

REPORT

Long-Term Vibration Monitoring Interim Report No. 1
Nation Rise Wind Farm, Stormont, Ontario

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Executive Summary

This report summarizes the results of seven months of vibration monitoring carried out for the Nation Rise Wind Farm project (NRWF), completed as part of Section K of the Renewable Energy Approval (REA) document No. 0871-AV3TFM issued by the Ontario Ministry of the Environment and Climate Change (MOECC) (now the Ontario Ministry of the Environment, Conservation and Parks (MECP)) in May 2018. The vibration monitoring program documented in this report addresses the long-term collection and interpretation of ground-borne vibration data during commercial operations of the NRWF, as required under a separate work plan reviewed and approved by the MECP. For the purpose of this report, ground-borne vibration levels are reported in terms of peak particle velocity (PPV), as defined in Section 3.0. .

The intent of the work described in this report was to evaluate the surface and subsurface magnitudes, propagation and attenuation characteristics of ground vibrations associated with the first seven months of operation of the NRWF since the Commercial Operating Date (COD) was granted on June 14, 2021; accordingly, the period of record for this report extends from June 14, 2021 to January 14, 2022. The expectation is that monitoring data analyses will be updated on an annual basis following the submission of this report.

Vibration monitoring and groundwater pressure data collected during the first seven months of turbine operations at the NRWF demonstrates:

- the largest vibration magnitudes, occurring at a frequency range of about >1 to 80 Hz, at the top of the mock well casings were on the order of 0.008 millimetres per second (mm/s), 0.054 mm/s and 0.002 mm/s at distances of about 50 metres (m), 65 m and 75 m, respectively, from the turbine centres;
- the largest vibration magnitudes, occurring at a frequency range of about >1 to 80 Hz, in the bedrock at each mock well location were on the order of 0.005 mm/s, 0.013 mm/s and 0.003 mm/s at a distance of about 50 m, 65 m and 75 m, respectively, from the turbine centres;
- vibration magnitudes at the mock well tops (near ground surface) were reasonably similar to those measured in the bedrock given the local ground density or stiffness conditions;
- vibration magnitudes at all of the mock wells, in bedrock or at the top of the mock well casings, were less than any of the thresholds identified within MECP guidelines¹ NPC-233, NPC-103 and NPC-207;
- maximum seasonal groundwater pressure changes at the mock wells ranged from about 12 kilopascals (kPa) at T32 to about 20 kPa at T46;
- maximum short-term (hourly and daily) groundwater pressure changes at the mock wells ranged from about 0.02 to 0.15 kPa and no clear relationship between ground vibration velocity or frequency could be discerned from the data;
- available data indicate that ground vibrations are unrelated to changes in short- or long-term groundwater pressure changes;

¹ Produced and published under multiple predecessor Government of Ontario agency names.

- at about 500 m from the turbines and beyond, and as shown herein, vibrations in the bedrock and at the ground surface would be expected to be on the order of 1×10^{-3} mm/s, or less, well below the threshold of human perception and $1/300^{\text{th}}$ of the lowest MECP regulatory threshold; and
- vibrations of the magnitude and frequency measured during the seven months of operation at distances greater than 500 m from the turbines would be expected to be inconsequential with respect to performance of water wells in the region.

This summary report does not separate and evaluate the influence of wind direction or constructive and destructive waveform interference and, instead, the report focuses on the largest ground vibration measurements that would have, necessarily, included the influences of such factors.

Data gathered as part of the long-term ground-borne vibration monitoring program at the NRWF site demonstrates that, while the measurements of vibrations at large distances from the wind turbines are of scientific interest and comparable to published research, the vibration magnitudes are extremely small and of no consequence to water wells in the area, regardless of wind direction or velocity and any potential for constructive vibration waveform interference.

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1.0 INTRODUCTION

WSP Golder (formerly Golder Associates Ltd., now a member of WSP Canada Inc.) has been retained by EDP Renewables Canada Ltd. (EDPR) to provide geotechnical engineering services for the Nation Rise Wind Farm Project (NRWF). This report summarizes the results of seven months of vibration monitoring carried out for the NRWF completed as part of Section K of the Renewable Energy Approval (REA) document No. 0871-AV3TFM issued by the Ontario Ministry of the Environment and Climate Change (MOECC) (now the Ontario Ministry of the Environment, Conservation and Parks (MECP)) in May 2018. The vibration monitoring program documented in this report addresses long-term data collection and interpretation of ground-borne vibrations described in the following work plan that was reviewed and approved by the MECP on October 16, 2020:

- Vibration Monitoring Program, Nation Rise Wind Farm, Stormont, Ontario, 19120626-1000-T01-Rev2, dated August 26, 2020.

The intent this report was to evaluate and describe the surface and subsurface magnitudes, propagation and attenuation characteristics of ground vibrations associated with the operation of wind turbines constructed within the boundaries of the NRWF. This report focuses on:

- vibration amplitudes and frequencies at 3 selected turbine sites, one of which was associated with a pair of turbines constructed within about 50 and 385 metres (m) of the instrumented turbine site (see T10/T11 site description), as recorded between June 14, 2021 (the Commercial Operating Date (COD)) to January 14, 2022;
- vibration amplitudes and frequencies in subsurface bedrock formations at known distances from the turbine locations;
- vibrations amplitudes and frequencies of steel casings installed to mimic local ground water supply well casings (i.e., mock well casings);
- actual vibration attenuation characteristics as compared to published research; and
- comparison of measured vibrations to regulatory thresholds (i.e., MECP's noise and vibration publications / NPC-207 criteria) .

This report presents:

- a description of the sources of vibrations;
- the subsurface conditions at the NRWF turbine sites;
- vibration monitoring systems and locations;
- a summary of the vibration monitoring data gathered during turbine operation within the period of record; and
- interpretations of the data.

The expectation is that monitoring data analyses will be updated on an annual basis following the submission of this report.

Where applicable, this report also references "Information to be Submitted for Approval of Stationary Sources of Sound (NPC-233)" and the two relevant references cited in NPC-233 "Procedures (NPC-103)" and "Impulse

Vibration in Residential Buildings, (NPC-207)” as published by MECP and predecessor agencies. The MECP NPC-233, NPC-103 and NPC-207 documents have been referenced for guidance related to background information and data provided in vibration monitoring reports and the thresholds for human perception of vibrations as a means for comparison purposes.

This report should be read in conjunction with the attached document “Important Information and Limitations of This Report”, which comprises an integral component hereof. The reader’s attention is specifically drawn to this material, as it is essential for proper use and interpretation of the information presented and discussed herein.

2.0 PROJECT DESCRIPTION

Twenty-nine wind turbines were constructed for the NRWF project within the Municipality of North Stormont and the United Counties of Stormont, Dundas, and Glengarry, Ontario at the locations illustrated on Figure 1. The wind power facility is situated within a region with a relatively flat topography, dominated by agricultural land use including dairy, corn, and soybean farms. The turbines were manufactured by Enercon (model E-138 EP3) with hub heights of 131 m, rotor diameters of 138.6 m, blade lengths of 66.9 m and a power rating of 3.44 megawatts (MW). Turbine specifications are provided in Appendix A.

Each turbine is supported by a 23.5-m diameter reinforced circular gravity base foundation. Due to the differing geologic conditions throughout the wind farm site (as described in Tulloch Engineering Report No. 184022-20-2050-001 entitled “Geotechnical Report, Nation Rise Wind Farm Project, Wind Turbine Generator Foundations”, dated March 2019) the gravity bases for different groups of wind turbines were founded either on shallow bedrock, on glacial till overlying bedrock, or on soft glaciomarine clay overlying glacial till. Sites that are the subject of study for the long-term monitoring have wind turbine bases founded on glacial till overlying bedrock (i.e., wind turbines T10, T11 and T46) and on shallow bedrock (wind turbine T32). The as-built drawing No. NRS-01-SW-000 issued for construction, and provided by EDPR to WSP Golder, shows the general ground surface elevation at the different, proposed underside of footing elevations, excavation depths, and foundation type at each wind turbine site. Table 1, below, was compiled with information for turbines T10, 11, T32 and T46.

Table 1: Construction Specifications for Wind Turbines T10, T11, T32 and T46.

Turbine ID	Ground Surface Elevation (masl)	Under Side of Footing Elevation (masl)	Excavation Elevation (masl)
T10	74.75	72.38	72.28
T11	74.00	71.23	71.13
T32	73.12	70.53	69.01
T46	86.25	83.64	83.54

For the construction of the wind turbine bases at the T10, T11 and T46 locations, the project specifications called for pouring a 100-millimetre (mm) thick lean concrete mud mat between the underside of the footing and the surface of the glacial till deposit. For turbine T32 a layer of compacted Granular A fill with a thickness of about 1.5 m was to be placed between the underside of the base and the exposed bedrock surface. As indicated in the as-built drawings provided by EDPR, the foundation bases were backfilled with recompacted material from the excavations.

In general, the wind turbine power facility was delivered in three stages: 1) construction; 2) commissioning; and 3) operation. Following access road and foundation construction, the turbine towers, nacelles, blades and power control and transmission systems were installed. Construction of these systems was completed in late December 2021. Commissioning of the turbines included testing of all power generating, emergency braking, power transmission, control and data systems on an individual turbine-by-turbine basis took place during the period of December 2020 through May 2021. The Commercial Operating Date (COD) was granted on June 14, 2021.

3.0 GROUND VIBRATIONS – BACKGROUND

Ground vibrations are caused by many every-day sources which may include normal road traffic, wind forces on structures and trees, wave impact on shorelines, railway traffic and construction among others. Seismic activity (earthquakes) is another natural source of large ground motion. Sources related to human activities include stationary and mobile machinery of all different sizes where the machinery is in contact with the ground, and construction operations such as soil compaction and pile driving for example. Much like ripples caused by dropping a stone in a pond, ground vibrations propagate radially in all directions from the source. As the ripples propagate away from the source, the amplitude (height of the wave) and frequency (e.g., time between wave peaks or troughs)² decreases. The rate at which the amplitude and frequency decrease is related to the physical character of the material (e.g., density, etc.) through which the wave propagates. Vibrations are usually described in terms of time and displacement, such as velocity or acceleration. For example, the distance a particle of ground (or water) moves up and down (displacement) as the wave propagates through the medium will be measured in units of length (e.g., millimetres). This average particle velocity is the distance that the particle travels in a given time (e.g., seconds). This same particle will also, however, accelerate from rest, to a maximum (peak) velocity before it decelerates and reverses direction in the pattern of wave oscillation. Wave velocity can also be used to express the speed at which a wave crest (or trough or any other part of the wave) travels through the medium (ground, water, steel, etc.) away from the source. Velocity of a particle moving up and down (or side to side) from trough to crest and back again in an oscillating wave, however, should not be confused with the possible or characteristic velocity that a moving vibration wave crest can pass through the medium.

For simple, harmonic motion (e.g., uniform waves), the mathematics relating acceleration, displacement, velocity and time can be summarized as³:

$$V = \frac{d}{dt}D = \int A dt$$

$$A = \frac{d}{dt}V = \frac{d^2}{dt^2}D$$

and, for a simple sine wave function, at peak values when the trigonometric function is equal to 1, these equations reduce to:

² measured in cycles per second or Hertz, Hz

³ See, for example, Fundamentals of Physics, 3rd Edition, by D. Halliday and R. Resnick, 1988 or USBM RI 8507 (see references at conclusion of text).

$$D_o = \frac{V_o}{2\pi f} = \frac{A_o}{(2\pi f)^2}$$

$$V_o = 2\pi f D_o = \frac{A_o}{2\pi f}$$

$$A_o = (2\pi f)^2 D_o = 2\pi f V_o$$

where:

A and A_o = acceleration and peak acceleration, respectively;

D and D_o = displacement and peak displacement, respectively;

V and V_o = velocity and peak velocity, respectively;

f = frequency;

Complex and transient vibrations, such as those created by construction, cannot be approximated by the basic equations noted above in isolation and usually computer-aided waveform⁴ analysis programs and reasonable approximations or simplifications are made. When characterizing ground vibrations as related to human perception and damage criteria, the most common parameters are frequency along with fractions of gravitational acceleration (g , with a value $1 g = 9.81 \text{ m/second}^2$), peak particle velocity (PPV)⁵ or root mean square (RMS) velocity⁵. Within this report, acceleration and PPV are used along with frequency to characterize the measured ground vibrations. For the purpose of this report, ground-borne vibration levels are reported in terms of PPV. Methods of evaluating the complex vibrations are also described in subsequent sections of this report.

