacts need not be considered. Given that the closest sensitive receptors lie closer to required blasting areas than any spawning habitats, there is no need for additional vibration monitoring at spawning habitats in the area as the DFO limit for vibration is higher than the MOECC limit.

RECOMMENDATIONS

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

1. An attenuation study shall be undertaken by an 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 an independent third party engineering firm with specialization in blasting and monitoring.

3. The guideline limits for vibration and overpressure as stipulated in the Model Municipal Noise Control By-law publication NPC 119 shall be adhered to.

4. Orientation of the aggregate extraction operation 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. Accordingly, operations have been designed to follow a general North to South retreat.

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 applicable guidelines and regulations. Decking, reduced hole diameters and sequential blasting techniques will be used to ensure minimal explosives per delay period initiated.

6. Clear crushed stone will be used for stemming.

7. Primary and secondary dust collectors will be employed on the rock drills to keep the level of rock dust to a minimum.

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

9. Detailed blast records shall be maintained. The MOE (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.

- The excess, if any, over the prescribed limit.

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 McClintock Quarry site can be carried out safely and within governing guidelines set by the Ministry of the Environment and Climate Change.

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.

Appendix A

Bacher Construction Limited McClintock Quarry / Pit Operational Plan

Creek
367.75

Existing Permit # 16023

15m setback

Stage 2 areas

15m setback

LOT 12 CON 2

Blandings turtle constraints

Stage 2 areas

Blandings turtle constraints

LOT 11 CON 2

Phase 1

Phase 2

30m setback

LOT-10 CON 2

15m setback

LOT 12 CON 1

LOT 11 CON 1

A

A-1
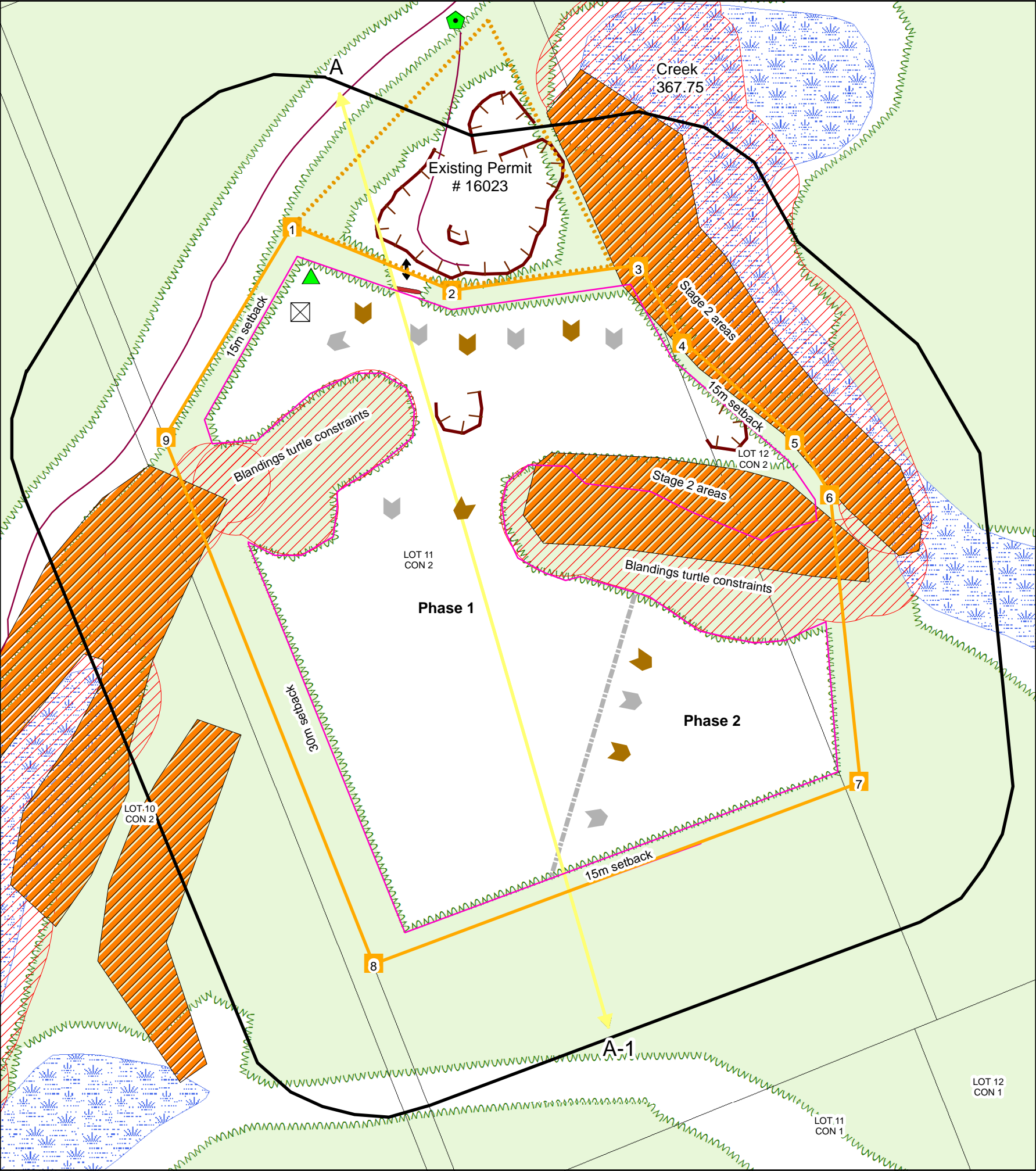
Legend

- ——— 120m Information Area
- ——— Permit Boundary
- ——— Setback
- ·········· existing pit boundary
- ⬌ Cross Section Line A-A1
- ⬠ Benchmark
- ▮ Corner Post
- ▬ Proposed Gate
- ↕ Proposed Entrance Exit
- ◄ Extraction direction pit operations
- ◄ Extraction direction quarry
- ——— Roads
- —·—·— Phasing
- ——— Existing excavation
- ▨ Archeological stage 2 work
- ▨ Blanding constraints
- ▨ Wetlands
- ▢ Lots/ concessions
- 〰〰 woodarea

AMENDMENTS/ VARIATIONS			
NO.	DESCRIPTION	DATE Approved	Approved by

1:3,500

0   100   200   400 Meters

N

Cross Section Scales
Horizontal 1:3500
Vertical 1:700
Vertical exaggeration 5x

Cross Section Line A-A1

A North

Quarry floor excavation will remain 2m above the watertable
Pit floor excavation will remain 1.5m above the watertable

