TECHNICAL MEMORANDUM

DATE September 25, 2012 **PROJECT No.** 11-1422-0046

TO Derek Holmes
BURNCO Rock Products Ltd

CC Kim Titus, BURNCO Rock Products Ltd; Les Cels, Inland Aggregates, Heidelberg Cement Group

FROM Zhaohui Yu, Virgini Senden **EMAIL** zhaohui_yu@golder.com, virgini_senden@golder.com

RE: TECHNICAL MEMORANDUM FOR BURNCO AGGREGATE PROJECT AT MCNAB CREEK/HOWE SOUND, BC – SOURCE MEASUREMENT PROGRAM FOR PINE RIDGES INLAND CLAMSHELL OPERATION IN MANITOBA

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by BURNCO Rock Products Ltd. (BURNCO) to conduct a Noise Impact Assessment (NIA) for their proposed BURNCO Aggregate Project at McNab Creek / Howe Sound (the Project). As part of the NIA for the Project, Golder will develop a computer noise model that will include representations of source acoustics of proposed equipment operating at the Project site. To obtain suitable inputs for the Project's computer noise model, noise source measurements of comparable equipment or similar scale equipment to that proposed for the Project were conducted at BURNCO and third-party aggregate and processing facilities in Alberta, British Columbia, and Manitoba during the summer of 2012. The following Technical Memorandum presents results from noise source measurements conducted at the Pine Ridges Inland aggregate mine in Manitoba.

Based on the Environmental Assessment Project description (Golder 2011) and information provided by BURNCO, a clamshell aggregate dredge will be used at the Project to excavate aggregate from an underwater pit. The dredge will comprise an electrically powered floating clamshell equipped with a screen system, a primary crusher, and a floating conveyor system. Golder conducted sound source measurements of a clamshell dredge at an operating aggregate pit at the Pine Ridges Inland aggregate mine. The clamshell dredge at Pine Ridge Inland site will be consistent to the equipment being proposed for use at the McNab site. The results of the sound source measurements are included in this Technical Memorandum.

2.0 SOUND SOURCES AT PINE RIDGES INLAND CLAMSHELL OPERATION AREA

The process of the operating the clamshell dredge consists of these steps:

- Dropping the clamshell dredge down deep into the pit;
- Grabbing and extracting sand and gravel below the water surface;
- Lifting sand and gravel in the dredge bucket out of the pit to the height of the dredge floats and track;
- Waiting while excess water is lost out of the dredge;
- Moving the dredge above the primary screens;

- Releasing sand and gravel from the clamshell dredge into the screens;
- (If necessary) transferring large rocks to the crusher and crushing them into smaller material sizes; and
- Moving screened aggregate on a conveyor system to stockpiles on shore.

The major sound sources observed at the Pine Ridges Inland clamshell operation area included:

- One floating clamshell dredge on the floating deck. Activity measured included digging gravel under water surface and release of material onto the screens. The main noise sources included the clamshell dredge electric motor, the falling water from the dredge bucket and the release of the gravel onto the screen.
- Two primary screens with motors on the floating deck;
- One water fine screen with motor on the floating deck;
- One primary crusher with motor on the floating deck;
- One conveyor system with motors installed on the bank of the pit;
- Falling sand and gravel from conveyors to screens and crushers;
- Several front end loaders on shore; and
- Several heavy duty trucks on shore.

Photo 1 shows the floating deck where the clamshell dredge with its track and its motor, screens with motors, crusher with motor, and operators' shed are located.

Photo 2 was taken from the bank of the pit, and the floating deck and part of the conveyor system are shown in this photo.

Photo 3 was taken on the edge of floating deck, and the clamshell dredge dumping water, two primary screens (blue), and one primary crusher (yellow) are shown in this photo.