Site-specific data collected, analysed and interpreted in this report can also be compared to published research, engineering practice (e.g., CALTRANS 2004) and MECP regulatory threshold values (e.g., NPC-207-2 and NPC-207-3). Typical vibration magnitudes associated with other causes, vibration thresholds for different conditions and the MECP regulatory thresholds are summarized in Table 2 and Table 3, below:

⁴ velocity or acceleration wave patterns as related to time

⁵ Peak particle velocity (PPV) is the maximum oscillation speed of a particular particle (of ground in this case) as it driven by a passing displacement wave. Typically, peak particle velocity is measured in three mutually perpendicular directions and maximum vector resultant is used to describe the vibration intensity. Peak particle velocity is the most common parameter used for defining threshold vibration amplitudes associated with construction and blasting. Other systems measure, report and limit vibrations based on the root mean square (RMS) velocity. The RMS velocity is the square root of the average of individual velocity measurements squared, typically calculated over a time interval of one second. The RMS amplitude is always less than the peak particle velocity and the two can be related through a "crest factor" that is defined as the peak particle velocity divided by the RMS velocity. The US Federal Transit Administration guidance on noise and ground-borne vibration notes that the crest factor is "...always greater than 1.71, although a crest factor of 8 or more is not unusual for impulsive signals." Sometimes, vibrations are also reported in terms of decibels (VdB) calculated as 20 times the logarithm (base 10) of RMS velocity divided by a reference velocity. Accepted reference vibration velocities are 1×10^{-6} inches/second in the U.S. and 1×10^{-8} m/s or 5×10^{-8} m/s elsewhere (FTA 2006).

Table 2: Examples of the effects, thresholds or conditions associated with small magnitude ground vibrations⁶

PPV (mm/s)	Effect or Condition
2 – 30	Pile driving in soft ground at 1 to 3 m from hammer using vibratory and impact hammers
23	Close-proximity nail driving in residential structure
2.5 – 12	Equates to normal daily family activity within residential structure
3 – 9	Vibration limits for pumps ranging from 10 horsepower (hp) to 3000 hp
7.6	Equivalent to jumping on floor of residential structure
6	Transient vibrations distinctly perceptible
5	Steady-state vibrations - annoying
2.5	Truck traffic on bumpy road at 16 m
2.3	Large bulldozer at 7.6 m
1.9	Loaded trucks at 7.6 m
1	Steady-state vibrations readily perceptible
1	Transient vibrations barely perceptible
0.8	Steady-state threshold for workshop
0.8	Equivalent to walking on floor of residential structure
0.8	Small bulldozer at 7.6 m
0.76	Vehicle traffic at 16 m
0.15 – 0.5	Steady-state vibrations threshold of perception
0.4	Steady-state threshold for office
0.3	Steady-state vibrations slightly perceptible
0.2	Steady-state threshold for residence
0.1	Steady-state threshold for hospital operating room
0.025	Quiet background

⁶ See references at conclusion of report text for cited vibration magnitudes, their causes, and other thresholds.

Table 3: Vibration Limits for Human Perception as Defined in NPC-207-2 and NPC-207-3

Applicable Clause	Observation Period	Limit on the Average Peak Vibration Velocity (mm/s)	
		Daytime	Nighttime
<i>Vibration Limits for Frequent Impulses</i>			
4(4)(b)	≤20 minutes	0.3	0.3
4(4)(c)(i)	20 < period ≤ 60 minutes	0.6	0.3
4(4)(c)(ii)	60 < period ≤ 120 minutes	1.0	0.3
<i>Vibration Limits for Infrequent Impulses</i>			
4(4)(c)(iii)	120 minutes	10.0	0.3

Note: mm/s = millimetres per second.

4.0 INSTRUMENTATION

Turbine sites T10/T11, T32 and T46 were selected for long-term vibration monitoring. The main rationale for the selected turbine locations was based on having the instrumented turbine sites spread out geographically throughout the wind farm. Turbine T10, within the T10/T11 group, was specifically identified for monitoring because these two turbines are in relatively close proximity to one another and, if there were to be concerns related to constructive or destructive interference of ground vibrations, these turbines could be shut down and/or operated independently to measure the relative differences (if any) in ground vibration characteristics. Moreover, due to the differing ground conditions throughout the NRWF, and to capture the influence of these various conditions, the T32 turbine site was selected as the turbine base is founded close to shallow bedrock. Consistent with published research and case histories, vibration magnitudes and frequencies were expected to change and diminish with increasing distance from the source (turbines in this case). Therefore, the instrumented turbine locations were chosen:

- to result in a diversity of turbine to turbine and turbine to vibration monitoring device distances;
- to offer a potential for evaluating hypotheses related to constructive vibration interference; and
- to potentially reduce the influence of background conditions by selecting sites for mock wells as far as practicable from busy rural roads.

4.1 Long-Term Vibration Monitoring Equipment

Figures 1 through 4, attached, illustrate the locations of all instrumented turbine sites and the instrumentation at each turbine is discussed below, in order of turbine number. In general, the equipment installed at each of the turbine sites consisted of the following:

- a 128-millimetre (mm) outside diameter steel casing installed within a drilled borehole, used to mimic the responses of a residential water well typical to the region; within this report, these casings are referred to as “mock” wells;

- a set of 3 accelerometers attached to the top of the mock well casing to measure well casing vibrations at or near the ground surface;
- a set of 3 accelerometers installed within the bedrock below the mock well casings;
- a conventional 50-mm diameter groundwater observation well installed near the mock well to measure groundwater levels (and pressures using pressure transducers);
- a vibrating wire water pressure transducer installed in a nearby borehole as a secondary groundwater pressure measuring device;
- electronic data logging systems; and
- solar and battery power systems.

Laboratory verification of accelerometer calibration was completed with a portable controlled vibration source before accelerometers were installed within the steel housings for in-rock installation at the mock well locations. Field verification of accelerometer calibration of all other accelerometers was completed with a portable controlled vibration source before accelerometers were installed on the well casings, turbine foundations and the turbine tower. Specifications, calibration and verification information for all the instruments are provided in Appendix B.

4.1.1 Accelerometers

The instrumentation design commonly used three accelerometers, consisting of ultra low noise uniaxial accelerometers (PCB 393B31), mounted so that two of the accelerometers captured movements in the horizontal plane at 90 degrees of separation with the third accelerometer arranged to capture movements in the vertical direction (i.e., 3 orthogonal directions). Where these instrument sets were installed within the bedrock below the mock wells, they were bolted to the inside of a protective steel housing that was sealed with cables extending from the accelerometers to the surface. The cables were protected using braided steel electromagnetic shielding. One set of accelerometers also was mounted directly on the side of each mock well at the ground surface (see Photographs 1 through 4).

4.1.2 “Mock Wells”

Steel well casings were installed into the ground at turbine sites T10/11, T32 and T46 to mimic the construction of residential water wells in the project area (i.e., “mock wells”). These well casings were designated as T10/T11MW, T32MW and T46MW. All mock wells were installed at locations along the turbine access roads where property access and long-term land use were available (see Figures 2 through 4 and Photographs 4 through 6). The casings were placed to reduce the potential for the instrumentation to be struck by farm equipment or turbine maintenance equipment (e.g., during snow removal). The original intent was to install the instrumented mock wells at distances of approximately 50, 100 and 200 m from turbines T10, T32 and T46. However, due to the locations of various distribution cables, access road location and use, and proximity to agricultural fields and other physical features, instrument cluster locations required field adjustments and the clusters were ultimately installed at distances of about 50, 65 and 75 m from turbines T10, T32 and T46.

As shown in Figures 2 through 4, the mock wells were installed at distances of about 485 to 1,095 m from the nearby municipal roads to reduce the influence of vibrations associated with traffic passing over the transverse joints of the composite broken concrete and asphalt surface roads that are ubiquitous in the area.

Fieldwork was carried out between January 19 and February 4, 2021. The boreholes were advanced using an all-terrain vehicle-mounted drill rig supplied and operated by Orbit Garant Drilling Inc. of Sharon, Ontario. The boreholes were each advanced using 168-mm inner diameter continuous flight hollow stem augers to a depth of about 2.1 m to protect the top layers of soil from caving into the borehole and to produce a larger diameter hole within this depth. Below the hollow stem augers, drilling was completed using PQ casing and mud rotary drilling within the casing. Samples of the soil were obtained at various depths using either a 50-mm outer diameter (O.D.) split spoon sampler, operated by an automatic hammer, in accordance with the Standard Penetration Test (SPT) procedures presented in ASTM D1586, or by hydraulically pushing thin wall tube samplers into the ground in accordance with ASTM D1587. Once bedrock was encountered, a 128-mm outside diameter steel casing, similar to many well casings in the area, was installed by forcing the casing into the slightly smaller diameter drilled hole (and around the PQ casing as a guide) to ensure intimate contact with the surrounding ground. Once the casing was in place, the bedrock was cored using PQ-size coring equipment to obtain rock samples and to produce a 122.6-mm diameter hole in the bedrock as necessary for grouting the instruments into the rock. After removing the coring equipment, the hole was flushed, the instruments were cemented into place and a surface seal of bentonite grout was installed around the annular space between the steel well casing and surrounding ground that had been drilled using the hollow stem augers.

Fieldwork was supervised on a full-time basis by a member of WSP Golder's staff who located the boreholes in the field, directed the drilling, sampling, coring and well casing installation. Borehole locations and elevations were measured in the field by WSP Golder personnel using GPS surveying systems and the locations (referenced to the MTM NAD83 coordinate system) and ground surface elevations (referenced to Geodetic datum) are shown on the Record of Borehole sheets in Appendix C.

One set of accelerometers (as described above) was enclosed within a sealed steel housing and grouted into the bedrock at the bottom of each mock well (see Photographs 1 through 3). Instrument cables for subsurface instruments were sealed into the mock wells from the top of grout to approximately 1.5 m below the ground surface. Above the bentonite grout, the well casing remained unfilled and the cables were permitted to hang with sufficient slack to protect against long-term strains that might be associated with temperature fluctuations of the steel casing, movements of the surrounding ground (e.g., frost heave), freezing of the internal bentonite (if it were to extend above the as-constructed elevations) and long-term consolidation of filler materials within the steel well casing.

The top of each mock well casing was instrumented with three PCB393B31 uniaxial accelerometers orthogonally mounted at 90-degree intervals to capture movements in all directions. These accelerometers were mounted using threaded connections to a steel block securely wired to the steel casing (see Photograph 4).

Instrumentation, data loggers and the top of the well casing at each mock well location was enclosed within a locking steel container. Accelerometers, cables, data loggers, solar power controls and batteries were enclosed within this box for protection from weather, inadvertent damage or tampering (see Photographs 7 and 8).

During the commissioning and early long-term monitoring phases, until October 19, 2021, the instruments and data loggers were powered using solar panels and marine batteries. The solar panel was located outside the box mounted on the box lid. To help address power supply continuity, once the turbines were fully commissioned and

in operation, the data logger protection boxes were relocated to the base of the turbine and data cables were buried between the mock wells and turbines. Standard alternating current voltage was then supplied from inside the turbine and the solar panel and battery systems were left in place as back up.

While these mock wells will not be used for actual water supply, the intent of the instrumentation design was that, by installing and monitoring the mock wells, conditions at other domestic water wells within the project area could be reasonably evaluated using the resulting data and distance relationships. Typically, the domestic water wells in the region are installed to contact the rock or are drilled into the rock but the steel casings are not cemented to the bedrock. Vibration measurements of the mock well casings cemented into the rock, however, were expected to produce measurements that would be equal to or greater than those for a typical domestic water well (thus producing a “worst case” measurement).