Quarry slopes 2:1
Pit slopes 3:1

15m setback

15m setback

South A-1

390
385
380
375
370

390
385
380
375
370

0 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750
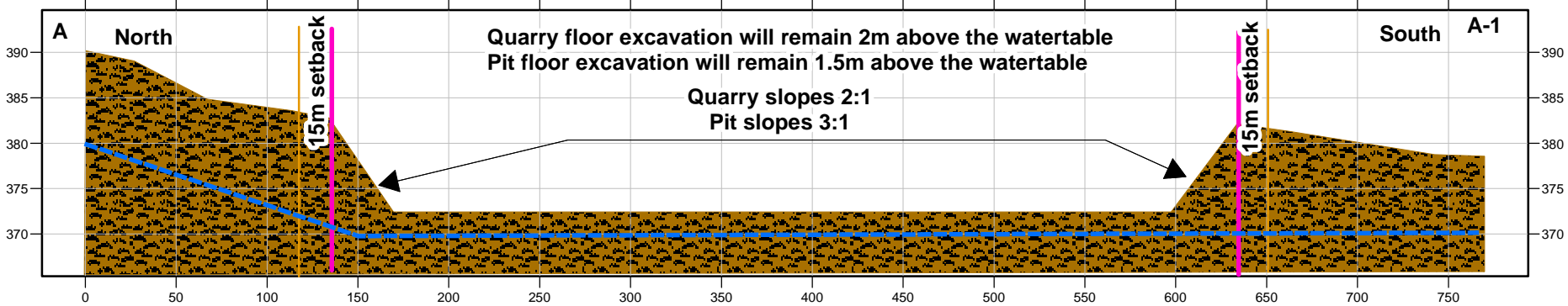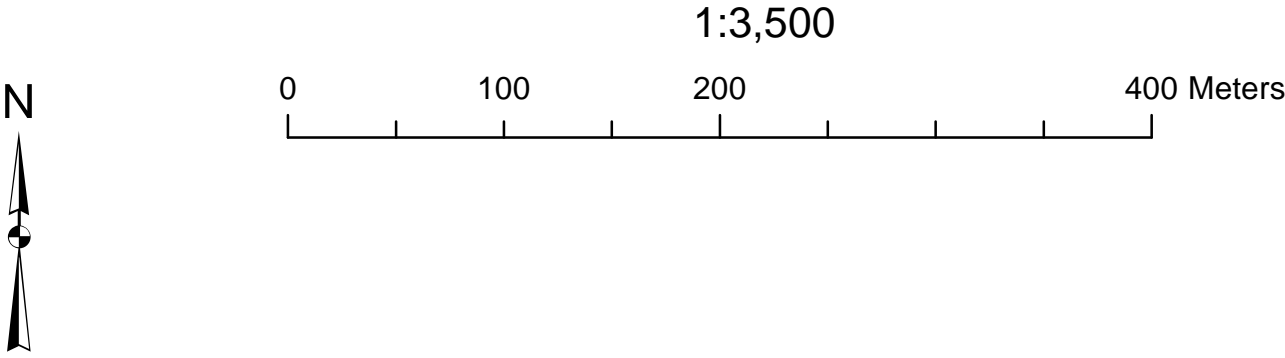
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Appendix B

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Bacher Construction - McClintock Quarry

PREVAILING METEOROLOGICAL CONDITIONS

Medians provided by Environment Canada

Date	Wind Direction	Wind Velocity Km/h	Temperature (Deg Celsius)
January	SE	17.4	-8.4
February	ESE	17.7	- 7.7
March	SE	19.3	- 2.1
April	SE	20.1	5.7
May	SE	16.8	12.9
June	SSE	14.3	17.1
July	WNW	14.2	20.6
August	WNW	14.1	19.4
September	WNW	15.1	14.8
October	WNW	16.1	8.2
November	WNW	17.5	2.2
December	WNW	17.7	- 4.8