Photo 1: Floating Deck and Equipment on Deck

Photo 2: Pit, Floating Deck and Conveyor System

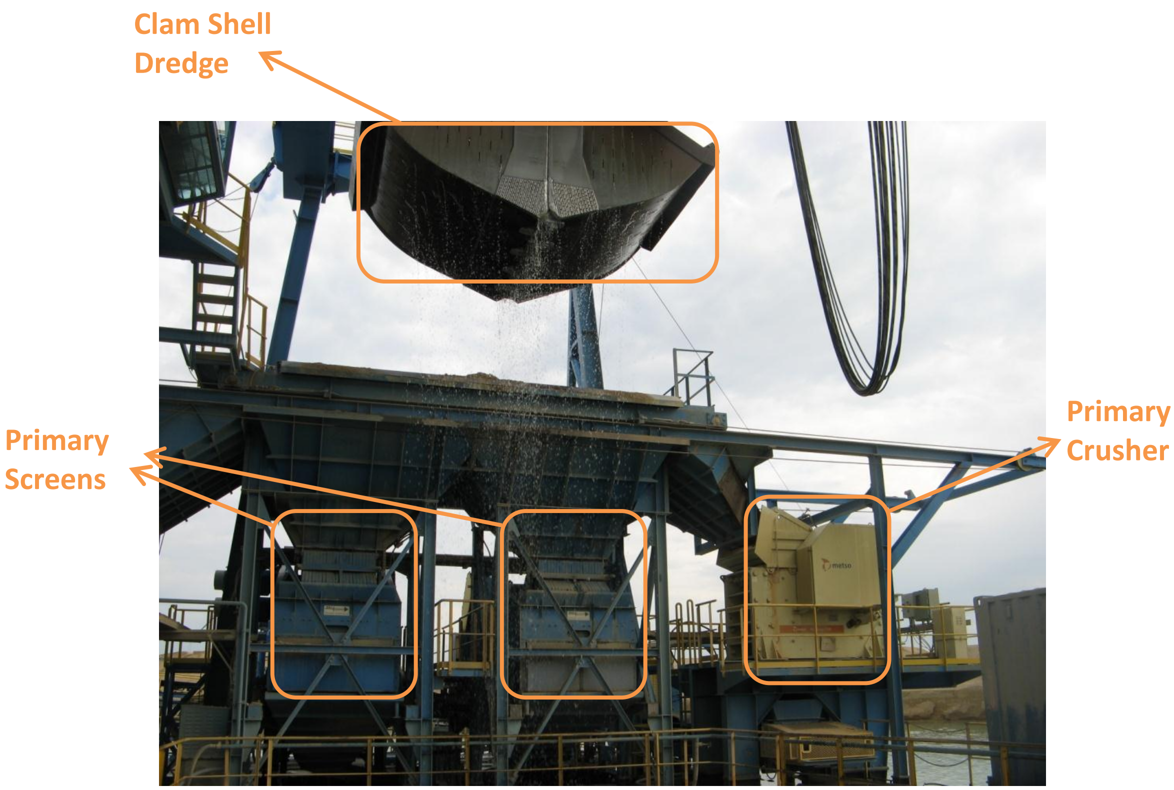

Photo 3: Screens, Crusher and Dredge

3.0 SOUND SOURCE MEASUREMENT METHODS AND RESULTS

Two methods, the envelope method (Section 3.1) and the concentrated source method (Section 3.2), were used to measure the sound pressure levels and calculate the sound power levels (PWLs) of the individual pieces of equipment and the operation area as a whole. The methods and results are described in the following sub-sections.

A Brüel and Kjær (B&K) model 2250 integrating sound level meter fitted with a B&K model 4189 outdoor microphone was used to measure sound pressure levels and collect audio recordings. A B&K model 4231 calibrator was used to field calibrate the meter before and after each day of measurements to ensure the sound meter's variance was within 0.5 dB. The calibrator has an estimated uncertainty for sound pressure level of ±0.12 dB at a 99% confidence level. The sound level meter was used to measure equivalent sound pressure level (L_{eq}) in A-weighted decibels (dBA) and in unweighted decibels (dB) for one-third octave bands between 20 Hz and 20 kHz. B&K software Acoustic Determinator V1.31 was used to process the measured sound pressure level data and to calculate the PWLs for each piece of equipment and for the clamshell dredge operation area as a whole.