4.1.3 Observation Wells

A conventional 50-mm diameter observation well was installed in a borehole located within about 2 to 3 m from each mock well instrumentation group. These observation wells allowed for sampling of local groundwater (if needed) and use of traditional water level reading devices (i.e., sensors on graduated tape measures, temporary submersible pressure transducers). Groundwater level or pressure measurements were obtained within the observation wells using either a submersible datalogger pressure transducer manufactured by vanEssen Instruments called TD-Diver 10 Model No. DI801 and/or manual readings measured with a Solinst Water Level Meter Model 101 P7. Record of Borehole sheets provided in Appendix C provide details regarding the depths of the well screens, surrounding sand packs and annular grout seals.

4.1.4 Vibrating Wire Pressure Transducers

A vibrating wire pressure (VWP) transducer, manufactured by Durham Geo Slope Indicator Model No. 52611033 and 52611034, was installed within a third borehole located about 2 to 3 m from each mock well instrumentation group. The VWPs were installed using the fully-grouted method⁷. The VWPs provided redundancy for being able to measure groundwater pressures. They could also be connected to a data logger for rapid measurements for short durations and would not be susceptible to accidental damage or plugging by silt or bacterial growth as might a traditional observation well. The Record of Borehole sheets provided in Appendix C provide details regarding the depths of the VWP installations.

4.2 Temporary Instrumentation Systems During Commissioning Phase

Shortly before the early commissioning work, the MECP required that ground vibrations and groundwater pressures be monitored during the commissioning phase. Therefore, prior to drilling and installing the mock wells

⁷ Dunncliff, J. 1993. Geotechnical Instrumentation for Measuring Field Performance. J. Wiley, New York, 577 pp. Contreras, I.A., Grosser, A.T. and Ver Strate, R.H. 2008. The Use of the Fully-grouted Method for Piezometer Installation, Parts 1 and 2. Geotechnical News, June 2008.

and deep instrumentation, a temporary commissioning-phase monitoring arrangement was implemented and consisted of:

- as accelerometers became available (predicated on supply-chain and delivery issues), a set of 3 orthogonally-oriented accelerometers was attached to a steel rod driven into the ground at the locations of T10/11 and T46, and a combination of one mounted accelerometer along with a conventional triaxial geophone was used at the T32 location;
- conventional triaxial geophone sensors used for construction vibration monitoring;
- electronic data logging systems; and
- solar and battery power systems.

The conventional triaxial geophone (velocity measurement system) construction vibration monitoring systems were used to supplement the accelerometer measurements and to address supply-chain problems during the early phases of commissioning. Instantel Minimate systems had a rated resolution up to 25.4 mm/s PPV with an accuracy of 0.5 mm/s over a frequency range of 2 to 250 Hz. These systems are commonly used for monitoring blasting, pile driving and other construction-related vibrations and are robust for difficult field environments. Although it was recognized that the geophones would not be as sensitive as the accelerometers chosen for the long-term monitoring program, these instruments would still capture ground vibrations of magnitudes that might be perceptible or otherwise cause concern for the surrounding environment.

Where accelerometers were installed, data was collected with portable battery-powered Rion DA-21 and Crystal Instruments Spider20 data loggers. While these were useful for capturing periodic data, their storage capacity required more frequent trips to the site for data collection. These systems were also more susceptible to shut-down when battery voltages dropped or harsh weather conditions arose.

4.3 Data Collection, Power and Communications Systems

Ground vibration data was collected from the three instrumented sites as summarized in Table 4, below. The availability of data was dependent upon multiple factors as discussed later in this report.

Table 4: Summary of instrumentation systems and installation dates.

Turbine Site	Operational Phase	System Components	Installation Date
T10/T11 Mock Well Location	Mock Well Area Temporary Instruments	3 Orthogonal Accelerometers, Triaxial Geophone, Portable Data Logger	01/12/2020
	Mock Well Long-Term Instruments	3 Orthogonal Accelerometers at Well Top, 3 Orthogonal Accelerometers in Bedrock, Observation Well, Vibrating Wire Piezometer, Fixed Data Loggers	14/04/2021 Solar Power 20/10/2021 AC Voltage
T32 Mock Well Location	Mock Well Area Temporary Instruments	3 Orthogonal Accelerometers, Triaxial Geophone, Portable Data Logger	01/12/2020
	Mock Well Long-Term Instruments	3 Orthogonal Accelerometers at Well Top, 3 Orthogonal Accelerometers in Bedrock, Observation Well, Vibrating Wire Piezometer, Fixed Data Loggers	13/04/2021 Solar Power

Turbine Site	Operational Phase	System Components	Installation Date
			20/10/2021 AC Voltage
T46 Mock Well Location	Mock Well Area Temporary Instruments	3 Orthogonal Accelerometers, Triaxial Geophone, Portable Data Logger	01/12/2020
	Mock Well Long-Term Instruments	3 Orthogonal Accelerometers at Well Top, 3 Orthogonal Accelerometers in Bedrock, Observation Well, Vibrating Wire Piezometer, Fixed Data Loggers	12/04/2021 Solar Power 20/10/2021 AC Voltage

During the commissioning phase of the project, data was collected from the temporary ground surface systems until the mock well instrumentation was fully installed and operable. Between December 01, 2020 and early January 2021, data from any accelerometers installed on site was collected using the self-contained memory modules within Crystal Instruments Spider 20 and Rion DA-21 data loggers. These were configured to permit up to 5 days of data storage and were powered by deep-cycle marine batteries. Data was stored in 10-minute file increments (i.e., 10-minute blocks of data collected at 250 Hz) to assist with reducing data loss risks from power or equipment outages. WSP Golder staff periodically visited the mock well locations, checked equipment status and performance, replaced batteries when needed, down-loaded data to WSP Golder computers and the data was subsequently stored on WSP Golder’s network server systems.

Approval of the long-term monitoring equipment design and procurement was provided on August 26, 2020 and fabrication of the customized, long-term monitoring data collection systems was completed between this date and mid-February 2021. Given the unique nature of this monitoring project, the Crystal Instruments data loggers were selected for the following reasons:

- a suite of dedicated data collection and management software packages were available for the data logger and would be customized by the supplier;
- the data loggers were designed to permit remote connections;
- the data loggers did not require separate computer interfaces for each system (i.e., the computing hardware was self-contained); and
- they could operate on either alternating or direct current, necessary for the remote and fixed monitoring requirements for this project.

Procurement and delivery of various instrumentation components was affected by the global COVID-19 pandemic. Supply-chain problems affected factory assembly of oriented accelerometers, shipment and customization of cable bundles, and shipment and programming of the data loggers. Once the long-term monitoring instruments were available, the mock data logging systems included solar and battery power and Crystal Instruments Spider 80x data loggers with internal mass data storage systems. Data from all accelerometers was collected at 250 Hz and stored in 10-minute files, similar to monitoring carried out using the portable data loggers during the commissioning of the turbines. The mass storage units were periodically removed and replaced, with the data then transferred to WSP Golder’s Ottawa office secure computer servers.

Groundwater level or pressure measurements were completed using the following systems:

- TD-Diver 10 submersible logger Model No. DI801, manufactured by vanEssen Instruments;
- Vibrating wire pressure (VWP) transducer Model No. 52611033 and 52611034, manufactured by Durham Geo Slope Indicator;
- Vibrating wire (VW) mini logger model No. 20313310, manufactured by Durham Geo Slope Indicator; and
- Water Level Meter Model No. 101 P7, manufactured by Solinst.

4.4 Equipment and Data Collection Challenges

While the work plan included appropriate steps for reducing the chances of data loss, the risks related to the intermittent inability to collect data and occasional data loss remained as with any complex field instrumentation program. The unique data collection systems and program customized for the applied research nature of this monitoring project experienced the following data continuity challenges within the first year of operation:

- weather events damaged some mock well monitoring locations resulting in tripped electrical fuses, power losses and damaged data connections (subsequently repaired);
- extended periods of inclement weather and limited daylight combined to exceed the balance of solar power generation and battery storage system capacity and electrical demand of the data logging and transmission systems – while supplementary batteries and solar panels were added, these were unable to fully off-set power supply/demand balances for some limited periods of time;
- rodents burrowed into and nested within the temporary enclosures. Some wires experienced damage from chewing (subsequently repaired);
- data collection had to be interrupted when directly downloading data from each of the data loggers (i.e., the systems cannot record and download simultaneously) or when swapping local mass storage units;
- internal or on-site external data logger storage capacity was exceeded – this was particularly troublesome when using the portable data logging systems during commissioning;
- switching the data logging systems from the temporary/portable to the long-term systems and when switching from solar/battery DC to AC power;
- periodic staff availability and public health mobility restrictions during the COVID19 pandemic, particularly during October 2020 to early 2021; and
- during construction, access to turbine sites was at times restricted due to the nature of the work being conducted at the turbine sites (e.g., major overhead lifts).

Dates for which data was collected and available for analysis are illustrated on Figure 5. Although this report focuses only on the analysis of the data collected during the first six months of wind turbine operations after COD was granted, data collection is shown on Figure 5 historically since sensors and long-term data logging systems were fully installed in early February 2021.

5.0 METEOROLOGICAL AND TURBINE OPERATION DATA

Meteorological and turbine operation data was provided to WSP Golder by NRWF in Microsoft Excel file format. This data included wind velocity, yaw angle and the power generated for each of the monitored turbines obtained at 10-minute intervals during operation. The reported yaw angle was measured from true north. Wind velocity and yaw angle data provided by NRWF are illustrated in Figures 5 and 6. Wind velocity data obtained from one meteorological tower within the wind farm is also illustrated on Figure 5 for comparison and to supplement data prior to the turbine meteorological data becoming available (e.g., during turbine commissioning). Figure 7 summarizes power output data from four turbines at this facility as related to wind velocity.

6.0 VIBRATION DATA ANALYSIS METHODOLOGY

Given the significant volume of data collected during the monitoring period, this report focuses on typical instrument responses at wind velocities, measured at the nacelles, of between 5 and 10 m/s, 10 and 15 m/s and higher than 15 m/s or more, categorized for the purposes of this report as low, moderate and high wind velocity events. The purpose of using these wind velocity categories (or “bins” of data) was to evaluate whether general relationships existed between wind velocity (the source mechanism for turbine, tower, foundation and ground vibration) and any instrument responses.

During analysis, 10-minute data files were selected from representative dates and times that captured the three wind velocity categories described above. Data were subjected to Fast-Fourier transform (FFT) analyses for transforming the acceleration-time data for each 10-minute data file into the frequency domain and to permit integration to velocity magnitudes for the entire 10 minutes of data, thus including both persistent and transient signals. Except for some specific instances when known activities occurred at the monitoring location, it was not possible to examine all acceleration time histories for all instruments to relate specific activities identified by time of occurrence to instrument responses. Accelerometer data was analysed using the MATLAB Version 2018B software along with the Signal Processing Toolbox. Data was detrended based on the mean acceleration values to address all but the most extreme temperature drift. Verification of Parseval’s theorem was also completed to ensure that the recorded energy in the time domain was the same as the energy in the frequency domain for this data evaluation methodology.

To separate and evaluate the continuous or semi-continuous vibrations that might be caused by operating turbines as separate from transient sources, a persistence spectrum was generated for each of the analysed files. The persistence spectrum signal processing tool within MATLAB (2018) was used for this process where: *“The persistence spectrum of a signal is a time-frequency view that shows the percentage of the time that a given frequency is present in a signal. The persistence spectrum is a histogram in power-frequency space. The longer a particular frequency persists in a signal as the signal evolves, the higher its time percentage and thus the brighter or “hotter” its color in the display.”* The persistence spectrum was used to reduce the influence of transient vibrations on the analysis of more persistent and continuous (even though variable) vibrations that might be associated with turbine operation. Once the persistence spectra were prepared, maximum velocity values were manually selected from each analysis.

Transient signals, in this case, could include:

- construction or maintenance vehicles entering the site and passing the instrumentation (e.g., turbine equipment repairs, access road snow plowing, site restoration);

- municipal road traffic;
- equipment owned by farm sites operating within the detection range of the instruments;
- pedestrian traffic and personnel movements near the instruments (i.e., opening instrument containers, instrument checks and maintenance, data collection, installation of additional solar panels and batteries, etc.);
- movements of rodents and other animals near and within the instrument containers;
- wind and rain striking the instrument containers and solar panels mounted to the containers;
- electrical voltage perturbations associated with manual changing of primary and backup batteries, solar power voltage regulators, electrical ground loops, and temporary loss of battery power (primary and backup) during longer periods of inclement weather and darkness; and
- Blasting activities at nearby quarries and aggregate pits.