** Data is not available specifically for the proposed quarry location.
   Nearest weather station is Orillia / Muskoka A (Gravenhurst area)
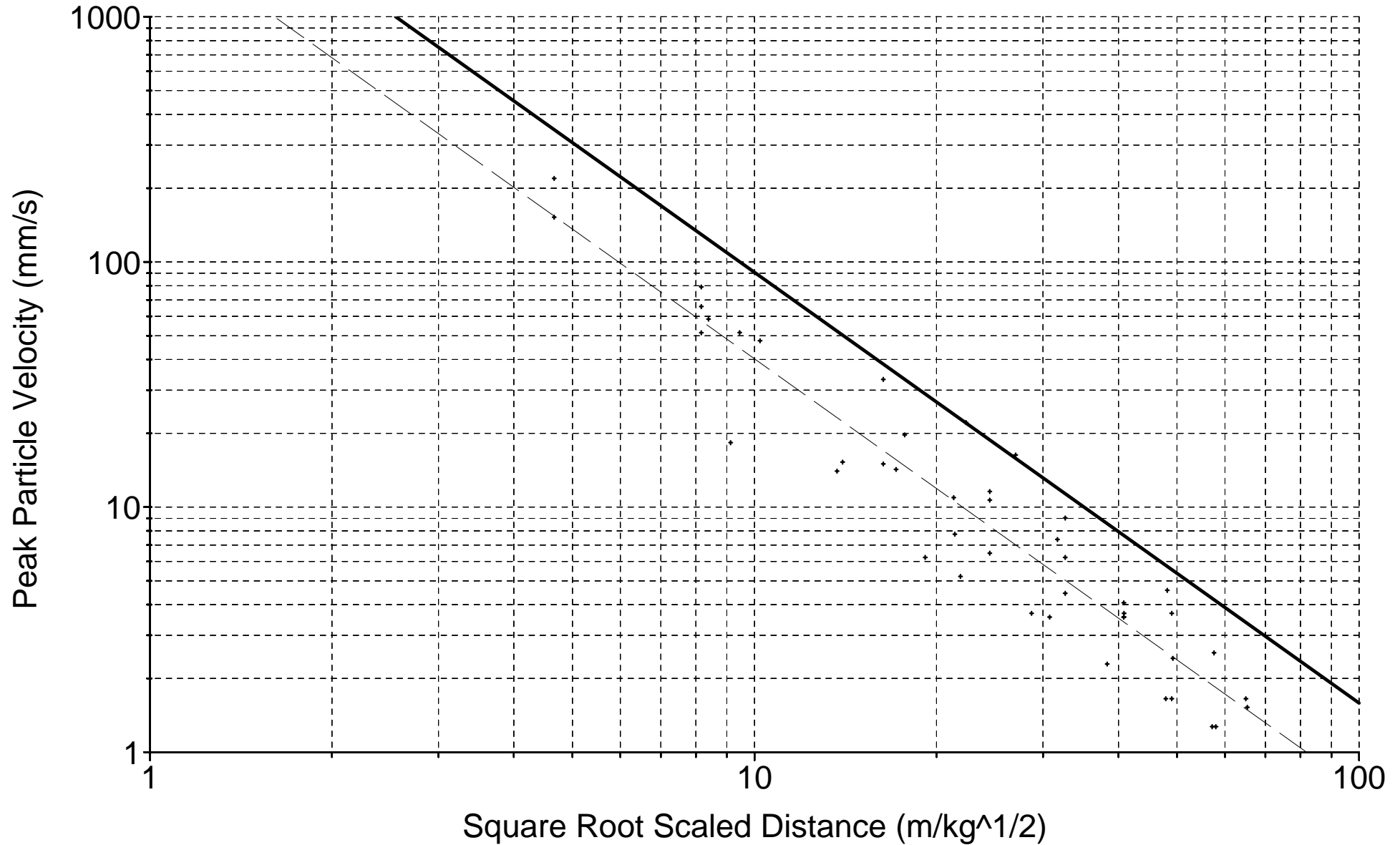** Data is based on averaged climate normals gathered 1951 – 1980.