3.1 Envelope Method

The envelope method is based on the Dutch Standard HMRI-II3 (B&K 2012). An imaginary envelope with the constant distance to the surface of the equipment was scanned by the B&K outdoor microphone unit. The equivalent sound pressure level L_{eq} was recorded for each measurement. Equation (1) was used to calculate the PWL of the sound source.

$$\mathrm{PWL} = \mathrm{L_{eq}} + 10\log(\mathrm{S_{meas}}) + \Delta\mathrm{L_F}, \quad (1)$$

where $\mathrm{S_{meas}}$ is the area of measurement surface and it is calculated from the dimensions of the imaginary envelope; $\Delta\mathrm{L_F}$ is the near field proximity correction.

Clamshell dredge screens and their motors, crusher and its motor, conveyor belts and their motors, and falling sand and gravel were measured and their PWLs were determined by envelope method. Because the distance between the measurement points and surface of the equipment was less than or equal to 0.5 m and measurement points were set up with the distance of more than 2 m to the other equipment, the contamination of the nearby equipment can be neglected.

3.1.1 Vibrating Screens

There were three vibrating screens, which are shown in Photos 1 - 3. Two of these screens were identical primary screens and the third one was a fine or water screen. The measurements were made for the imaginary envelope around each piece of equipment. The equivalent sound pressure level L_{eq} of the measurements was recorded by the sound level meter and PWL of the sound sources was determined by Equation (1). The measurement surface area S_{meas} was 36.9 m^2 for each primary screen and 22.9 m^2 for the fine screen.

Table 1 presents the recorded L_{eq} and calculated PWLs in octave bands (31.5 Hz ~ 8000 Hz) of these three screens.

Table 1: Recorded L_{eq} and calculated PWLs of Vibrating Screens

Equipment	Recorded L_{eq} / Calculated PWL	Central Frequencies of Octave Bands [Hz]									Overall
		32	63	125	250	500	1000	2000	4000	8000	
Primary Screen 1	L_{eq} [dBA]	75.1	83.7	77.7	83.4	90.7	86.0	85.1	80.7	77.4	94.2
	PWL [dBA]	90.8	99.4	93.3	99.1	106.4	101.7	100.8	96.4	93.1	109.9
Primary Screen 2	L_{eq} [dBA]	77.6	81.4	79.6	83.9	89.7	87.5	86.2	82.4	79.0	94.3
	PWL [dBA]	93.3	97.1	95.3	99.6	105.3	103.1	101.9	98.1	94.7	110.0
Fine Screen	L_{eq} [dBA]	69.5	77.8	72.2	75.2	78.9	76.8	75.7	74.9	73.3	85.2
	PWL [dBA]	83.1	91.4	85.8	88.8	92.5	90.4	89.3	88.5	87.0	98.8

3.1.2 Screen Motors

Each screen had two motors which are shown in Photo 4. L_{eq} of one pair of screen motors was measured by scanning the microphone along the imaginary envelope around the motors and PWL for the pair of screen motors was determined by the envelope method. The measurement surface area S_{meas} was 7.1 m^2.