Within the persistence spectra, natural ground motions at frequencies less than about 1 Hz can be characterized as “slow ground motion” and this threshold has been used as a lower bound cut-off frequency for comparing anthropogenically-induced seismic noise at sites of extraordinarily sensitive scientific facilities (e.g., linear particle colliders, synchrotron systems, gravitational wave detectors)^{8, 9}. Natural sources of seismic noise “...caused by the coastal waves...[that]...can even be seen in the center of the continents”¹⁰ also produce micro-seismic peaks in the range of 0.1 to 0.25 Hz. Seismic noise generated by a highway at 700 m from a seismic measuring station used for measuring turbine-associated seismic responses has been reported to be within the 2 and 10 Hz frequency band¹¹. The turbines used for the NRWF project would be expected to exhibit a blade pass frequency in the range of about 0.25 to 0.53 Hz. Marcillo and Carmichael (2018) note that similar turbines can produce a distinct and persistent seismic noise characterized by peaks at integer harmonics of the blade pass frequency. Seismic noise generated by wind turbines, with distinguishable spectral characteristics that, while commonly “masked” by typical seismic background noise (natural and anthropogenic), can sometimes be identified in the range of 0.7 to 1 Hz through use of “high fidelity seismic stations” and complex statistical algorithms.¹² However, in published research related to measurements of ground-borne vibrations associated with wind turbines (as cited in this report) particle velocity amplitudes at distances of 100 m or more from the turbine were reported in nanometres per second (i.e., on the order of one hundredth to one millionth of the magnitudes referenced by the MECP thresholds). Based on available research, ground motion amplitudes identified in the persistence spectra at 1 Hz (and any higher frequency harmonics that result in larger velocity values) have been used as a common

⁸ Sery, A. and Napoly, O. 1996. Influence of ground motion on the time evolution of beams in linear colliders. *Physical Review E*, Vol. 53, 5323-5337.

⁹ Amirikas, R., Bertolini, A., Bialowons, W., Ehrlichmann, H. Measurement of Ground Motion in Various Sites. 36th ICFA Advanced Beam Dynamics Workshop and EUROTeV Report 2005-023-1.

¹⁰ Bialowons, W., Amirikas, R., Bertolini, A. Kruecker, D. 2006. Measurement of Ground Motion I Various Sites. 10th European Particle Accelerator Conference (EPAC 06), Edinburgh.

¹¹ Flores Estrella, H. Korn, M. and Alberts, K. 2017. Analysis of the influence of wind turbine noise on seismic recordings at two wind parks in Germany. *Journal of Geoscience and Environmental Protection*, Vol. 5, 76 – 91.

¹² Marcillo, O.E. and Carmichael, J. 2018. The detection of Wind-Turbine Noise in Seismic Records. *Seismological Research Letters (SRL)* Early Edition, in press).

basis among the various turbine and mock well sites for evaluation of distance-amplitude attenuation characteristics for the NRWF project.

Examples of the data analyses and associated graphs are included in Appendix D (see Figures D-3 to D-13). Several different graphs are provided, the first of which is a time history of acceleration to illustrate measurements obtained within a 10-minute data file. By visually examining the graph, the overall character of the ground vibrations can be interpreted with respect to transient and persistent, repetitive influences on the signal. The second graph illustrates the results of an FFT analysis on the entire 10-minute data file, used to define the value of the largest influence on the accelerometers over the 10-minute period as transformed from time to frequency domain. This simple linear plot illustrates the effects of low-frequency artefacts generated by the FFT process. The third type of plot provided in Appendix D is a persistence spectrum of acceleration responses in the frequency domain plotted using the logarithmic decibel (dB) scale for the y axis where the relationship between acceleration (a in m/s^2) and decibels is $y \text{ dB} = 20 \log_{10}(a)$. For example, when reading a graph that indicates a magnitude of -50 dB at a frequency of 1 Hz, the corresponding value of acceleration would be $3.16 \times 10^{-3} m/s^2$, and after integration the associated particle velocity would be 0.5 mm/s. Since the dB scale is logarithmic, a value of -100 dB at 1 Hz in this case corresponds to a particle velocity of $1.6 \times 10^{-3} mm/s$.

Given the complexity of the persistence spectra, where multiple data peaks can be identified within the signal at different frequencies and given that integration of acceleration to velocity is governed by the frequency, multiple peak values were selected from the persistence spectra as a first point of comparison amongst the instruments. The velocity amplitude at a frequency of 1 Hz was disregarded for all instruments as it was found to be affected by background noise present at the site. In addition, the velocity amplitudes obtained through the persistence spectra typically fell within frequency bands of about 4 to 80 Hz. Examples of these peaks in the persistence spectra can be observed in the graphs provided in Appendix D. All examples illustrate the influence of the typical background seismic noise below about 1 Hz.

7.0 DATA SUMMARY AND INTERPRETATION

7.1 Ground-Borne Vibrations

Data analysed as described above is presented on Figure 8 where the particle velocity of the mock well casing or bedrock is illustrated as related to distance from the turbine tower centre. The data analyses results are described below as related to each of the physical locations of the accelerometers. In all cases, the data summarized in the tables below represent the largest values of particle velocity, regardless of direction or wind velocity. When selecting peak values from the persistence spectra, the first four peaks typically fell within the frequency bands as described above and each table below has grouped the four peaks into these general frequency bands.

Analyzed data for the accelerometers mounted to the top of the mock well casings and within the bedrock at these locations are summarized in Tables 5 and 6, respectively. These tables also provide, in parentheses, the 95th percentile values to assist with understanding the relative proportions of the highest velocity values within the total data analyzed as part of this report.

Table 5: Summary of largest and 95th percentile vibration velocity values for mock well casings.

Turbine Site	Mock Well Casings – Particle Velocity (mm/s)
	>1 to 80 Hz (typical)
T10/11	0.008 (0.005)
T32	0.054 (0.024)
T46	0.002 (0.001)

Table 6: Summary of largest and 95th percentile vibration velocity values in rock at mock wells.

Turbine Site	Rock at Mock Well Locations – Particle Velocity (mm/s)
	>1 to 80 Hz (typical)
T10/11	0.005 (0.005)
T32	0.013 (0.013)
T46	0.003 (0.003)

Figure 8 illustrates the analysis of data collected from the uniaxial accelerometers at the mock wells at the surface and in the bedrock. While in deep soft soil conditions ground vibrations measured at the at the ground surface would be expected to be greater than those within the rock, at this site the vibration magnitudes at the top of the well casings (i.e., near ground surface) were reasonably similar to those within the bedrock at the three instrumented wind turbine sites. This can be attributed to the geological conditions at the instrumented turbine sites where the overburden is mainly characterized by glacial till overlying bedrock and relatively thin deposits of soft glaciomarine clay (<5 m thick) overlying the till and shallow bedrock.

Notably, and as shown in Figure 8, the instruments located at the T32 turbine site exhibited higher peak particle velocities at times when compared to those installed at the T10/11 and T46 turbine sites. This could be due to the proximity of shallow bedrock to the ground surface and natural soil amplification due to the presence of soft glaciomarine clay deposits near ground surface at the T32 turbine site.

A site-specific attenuation relationship of peak particle velocities in bedrock compared to distance from the turbine centre has been defined using the data analyzed herein along with published and unpublished ground vibration attenuation relationships from two other wind farm sites in Ontario^{13, 14} (see Figure 8). Of note, these attenuation relationships represent an “envelope” of measurements in that the graphed relationship captures the boundaries of maximum measurements and is not intended to be measurement specific; these envelopes define a “conservative” relationship providing a qualitatively high degree of confidence that field measurements at any given time will be below the particle velocity and distance attenuation line. Based on the site-specific data and attenuation relationships, the expected PPV in the bedrock and at the ground surface at about 500 m or greater

¹³ Golder Report No.1668031-3000-R01 titled “Long-Term Vibration Monitoring Interim Report No. 1, North Kent Wind 1, Chatham-Kent, Ontario” dated November 2018.)

¹⁴ Gonzalez-Hurtado, J., He, P., Newson, T., Hong, H., Postman, M., and Molnar, S. (2017). “Field monitoring and analysis of an onshore wind turbine shallow foundation system”. Canadian Geotechnical Society: Geo Ottawa, Ottawa, Canada.

from the turbine centre is equal to or less than 0.001 mm/s for typical conditions. Using the maximum measured ground surface particle velocity values at turbine T32, ground surface particle velocities measured at 500 m from the turbines would be expected to be less than 0.01 mm/s for turbine sites with a mix of soft and hard ground conditions.

7.2 Groundwater Pressures

As required by the MECP, the instrumentation program included monitoring of groundwater pressures during turbine operation under the assumption that that the ground particle velocity might be directly correlated to short-term changes in groundwater pressures. Groundwater level data (also readily convertible to pressures) for the data monitoring period are summarized on Figure 9 (hydrograph). Figures 10A through 10C illustrate examples of groundwater pressure variability for three 24-hour and 1-hour periods for each of the turbine locations for low, moderate and high wind velocity events (within the data sets examined in this report). Moreover, Figures 10A to 10C illustrate examples of groundwater pressure changes associated with the same data analysis events used for evaluating ground vibration particle velocities described above, whereby the change in groundwater pressure measured within the 10-minute ground vibration data analysis interval is compared to:

- the lowest groundwater level within the same 10-minute vibration analysis interval as measured by the observation well pressure transducer; and
- the lowest groundwater level within the same calendar day of the 10-minute vibration analysis interval as measured by the observation well pressure transducer.

These figures illustrate several data characteristics and trends:

- A broad correlation can be observed between precipitation events and peaks in the hydrographs, particularly for T32. The hydrograph from T46 is more attenuated with respect to rainfall events. The differences in hydrographs are principally related to differences in ground permeability (hydraulic conductivity) between the ground surface and the layer within which the groundwater measuring system is installed. For example, sandy or more permeable ground would be expected to have little time lag or attenuation between rainfall events and infiltration to the groundwater as compared to ground that is more clayey or has lower permeability. Where typical groundwater levels are close to the surface, the time-lag between precipitation, infiltration and groundwater level changes may be nominal. Further, rainfall events following a relatively dry period may not have an immediate or discernable effect on groundwater levels since infiltration may be attenuated depending on the extent to which soil water contents are below saturated conditions.
- The maximum seasonal changes in groundwater levels ranged from about 0.5 m to 2 m, equivalent to a pressure change range of about 5 kPa at T10/11, about 12 kPa at T32, and about 20 kPa at T46; and
- maximum short-term (hourly and daily) groundwater pressure changes at the mock wells ranged from about 1.7 to 0.1 kPa during the high velocity wind events, from about 0.4 to 0.04 kPa during moderate velocity wind speeds, and from about 0.9 to 0.2 kPa during low velocity wind events.

Based on the available data, no clear relationship between ground vibration velocity or frequency could be discerned. Further, changes in groundwater pressures are dominated by incidental precipitation events and seasonal fluctuations.

8.0 CONCLUSIONS

This report summarizes the results of seven months (between June 14, 2021 to January 14, 2022) of vibration and groundwater pressure monitoring carried out for the Nation Rise Wind Farm project (NRWF). Vibration monitoring and groundwater level (pressure) data collected during the first six months of operations at the NRWF demonstrate:

- the largest vibration magnitudes, occurring at a frequency range between >1 Hz and about 80 Hz, at the top of the mock well casings were on the order of 0.002 to 0.054 mm/s at distances of about 50 m to 75 m from the existing wind turbines;
- mock well vibration magnitudes at the mock well top (near ground surface) were reasonably similar to those measured in the bedrock, given the local ground density or stiffness conditions, with the largest vibration magnitudes measured in bedrock at the turbine sites ranging from about 0.003 to 0.013 mm/s;
- vibration magnitudes at all of the mock wells, in bedrock or at the top of the mock well casings, at distances of 50 to 75 m were less than any of the thresholds identified within MECP guidelines¹⁵ NPC-233, NPC-103 and NPC-207;
- maximum seasonal groundwater pressure changes at the mock wells ranged from about 5 kPa at T10/11, 12 kPa at T32, and about 20 kPa at T46;
- maximum short-term (hourly and daily) groundwater pressure changes at the mock wells ranged from about 1.7 to 0.2 kPa and no clear relationship between ground vibration velocity or frequency could be discerned from the data;
- available data indicate that ground vibrations are unrelated to changes in short- or long-term groundwater pressure changes;
- based on the site-specific attenuation relationship obtained and shown on Figure 8, at a distance of about 500 m from the turbines and beyond, vibrations in the bedrock and at the ground surface would be expected to be on the order of 0.001 mm/s, or less, well below the threshold of human perception and 1/300th of the lowest MECP regulatory threshold; and
- vibrations of the magnitude and frequency measured during the first seven months of operation at distances greater than 500 m from the turbines would be expected to be inconsequential with respect to performance of water wells in the region.