Appendix C

Regression Behind the shot

Regression Line For GROUND VIBRATION BEHIND.SDF
95% Line Equation: V = 5175 * (SD)^(-1.76)
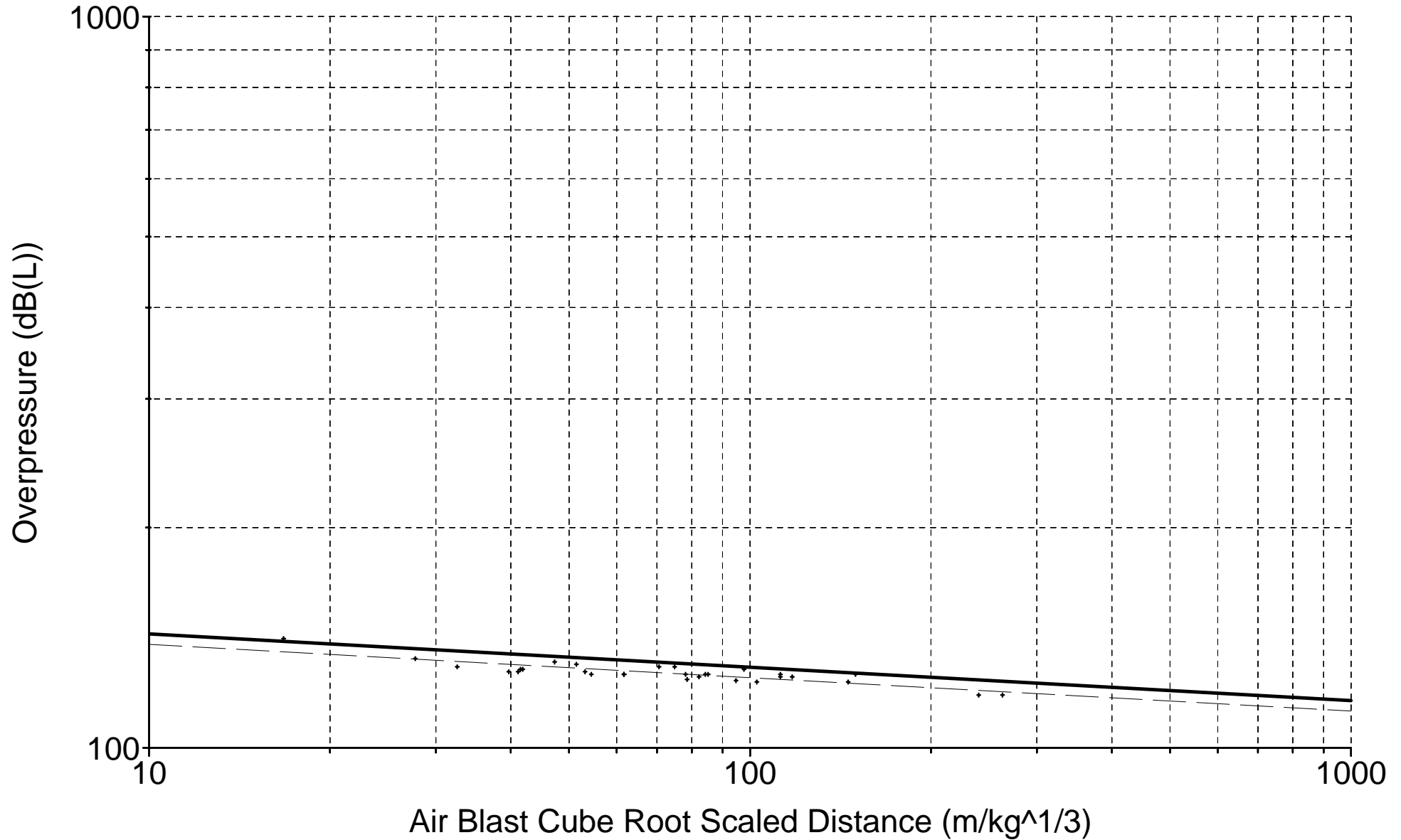### Coefficient of Determination = 0.903 Standard Deviation = 0.176

Regression analysis in front of the shot

Regression Line For OVERPRESSURE IN FRONT.SDF
95% Line Equation: V = 159 * (SD)^(-0.0456)
Coefficient of Determination = 0.731 Standard Deviation = 0.00714

Appendix D

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Specialists in Explosives, Blasting and Vibration
Consulting Engineers

Robert J. Cyr, P. Eng.

Principal, Explotech Engineering Ltd.

EDUCATION

Bachelor of Applied Science,
Civil Engineering, Queen's University

PROFESSIONAL AFFILIATIONS

Association of Professional Engineers of Ontario (APEO)
Association of Professional Engineers and Geoscientists of BC (APEG)
Association of Professional Engineers, Geologists and Geophysicists of Alberta
Association of Professional Engineers and Geoscientists of New Brunswick
Association of Professional Engineers of Nova Scotia
Association of Professional Engineers and Geoscientists Manitoba
Professional Engineers and Geoscientists Newfoundland and Labrador
International Society of Explosives Engineers (ISEE)
Aggregate Producers Association of Ontario (APAO)
Surface Blaster Ontario Licence 450109

SUMMARY OF EXPERIENCE

Over thirty years experience in many facets of the construction and mining industry has provided the expertise and experience required to efficiently and accurately address a comprehensive range of engineering and construction conditions. Sound technical training is reinforced by formidable practical experience providing the tools necessary for accurate, comprehensive analysis and application of feasible solutions. Recent focus on vibration analysis, blast monitoring, blast design, damage complaint investigation for explosives consumers and specialized consulting to various consulting engineering firms.