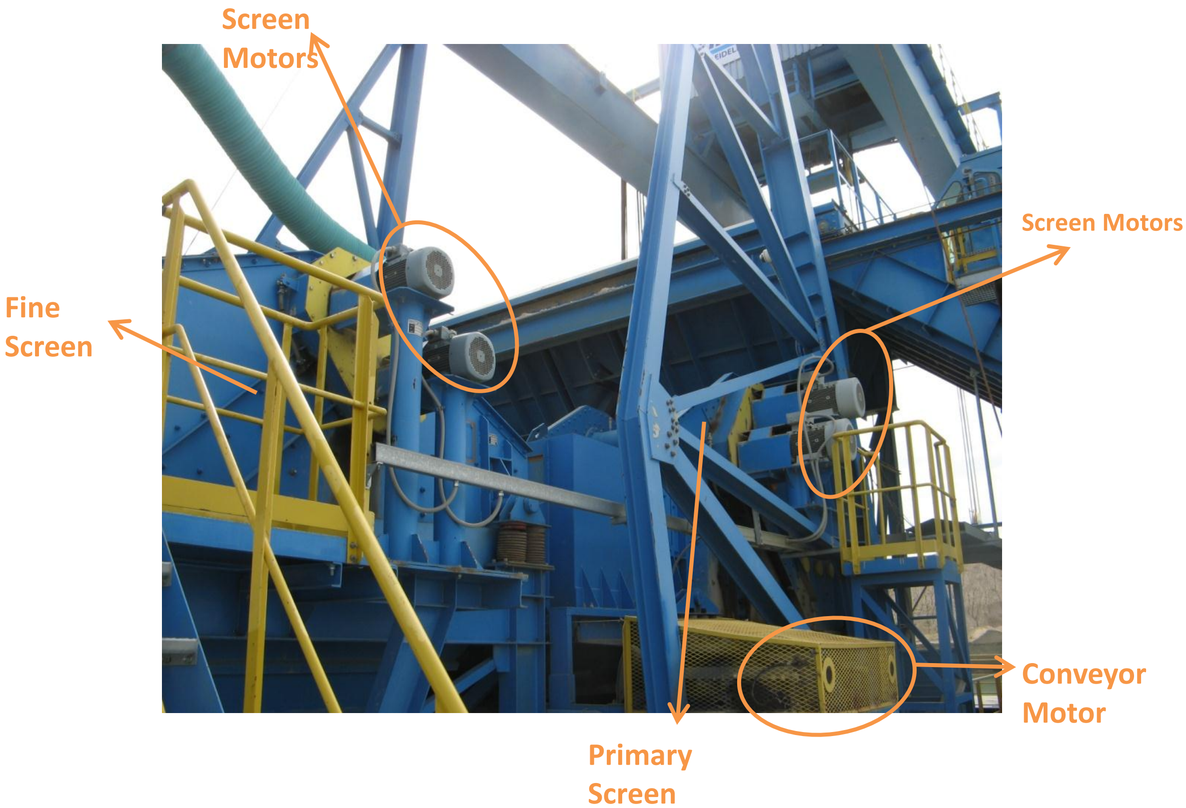

Photo 4: Screens with Motors

Table 2 presents the recorded L_{eq} and calculated PWLs in octave bands (31.5 Hz ~ 8000 Hz) of the pair of screen motors.

Table 2: Recorded L_{eq} and calculated PWLs of Screen Motors

Equipment	Recorded L_{eq} / Calculated PWL	Central Frequencies of Octave Bands [Hz]									Overall
		31.5	63	125	250	500	1000	2000	4000	8000	
Screen Motors	L_{eq} [dBA]	68.9	78.1	72.3	74.8	78.0	76.8	76.0	73.9	71.6	84.9
	PWL [dBA]	77.4	86.6	80.8	83.4	86.5	85.3	84.5	82.4	80.2	93.4

3.1.3 Primary Crusher

The primary crusher was the yellow coloured equipment beside the two primary screens shown in Photo 3. L_{eq} of the primary crusher was measured by scanning the microphone along the imaginary envelope around the crusher and PWL for the crusher was determined by the envelope method. The measurement surface area S_{meas} was 33.3 m^2.

Table 3 presents the recorded L_{eq} and calculated PWLs in octave bands (31.5 Hz ~ 8000 Hz) of the crusher.

Table 3: Recorded L_{eq} and calculated PWLs of Primary Crusher

Equipment	Recorded L_{eq} / Calculated PWL	Central Frequencies of Octave Bands [Hz]									Overall
		31.5	63	125	250	500	1000	2000	4000	8000	
Primary Crusher	L_{eq} [dBA]	61.4	74.3	81.0	87.0	91.9	92.3	88.4	80.6	73.7	96.7
	PWL [dBA]	76.6	89.6	96.2	102.2	107.1	107.5	103.7	95.8	88.9	112.0

3.1.4 Crusher Motor

There was one motor for the primary crusher. L_{eq} of crusher motor was measured by scanning the microphone along the imaginary envelope around the motor and PWL for the motor was determined by the envelope method. The measurement surface area S_{meas} was 3.5 m^2.

Table 4 presents the recorded average L_{eq} and calculated PWLs in octave bands (31.5 Hz ~ 8000 Hz) of the crusher motor.