This operational report does not separate and evaluate the influence of wind direction or constructive and destructive waveform interference and, instead, focused on the largest ground vibration measurements that would have, necessarily, included the influences of such factors.

Data gathered as part of the long-term ground-borne vibration monitoring program at the NRWF site demonstrates that, while the measurements of vibrations at large distances from the wind turbines are of scientific interest and comparable to published research, the vibration magnitudes are extremely small and of no

¹⁵ Produced and published under multiple predecessor Government of Ontario agency names.

consequence to water wells in the area, regardless of wind direction or velocity and any potential for constructive vibration waveform interference.

Signature Page

WSP Canada Inc.



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A handwritten signature in blue ink that reads "J. Stephen Ash".

J. Stephen Ash, P.Eng., P.Geo.
Lead Principal Geotechnical Engineer

JGH/SJB/JAK/MAS/cr



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The report is of a summary nature and is not intended to stand alone without reference to the instructions given to WSP by the Client, communications between WSP and the Client, and to any other reports prepared by WSP for the Client relative to the specific site described in the report. In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. WSP can not be responsible for use of portions of the report without reference to the entire report.

Unless otherwise stated, the suggestions, recommendations and opinions given in this report are intended only for the guidance of the Client in the design of the specific project. The extent and detail of investigations, including the number of test holes, necessary to determine all of the relevant conditions which may affect construction costs would normally be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual data presented in the report, as to how subsurface conditions may affect their work, including but not limited to proposed construction techniques, schedule, safety and equipment capabilities.

Soil, Rock and Ground Water Conditions: Classification and identification of soils, rocks, and geologic units have been based on commonly accepted methods employed in the practice of geotechnical engineering and related disciplines. Classification and identification of the type and condition of these materials or units involves judgment, and boundaries between different soil, rock or geologic types or units may be transitional rather than abrupt. Accordingly, WSP does not warrant or guarantee the exactness of the descriptions.

Special risks occur whenever engineering or related disciplines are applied to identify subsurface conditions and even a comprehensive investigation, sampling and testing program may fail to detect all or certain subsurface conditions. The environmental, geologic, geotechnical, geochemical and hydrogeologic conditions that WSP interprets to exist between and beyond sampling points may differ from those that actually exist. In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the site or on adjacent properties. The professional services retained for this project include only the geotechnical aspects of the subsurface conditions at the site, unless otherwise specifically stated and identified in the report. The presence or implication(s) of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources are outside the terms of reference for this project and have not been investigated or addressed.

Soil and groundwater conditions shown in the factual data and described in the report are the observed conditions at the time of their determination or measurement. Unless otherwise noted, those conditions form the basis of the recommendations in the report. Groundwater conditions may vary between and beyond reported locations and can be affected by annual, seasonal and meteorological conditions. The condition of the soil, rock and groundwater may be significantly altered by construction activities (traffic, excavation, groundwater level lowering, pile driving, blasting, etc.) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. Unless otherwise indicated the soil must be protected from these changes during construction.

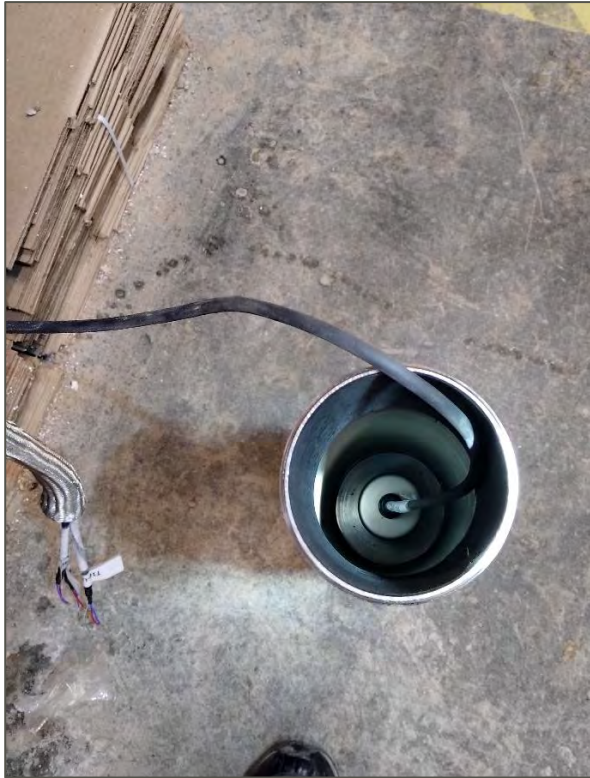
Sample Disposal: WSP will dispose of all uncontaminated soil and/or rock samples 90 days following issue of this report or, upon written request of the Client, will store uncontaminated samples and materials at the Client's expense. In the event that actual contaminated soils, fills or groundwater are encountered or are inferred to be present, all contaminated samples shall remain the property and responsibility of the Client for proper disposal.

Follow-Up and Construction Services: All details of the design were not known at the time of submission of Golder's report. WSP should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of Golder's report.

During construction, WSP should be retained to perform sufficient and timely observations of encountered conditions to confirm and document that the subsurface conditions do not materially differ from those interpreted conditions considered in the preparation of Golder's report and to confirm and document that construction activities do not adversely affect the suggestions, recommendations and opinions contained in Golder's report. Adequate field review, observation and testing during construction are necessary for WSP to be able to provide letters of assurance, in accordance with the requirements of many regulatory authorities. In cases where this recommendation is not followed, Golder's responsibility is limited to interpreting accurately the information encountered at the borehole locations, at the time of their initial determination or measurement during the preparation of the Report.

Changed Conditions and Drainage: Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that WSP be notified of any changes and be provided with an opportunity to review or revise the recommendations within this report. Recognition of changed soil and rock conditions requires experience and it is recommended that WSP be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. WSP takes no responsibility for the effects of drainage unless specifically involved in the detailed design and construction monitoring of the system.



Photograph 1: Uniaxial accelerometer (vertical direction) bolted to bottom of steel casing.



Photograph 2: Uniaxial accelerometers (longitudinal and transverse direction) bolted to the steel .



Photograph 3: Assembled protective steel casings containing sets of accelerometers (3 orthogonal directions); Installation of protective steel casing containing a set of accelerometers (3 orthogonal directions) (right)



Photograph 4: One set of accelerometers (3 orthogonal directions) mounted on one mock well at ground surface.



Photographs 5 and 6: “Mock Well” steel casing installed and protruding above ground surface at one turbine site (left); Mock Well casing location with respect a wind turbine structure (right).



Photograph 7: T10/11 Mock Well protective steel box. Note lid-mounted solar panel arrangement.



Photograph 8: T10/11 Mock Well data logging and solar power controls inside protective steel box.



LEGEND

- TURBINE LOCATION
- MOCK WELL / INSTRUMENTED BOREHOLE LOCATION

SCALE 1:2,000,000

0 1,000 2,000
1:60,000 METRES

NOTE(S)
 THIS DRAWING IS SCHEMATIC ONLY AND IS TO BE READ IN CONJUNCTION WITH ACCOMPANYING TEXT.

BASE IMAGERY FOR ILLUSTRATION PURPOSES ONLY AND NOT TO BE USED FOR MEASUREMENTS.

ALL LOCATIONS ARE APPROXIMATE.

REFERENCE(S)

1. BASE DATA - MNRF (2022), MECP (2022)
2. BASE IMAGERY SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), (C) OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 1983 COORDINATE SYSTEM: UTM ZONE 18N.

CLIENT
EDP RENEWABLES CANADA LTD.

PROJECT
**VIBRATION MONITORING PROGRAM
 NATION RISE WIND FARM, STORMONT, ONTARIO**

TITLE
LOCATION PLAN

CONSULTANT	YYYY-MM-DD	2022-07-11
GOLDER	DESIGNED	JGH
	PREPARED	STB
	REVIEWED	JGH
	APPROVED	---

RPT: H. S. CHINESE EDP - Stormont (see Vision), Rev. 08, PROJ: 19120626, VMP: 00, PROD: 0001, Version: Moncton, Proj: 19120626-000, EN: 0001.mxd, PRINTED ON: 2022-07-11 AT: 2:51:28 PM

THIS MEASUREMENT DOES NOT MATCH WHAT'S SHOWN IN THE SHEET SIZE HAS BEEN MODIFIED FROM: ANS 6



LEGEND

- TURBINE LOCATION
- MOCK WELL / INSTRUMENTED BOREHOLE LOCATION
- MONITORING WELL LOCATION
- VIBRATING WIRE PIEZOMETER LOCATION

KEY MAP

SCALE 1:2,000,000

0 100 200
1:5,000 METRES

NOTE(S)
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BASE IMAGERY FOR ILLUSTRATION PURPOSES ONLY AND NOT TO BE USED FOR MEASUREMENTS.

ALL LOCATIONS ARE APPROXIMATE.

REFERENCE(S)

1. BASE DATA - MNRF (2022), MECP (2022)
2. BASE IMAGERY SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), (C) OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 1983 COORDINATE SYSTEM: UTM ZONE 18N.

CLIENT
EDP RENEWABLES CANADA LTD.

PROJECT
**VIBRATION MONITORING PROGRAM
 NATION RISE WIND FARM, STORMONT, ONTARIO**

TITLE
INSTRUMENT LOCATION PLAN, T46





CONSULTANT	YYYY-MM-DD	2022-07-11
GOLDER	DESIGNED	JGH
	PREPARED	STB
	REVIEWED	JGH
	APPROVED	---

R:\14_5\CHM\EDP_Renewables\Map\Map_19120626_VMP\10_PROD\0001_Vibration_Monitoring_Plan\19120626_0001_INSTRUMENT_LOCATION_PLAN.dwg PRINTED ON: 2022-07-11 AT: 2:53:56 PM

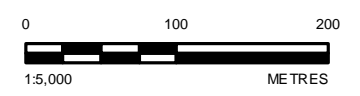
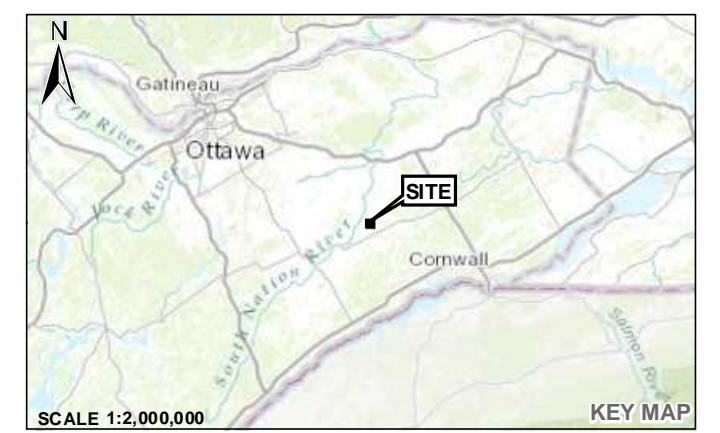
IF THIS MEASUREMENT DOES NOT MATCH WHAT'S SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B



LEGEND

-  TURBINE LOCATION
-  MOCK WELL / INSTRUMENTED BOREHOLE LOCATION
-  MONITORING WELL LOCATION
-  VIBRATING WIRE PIEZOMETER LOCATION

20-2A
20-2B
20-2C



NOTE(S)

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ALL LOCATIONS ARE APPROXIMATE.

REFERENCE(S)

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2. BASE IMAGERY SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), (C) OPENTREE TMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 1983 COORDINATE SYSTEM: UTM ZONE 18N.

CLIENT


EDP RENEWABLES CANADA LTD.