PROFESSIONAL RECORD

2001 – Present   -Principal, Explotech Engineering Ltd.

1996 – 2001   -Leo Alarie & Sons Limited - Project Engineer/Manager

1993 – 1996   -Rideau Oxford Developments Inc. – Project Manager

1982 – 1993:   -Alphe Cyr Ltd. – Project Coordinator/Manager

Mitch Malcomson, P.Eng.

Explotech Engineering Ltd.

EDUCATION

Bachelor of Engineering,
Civil Engineering with Concentration in Business Management,
Carleton University

PROFESSIONAL AFFILIATIONS

Association of Professional Engineers of Ontario (APEO)
International Society of Explosives Engineers (ISEE)

SUMMARY OF EXPERIENCE

A Civil Engineer and Project Organizer for Explotech Engineering Ltd. Mitch holds a Bachelor of Engineering degree from Carleton University in Civil Engineering with a Concentration in Business Management. Mitch has strong analytical, technical, business and leadership skills. Recent projects have focused on vibration analysis and the drilling and blasting portions of mining, quarrying and construction projects across Canada.

PROFESSIONAL RECORD

2008 – Present   - Engineer / Project Manager, Explotech Engineering Ltd.

Erik Hunnisett

Explotech Engineering Ltd.

EDUCATION

BA Philosophy
Nipissing University

PROFESSIONAL AFFILIATIONS

International Society of Explosives Engineers (ISEE)
Ontario Stone Sand and Gravel Association (OSSGA)

SUMMARY OF EXPERIENCE

A technician working for Explotech Engineering Ltd., Erik holds a Bachelor of Arts in Philosophy and has 10 years of experience in the blasting, construction and mining industries. Recognized as an effective communicator with the ability to enhance procedures while simultaneously monitoring compliance of Government regulations, Erik possesses the strong technical background necessary for accurate vibration data analysis as well as the interpersonal skills necessary to develop lasting client relationships and effectively resolve damage complaints.

PROFESSIONAL RECORD

2015 – Present   - Technician, Explotech Engineering Ltd.

2013 – 2015   - Account Manager, Nordex Explosives Ltd.

2008 – 2011   - Technician, Explotech Engineering Ltd.

2006 – 2008   - Summer Student, Explotech Engineering Ltd.

2005 – 2006   - Labourer, NWT Rock Services.

Appendix E

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Blasting Terminology

ANFO: Ammonium Nitrate and Fuel Oil – explosive product

ANFO WR: Water resistant ANFO

Blast Pattern: Array of blast holes

Body hole: Those blast holes behind the first row of holes (Face Holes)

Burden: Distance between the blast hole and a free face

Column: That portion of the blast hole above the required grade

Column Load: The portion of the explosive loaded above grade

Collar: That portion of the blast hole above the explosive column, filled with inert material, preferably clean crushed stone

Face Hole: The blast holes nearest the free face

Overpressure: A compressional wave in air caused by the direct action of the unconfined explosive or the direct action of confining material subjected to explosive loading.

Peak Particle Velocity: The rate of change of amplitude, usually measured in mm/s or in/s. This is the velocity or excitation of the particles in the ground resulting from vibratory motion.

Scaled distance: An equation relating separation distance between a blast and receptor to the energy (usually expressed as explosive weight) released at any given instant in time.

Spacing: Distance between blast holes

Stemming: Inert material, preferably clean crushed stone applied into the blast hole from the surface of the rock to the surface of the explosive in the blast hole.

Sub-grade: That portion of the blast hole drilled band loaded below the required grade

Toe Load: The portion of explosive loaded below grade