Table 4: Recorded L_{eq} and calculated PWLs of Crusher Motor

Equipment	Recorded L_{eq} / Calculated PWL	Central Frequencies of Octave Bands [Hz]									Overall
		31.5	63	125	250	500	1000	2000	4000	8000	
Crusher Motor	L_{eq} [dBA]	59.5	69.6	69.8	75.8	79.4	79.6	78.3	76.2	73.8	85.7
	PWL [dBA]	65.0	75.1	75.3	81.3	84.9	85.1	83.8	81.7	79.2	91.2

3.1.5 Conveyor Belts

The conveyor system included at least six conveyor belt systems. Part of the conveyor system is shown in Photo 2. L_{eq} of one of conveyor belts was measured by scanning the microphone along the imaginary envelope around the conveyor belt and the PWL for the conveyor belt was determined by the envelope method. The measurement surface area S_{meas} was 28.0 m^2. The conveyor belt measured was 28 m long.

Table 5 presents the recorded L_{eq} and calculated PWLs in octave bands (31.5 Hz ~ 8000 Hz) of the conveyor belt.

Table 5: Recorded L_{eq} and calculated PWLs of Conveyor Belt

Equipment	Recorded L_{eq} /Calculated PWL	Central Frequencies of Octave Bands [Hz]									Overall
		31.5	63	125	250	500	1000	2000	4000	8000	
Conveyor Belt	L_{eq} [dBA]	46.8	49.9	58.8	68.2	70.8	69.4	68.7	67.6	63.2	76.4
	PWL [dBA]	61.3	64.4	73.2	82.7	85.3	83.9	83.2	82.1	77.7	90.9

3.1.6 Conveyor Motors

Each conveyor belt had one motor on the end. L_{eq} of one of conveyor motors was measured by scanning the microphone along the imaginary envelope around the motor and PWL for the conveyor motor was determined by the envelope method. The measurement surface area S_{meas} was 2.8 m^2.

Table 6 presents the recorded L_{eq} and calculated PWLs in octave bands (31.5 Hz ~ 8000 Hz) of the conveyor motor.

Table 6: Recorded L_{eq} and calculated PWLs of Conveyor Motor

Equipment	Recorded L_{eq} / Calculated PWL	Central Frequencies of Octave Bands [Hz]									Overall
		31.5	63	125	250	500	1000	2000	4000	8000	
Conveyor Motor	L_{eq} [dBA]	61.6	66.3	69.0	75.9	84.2	79.1	76.7	71.8	69.1	86.7
	PWL [dBA]	66.1	70.7	73.4	80.4	88.6	83.5	81.1	76.3	73.5	91.1

3.1.7 Falling Sand/Gravel

There was 1 inch to 2 inch size gravels combined with approximately 50 percent sand falling from screens to conveyors and from one conveyor belt to another. L_{eq} of falling sand/gravel from one conveyor to another was measured by scanning the microphone along the imaginary envelope around the falling sand/gravel and PWL for the falling sand/gravel was determined by the envelope method. The measurement surface area S_{meas} was 2.0 m^2.

Table 7 presents the recorded L_{eq} and calculated PWLs in octave bands (31.5 Hz ~ 8000 Hz) of the falling sand/gravel.

Table 7: Recorded L_{eq} and calculated PWLs of falling Sand/Gravel

Sound Source	Recorded L_{eq} / Calculated PWL	Central Frequencies of Octave Bands [Hz]									Overall
		31.5	63	125	250	500	1000	2000	4000	8000	
Falling Sand/Gravel	L_{eq} [dBA]	49.6	55.2	67.3	76.1	80.6	84.4	85.4	83.6	79.5	90.4
	PWL [dBA]	52.7	58.2	70.3	79.1	83.6	87.5	88.4	86.6	82.5	93.4

3.2 Concentrated Source Measurement Method

The concentrated source measurement method is based on the Dutch Standard HMRI-II2 (B&K 2012). The distance between measurement location and sound source should be at least 2 times the longest dimension of the source so that the measurement location can be considered to be in the far field of the sound source. The measurement location should be set up with no obstructions between source and receiver location and no objects close to the microphone. The measurement location should be in the free field with no reverberation around the measurement point. The B&K outdoor microphone unit was used to record the L_{eq} at the measurement location. Equation (2) was used to calculate the sound power level (PWL) of the sound source.