PROJECT

VIBRATION MONITORING PROGRAM
NATION RISE WIND FARM, STORMONT, ONTARIO

TITLE

INSTRUMENT LOCATION PLAN, T32

CONSULTANT	YYYY-MM-DD	2022-07-11
	DESIGNED	JGH
	PREPARED	STB
	REVIEWED	JGH
	APPROVED	---

PROJECT NO.	CONTROL	REV.	FIGURE
19120626	0001	A	3

P:\14_S\CH\EDP_Renewable\GIS\Map\Map_19120626_VMP\10_PROD\10_PROD\0001_Vibration_Monitoring_Plan\19120626_0001_INSTRUMENT_LOCATION_PLAN.dwg PRINTED ON: 2022-07-11 AT: 2:55:34 PM

IF THIS MEASUREMENT DOES NOT MATCH WHAT'S SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

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LEGEND

- TURBINE LOCATION
- MOCK WELL / INSTRUMENTED BOREHOLE LOCATION
- MONITORING WELL LOCATION
- VIBRATING WIRE PIEZOMETER LOCATION



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 ALL LOCATIONS ARE APPROXIMATE.

REFERENCE(S)

1. BASE DATA - MNRF (2022), MECP (2022)
2. BASE IMAGERY SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), (C) OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 1983 COORDINATE SYSTEM: UTM ZONE 18N.

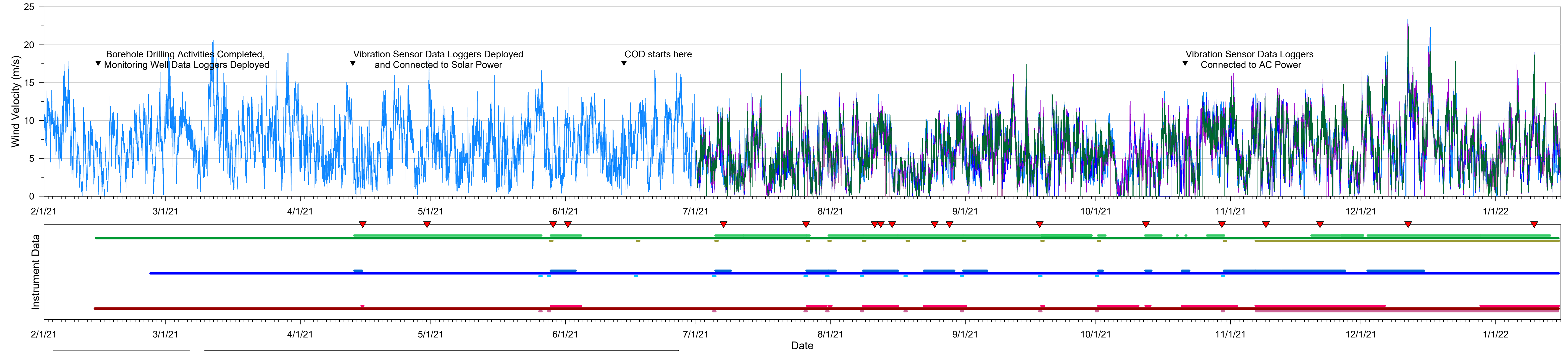
CLIENT
EDP RENEWABLES CANADA LTD.

PROJECT
**VIBRATION MONITORING PROGRAM
 NATION RISE WIND FARM, STORMONT, ONTARIO**

TITLE
INSTRUMENT LOCATION PLAN, T10/11

CONSULTANT	YYYY-MM-DD	2022-07-11
	DESIGNED	JGH
	PREPARED	STB
	REVIEWED	JGH
	APPROVED	---

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B



Wind Velocity Legend

— MET Tower	— T32
— T10	— T46
— T11	

Data Logger Legend

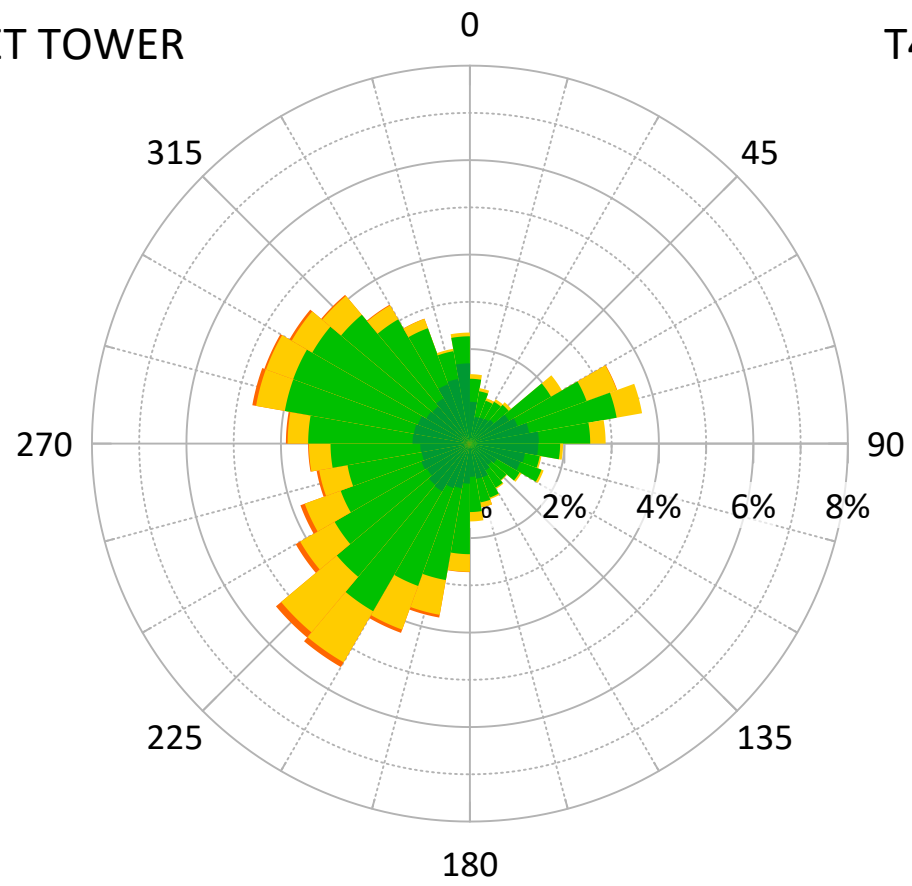
— T46 Mock Well Vibration Sensors Data Logger	— T32 Vibrating Wire Piezometer (VWP)
— T46 Monitoring Well TD-Diver Data Logger	— T10/11 Mock Well Vibration Sensors Data Logger
— T46 Vibrating Wire Piezometer (VWP)	— T10/11 Monitoring Well TD-Diver Data Logger
— T32 Mock Well Vibration Sensors Data Logger	— T10/11 Vibrating Wire Piezometer (VWP)
— T32 Monitoring Well TD-Diver Data Logger	▼ Dates for Data Analysis

- Notes:
1. Meteorological data prior to Commercial Operations Date (COD) based on digitizing limited data images provided by turbine supplier.
 2. COD starts on June 14, 2021. Date provided by turbine supplier.
 3. Refer to report text for periods during which data was not gathered for particular instruments.
 4. Symbol '▼' refers to some field work milestones.

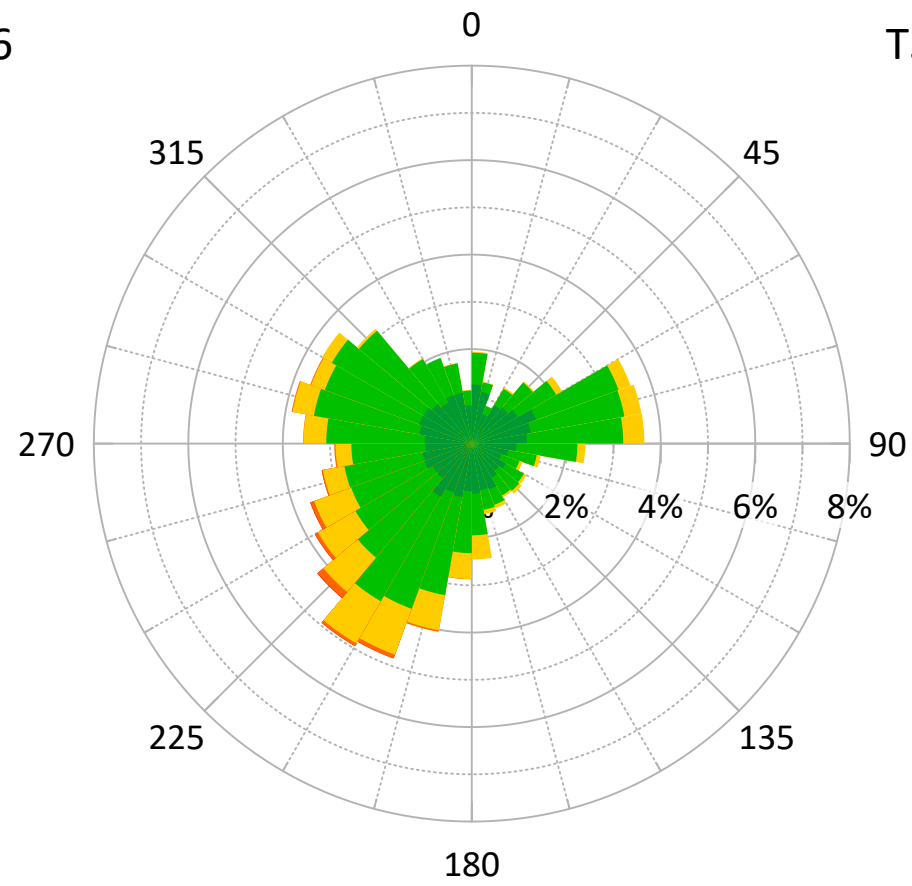
PROJECT	NATION RISE WIND FARM VIBRATION MONITORING		
TITLE	WIND VELOCITY AND DATA AVAILABILITY (FEBRUARY 1, 2021 TO JANUARY 15, 2022)		
wsp GOLDER	PROJECT No.	19120626	FILE No. 19120626-300-001004
	DRAWN	JGH	July 2022
	CHECK		SCALE AS SHOWN REV. 0
			FIGURE 5

T:\Golder\44419120626-300-001005.dwg

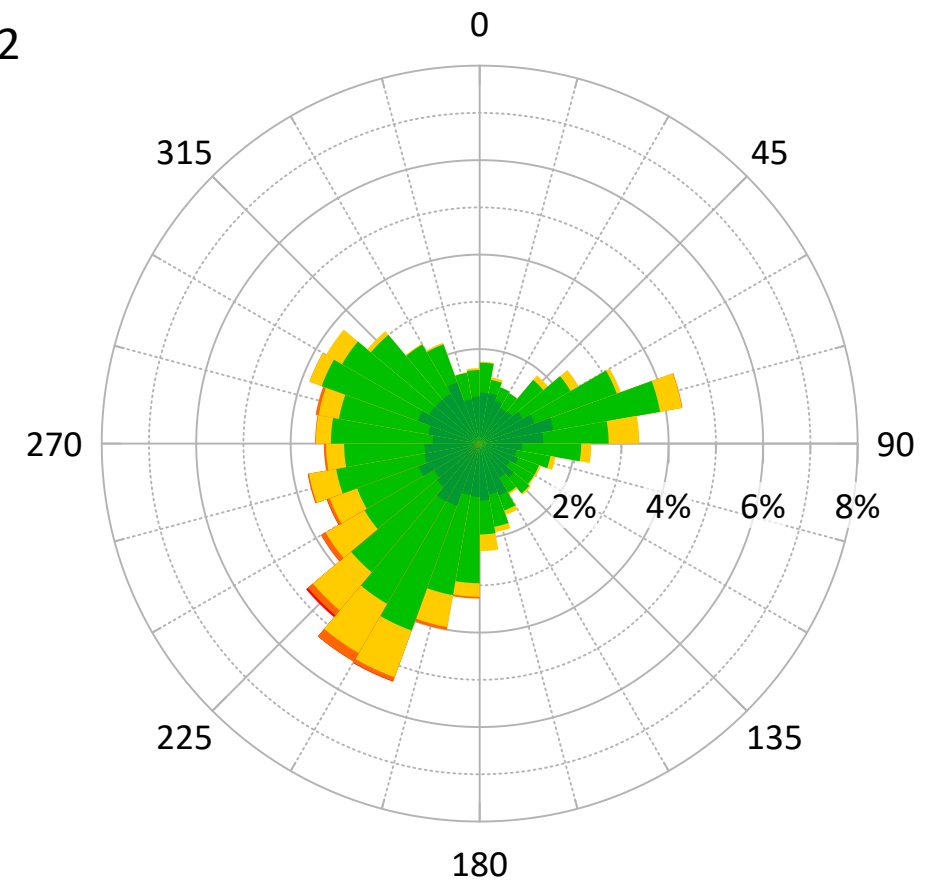
MET TOWER



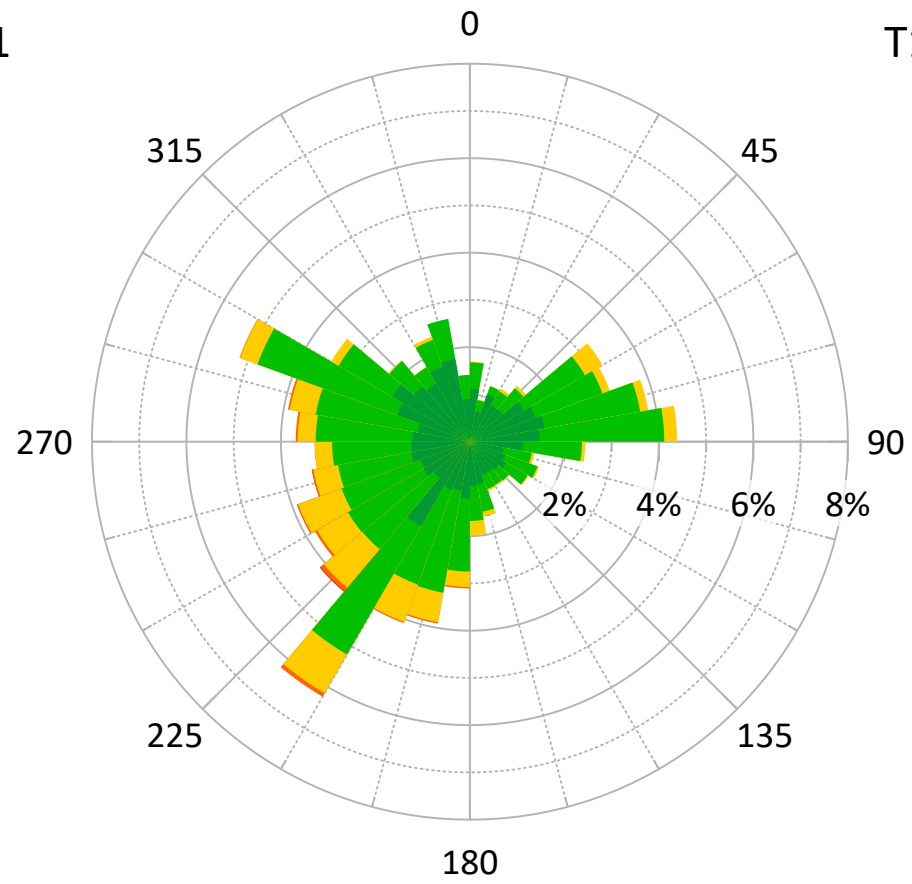
T46



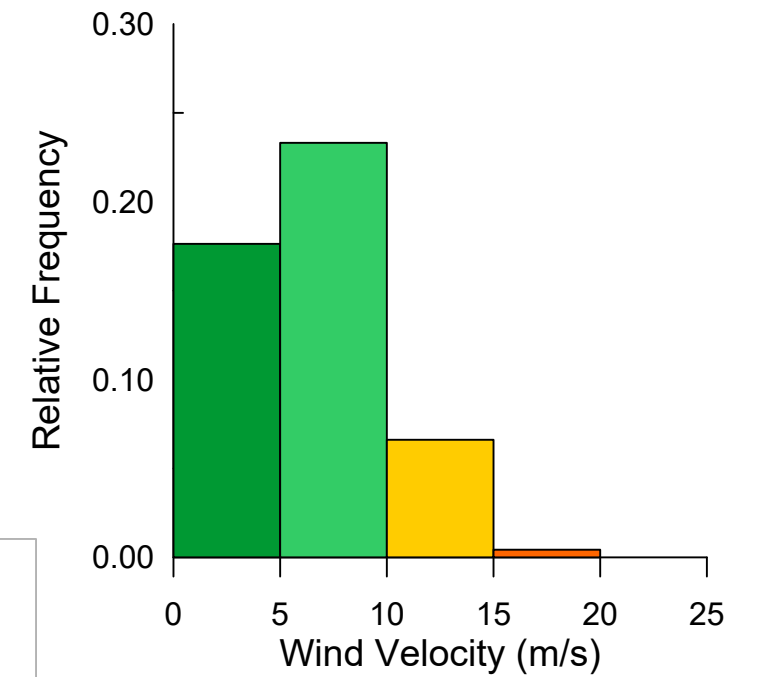
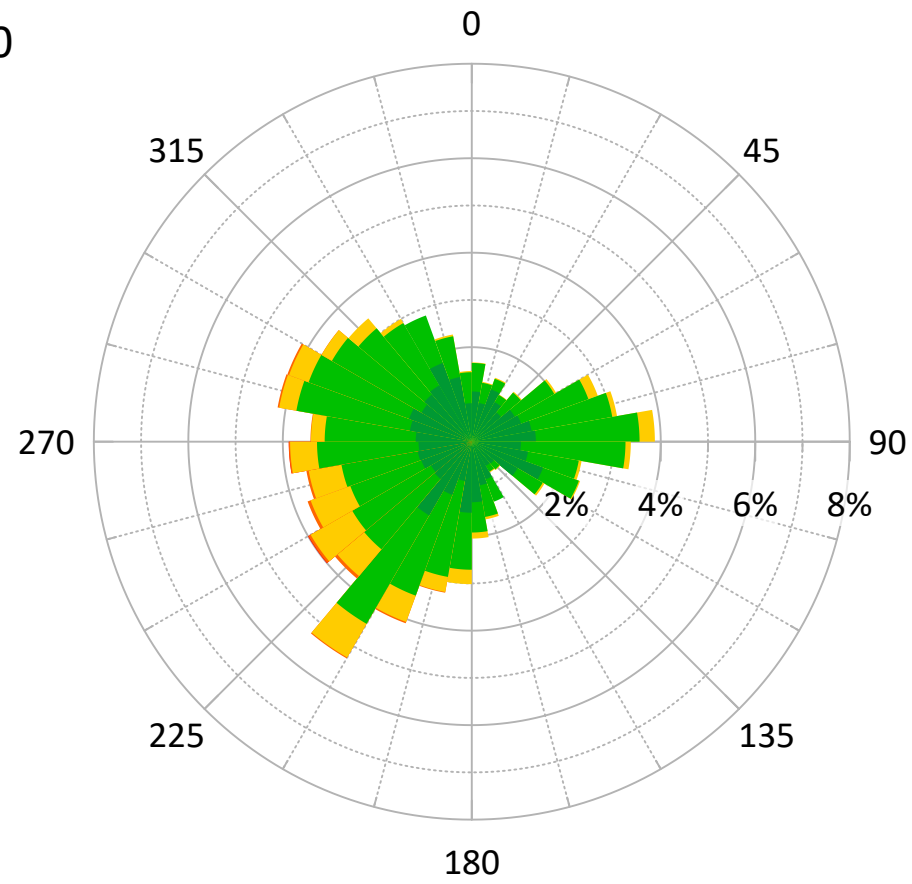
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T11

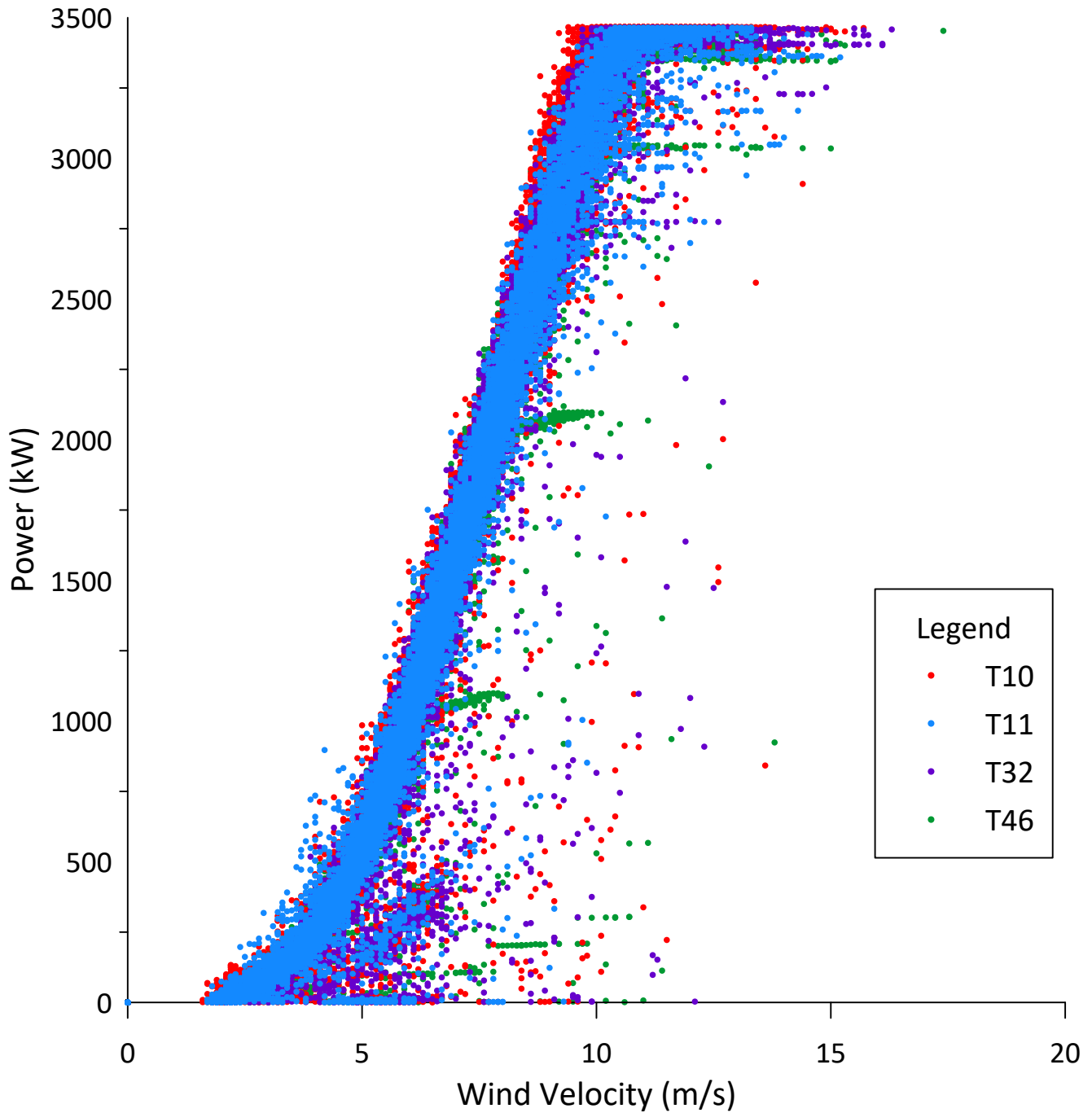


T10



Notes: 1. Graphs are to be read in conjunction with accompanying text
 2. Nacelle position angle shown relative to true north (0 degrees on graphs)
 3. Radial distance on nacelle position angle graphs indicates proportional number of measurements within band of nacelle position angles (e.g., 3%, 6% etc.)
 4. Colour legend illustrates relative proportion of wind velocity within nacelle position angle band.