$$\mathrm{PWL} = \mathrm{L_{eq}} + 10\log(\mathrm{D_{geo}}) + \mathrm{C}, \quad (2)$$

where $\mathrm{D_{geo}}$ is the geometric spreading and is calculated for the imaginary whole sphere or half sphere around the source depending on the distance between the source and the ground:

$$\mathrm{D_{geo}} = \begin{matrix} 4\pi r^2 & \text{for the whole sphere} \\ 2\pi r^2 & \text{for the half sphere} \end{matrix}, \quad (3)$$

and r is the average distance between the measurement point and sound source; C is a correction term which accounts for ground attenuation and air absorption.

The clamshell dredge, front end loader, and heavy duty truck were measured and their PWLs were determined by the concentrated source method. In addition, for the purposes of calibration and confirmation, two measurement points were set up in the far field of the whole clamshell operation area and the PWLs of the entire clamshell operation were calculated by concentrated source method.

3.2.1 Clamshell Dredge

The envelope method could not be applied to the clamshell dredge given water access issueses. Instead, the concentrated source method was used to determine the PWL of clamshell dredge. The measurement was set up on the end of the floating deck. The screens and crusher were located on the opposite side of the deck, shown in Photo 3, farther away from the measurement location. The crusher with motor was turned on only for sound source testing purpose and was turned off for the rest of the measurement period, so there was not contamination from the crusher. Contamination from the screens was estimated to be about 2 dB based on individual calculations for these pieces of equipment. A correction of 2 dB was therefore applied to the measured L_{eq} before calculating the PWL of the clamshell dredge with Equation (2). The average measurement distance was 8 m. Because of the height of the main source the geometric spreading was calculated for a whole sphere.

Table 8 presents the recorded L_{eq} and calculated PWLs in octave bands (31.5 Hz ~ 8000 Hz) of the clamshell dredge.

Table 8: Recorded L_{eq} and calculated PWLs of Clamshell Dredge

Sound Source	Recorded L_{eq} / Calculated PWL	Central Frequencies of Octave Bands [Hz]									Overall
		31.5	63	125	250	500	1000	2000	4000	8000	
Clamshell Dredge	L_{eq} [dBA]	57.0	64.1	61.8	70.8	77.2	74.4	73.3	69.3	67.3	81.2
	PWL [dBA]	84.1	91.2	88.9	97.9	104.3	101.5	100.4	96.4	94.4	108.3

3.2.2 Front End Loaders

Several front end loaders were loading trucks beside the stockpiles on the shore of the aggregate pit. Source measurements were made for one of the front end loaders when it was taking material from the stockpiles and dumping it into nearby trucks. The measurements were taken when the clamshell operation was shut down for repairs and trucks were waiting for loading. No contamination from other sources was observed at the time of the front end loader source measurement. There was a free line of sight to the loading activities and the front end loader was not shielded by the truck. The concentrated source method was used to determine the PWL of the front end loader. The average measurement distance was 152 m. The geometric spreading D_{geo} was calculated for a half sphere.

Table 9 presents the recorded L_{eq} and calculated PWLs in octave bands (31.5 Hz ~ 8000 Hz) of the front end loader.

Table 9: Recorded L_{eq} and calculated PWLs of Front End Loader

Sound Source	Recorded L_{eq} / Calculated PWL	Central Frequencies of Octave Bands [Hz]									Overall
		31.5	63	125	250	500	1000	2000	4000	8000	
Front End Loader	L_{eq} [dBA]	30.1	44.2	40.3	41.1	40.7	41.6	38.5	27.9	20.3	49.3
	PWL [dBA]	78.8	92.9	92.9	93.9	93.6	94.7	92.1	83.4	83.2	101.4

3.2.3 Heavy Duty Trucks

Several heavy duty trucks were transporting resources in the stockpile area (Photo 5). The concentrated source method was used to determine the PWL of the truck. The nearest measurement distance was 21 m. The speed of the truck was estimated to be 20 to 30 km/hr. The maximum noise level (L_{max}) in dBA was used to calculate the PWL of the heavy duty truck. The geometric spreading D_{geo} was calculated for a half sphere.

Photo 5: Heavy Duty Truck

Table 10 presents the recorded maximum noise level L_{max} and calculated PWLs in octave bands (31.5 Hz ~ 8000 Hz) of the truck.

Table 10: Recorded L_{max} and calculated PWLs of Heavy Duty Truck

Sound Source	Recorded Lmax / Calculated PWL	Central Frequencies of Octave Bands [Hz]									Overall
		31.5	63	125	250	500	1000	2000	4000	8000	
Heavy Duty Truck	L_{max} [dBA]	35.5	57.1	64.4	66.3	69.2	64.8	61.1	54.7	52.4	73.2
	PWL [dBA]	66.9	88.6	99.9	101.8	104.7	100.3	96.7	90.5	89.3	108.6

3.2.4 Clamshell Operation Area as a Whole

Two measurements were made for the clamshell operation area as a whole. The purpose of these measurements was to confirm the accuracy of the measurements of the individual pieces of equipment. The average measurement distances between the microphone location and primary screens, which were considered to be the source center, were 103 m and 95 m, respectively for these two measurements. The geometric spreading D_{geo} was calculated for a half sphere.

Table 11 presents the recorded L_{eq} and calculated PWLs in octave bands (31.5 Hz ~ 8000 Hz) of the whole clamshell operation area.

The estimated PWLs of the individual pieces of operating equipment – screens with motors, conveyor belts with motors, clamshell dredge, falling sand/gravel, were combined to estimate the PWL of the whole clamshell operation area. The crusher with motor was not included because the equipment was turned on only for sound source testing purpose and was turned off for the rest of the measurement period. The screens were not loaded all the time. An estimated 60% operation time was given for the loaded screens. The sum of PWLs of the operating equipment is shown in Table 11, as well.

The PWLs of the measurements for the clamshell operation area as a whole are about 1 dB lower than the sum of estimated PWLs of operating equipment. This is considered to be a very good agreement in light of uncertainty inherent to field measurements. One reason the measurements of the clamshell operation as a whole is slightly lower than the sum of the individual pieces of equipment is likely due to screening – i.e., the physical presence of one piece of equipment partially blocks the sound energy from another piece of equipment from reaching the measurement location.

Table 11: Recorded L_{eq} and calculated PWLs of Whole Clamshell Operation Area and Comparison with Sum of Estimated PWLs of Operating Equipment

Whole Clamshell Operation Area	Recorded L_{eq} / PWL	Central Frequencies of Octave Bands [Hz]									Overall
		31.5	63	125	250	500	1000	2000	4000	8000	
Measurement 1	L_{eq} [dBA]	47.9	48.0	45.3	52.1	57.5	56.4	56.6	49.8	39.6	62.7
	PWL [dBA]	93.2	93.2	94.5	101.4	106.9	106.0	106.5	101.0	95.8	112.3
Measurement 2	L_{eq} [dBA]	39.3	46.2	46.5	52.5	58.1	57.6	56.9	49.3	42.0	63.2
	PWL [dBA]	83.9	90.7	95.1	101.1	106.8	106.4	106.0	99.6	96.9	112.1
Sum of PWLs of Operating Equipment Based on Individual Measurements	PWL [dBA]	93.9	100.4	96.5	102.5	108.8	105.7	104.7	100.9	98.1	112.9

4.0 DISCUSSION AND SUMMARY

The measurement results are presented in this Technical Memorandum. The sound source measurement data will be used to model similar scale equipment for the BURNCO aggregate facility at McNab Creek/Howe Sound. The equipment in the clamshell operation area was measured and their PWLs were determined by envelope method or concentrated source method. The whole operation area was measured and its PWL was determined by concentrated source method. The sum of the individual measurements and the overall measurement are consistent and in agreement.

5.0 CLOSURE

We trust that the above meets your present requirements. If you have any questions or require additional details, please contact the undersigned.

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6.0 REFERENCES

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