PROJECT		NATION RISE WIND FARM OPERATIONAL VIBRATION MONITORING	
TITLE		WIND DIRECTION AND VELOCITY	
PROJECT No.	19120626-3000	FILE No.	19120626-3000-R01
		SCALE	AS SHOWN
		REV.	0
DRAWN		JGH	July 2022
CHECK			
wsp GOLDER		FIGURE 6	

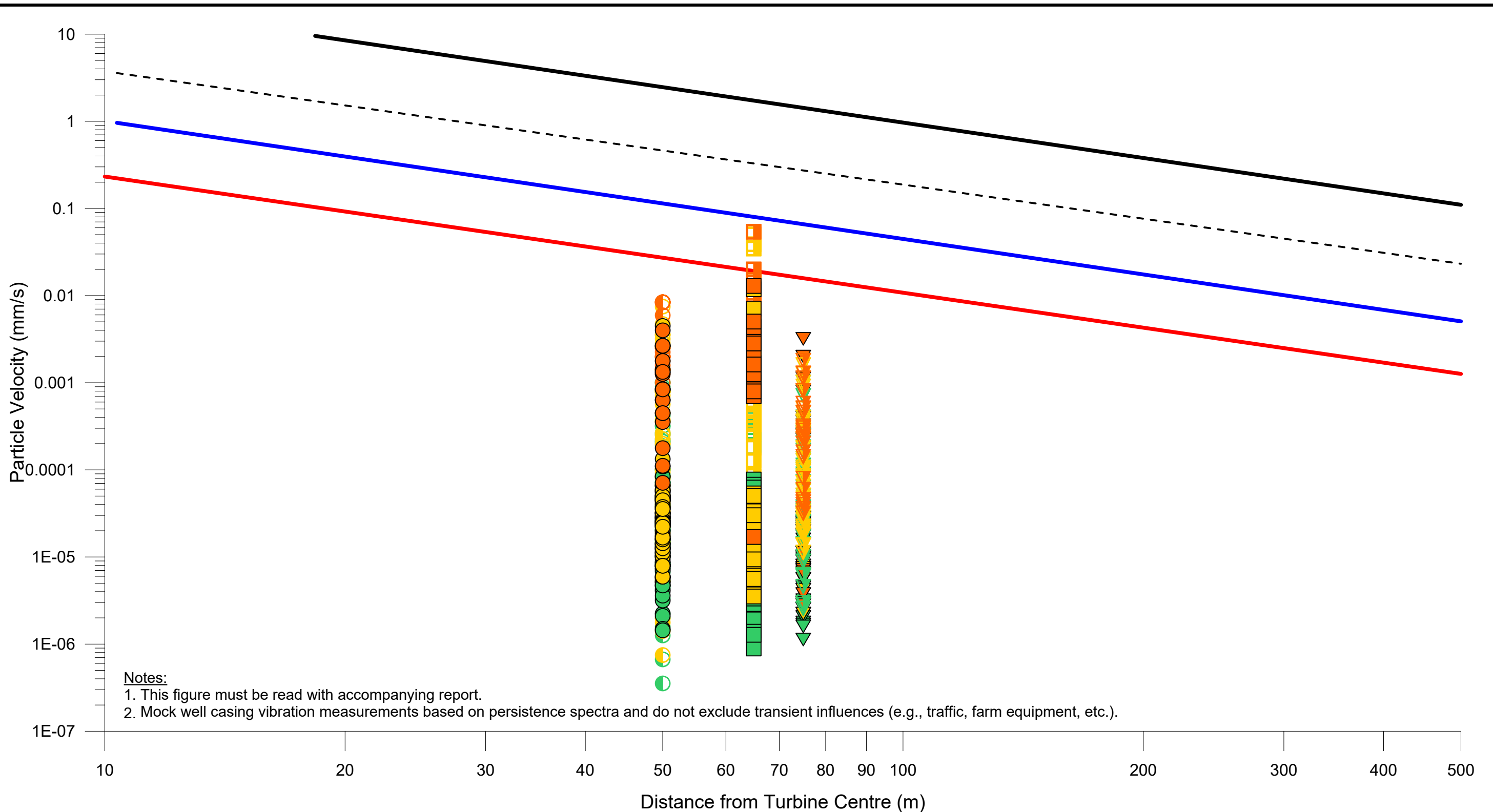


Notes:

1. This figure is to be read in conjunction with accompanying text
2. Data provided by Nation Rise Wind Farm

PROJECT				NATION RISE WIND FARM OPERATIONAL VIBRATION MONITORING			
TITLE				WIND VELOCITY AND TURBINE POWER OUTPUT			
PROJECT No.		19120626-3000		FILE No.		19120626-3000-R01	
DRAWN		JGH		SCALE		AS SHOWN	
CHECK				REV.		0	
wsp GOLDER				FIGURE 7			

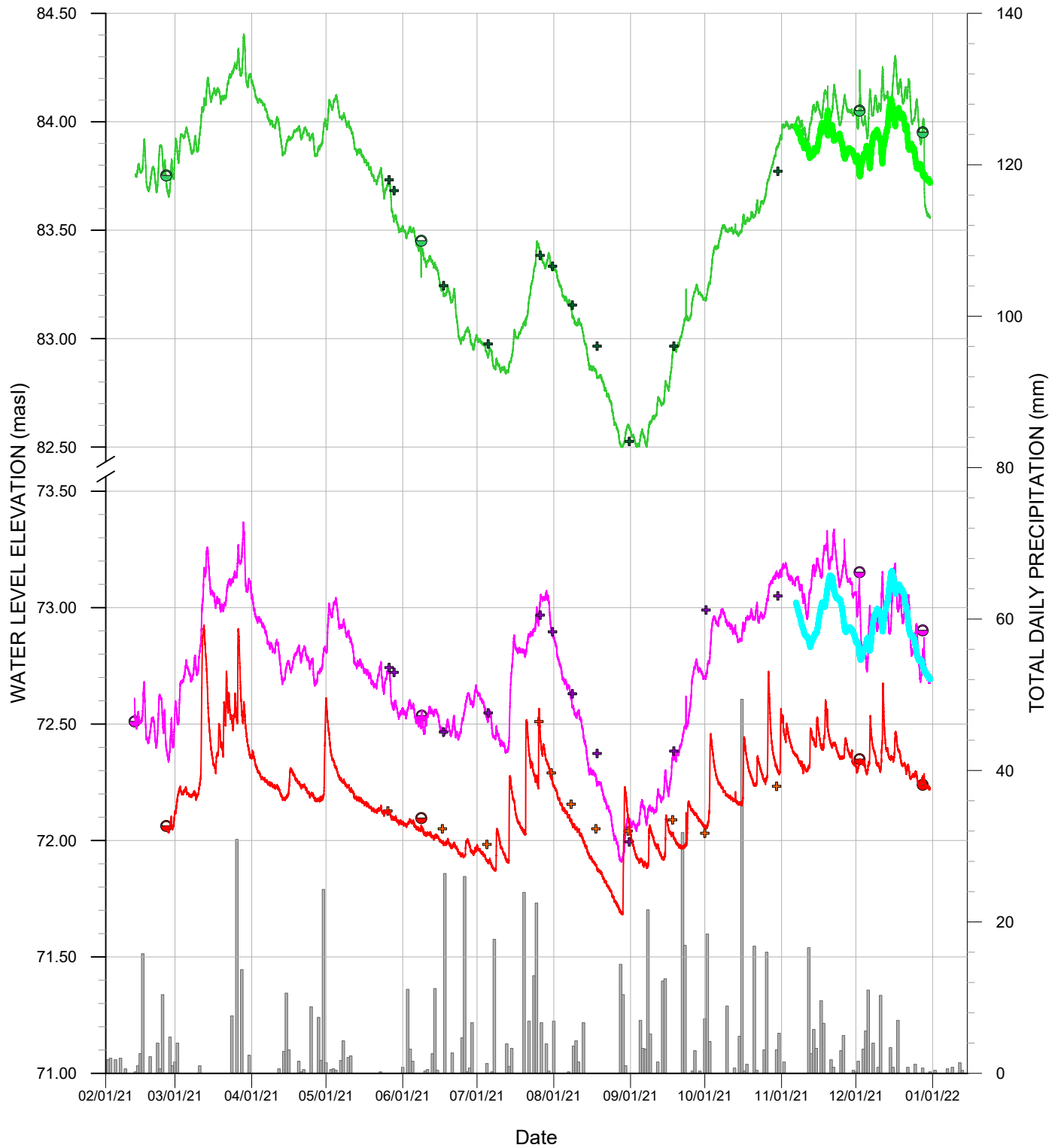
C:\Users\ignozalez\hurdado\Golder\Associates\19120626_EDP_Vib_Monit\Nation Rise Wind Stomont - Ph 3000-T03 Operational Monit\4-Technical Work\Persistence Plots\Grapher Plots\19120626-3000-R01008A_revised V2.gpj



Notes:
 1. This figure must be read with accompanying report.
 2. Mock well casing vibration measurements based on persistence spectra and do not exclude transient influences (e.g., traffic, farm equipment, etc.).

Legend					
	T10/11 MW (Surface, 5-10 m/s)		T32 MW (Surface, >15 m/s)		T46 MW (Bedrock, 5-10 m/s)
	T10/11 MW (Surface, 10-15 m/s)		T32 MW (Bedrock, 5-10 m/s)		T46 MW (Bedrock, 10-15 m/s)
	T10/11 MW (Surface, >15 m/s)		T32 MW (Bedrock, 10-15 m/s)		T46 MW (Bedrock, >15 m/s)
	T10/11 MW (Bedrock, 5-10 m/s)		T32 MW (Bedrock, >15 m/s)		Site-Specific Attenuation - Nation Rise Wind Farm
	T10/11 MW (Bedrock, 10-15 m/s)		T46 MW (Surface, 5-10 m/s)		Construction Attenuation - North Kent 1 Wind Farm
	T10/11 MW (Bedrock, >15 m/s)		T46 MW (Surface, 10-15 m/s)		Site-Specific Attenuation - Wind Farm Located in SW Ontario
	T32 MW (Surface, 5-10 m/s)		T46 MW (Surface, >15 m/s)		Construction Equipment Attenuation - Vibratory Roller (CALTRANS, 2013)
	T32 MW (Surface, 10-15 m/s)				

PROJECT				NATION RISE WIND FARM VIBRATION MONITORING			
TITLE				VIBRATION VELOCITY AND ATTENUATION (>1 to 80 Hz)			
PROJECT No.		19120626-3000		FILE No.		19120626-3000-R01008A	
DRAWN		JGH		SCALE		AS SHOWN	
CHECK				REV.		0	
wsp GOLDER				FIGURE 8			



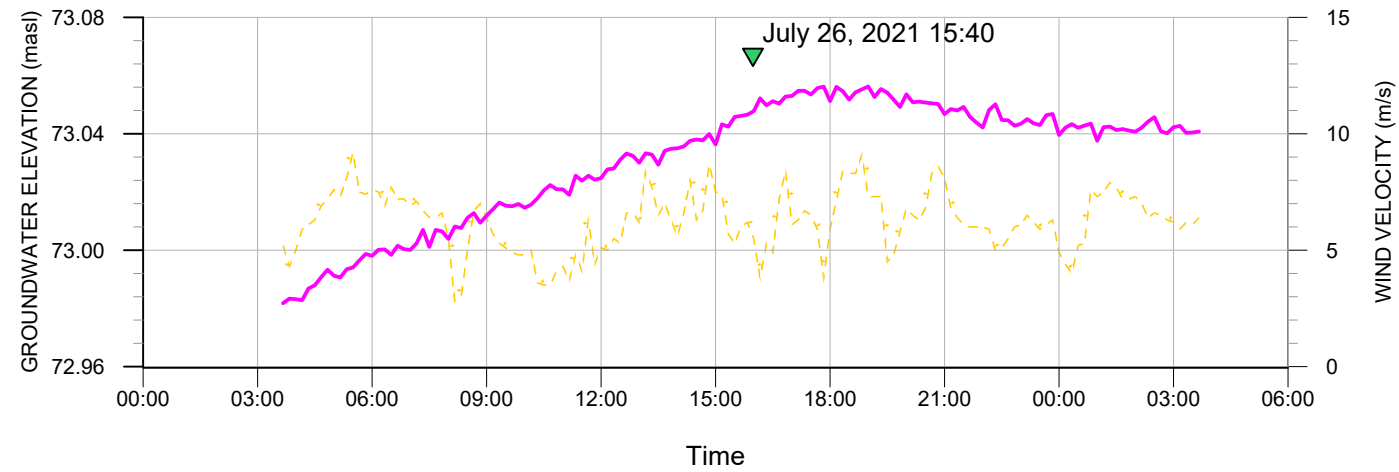
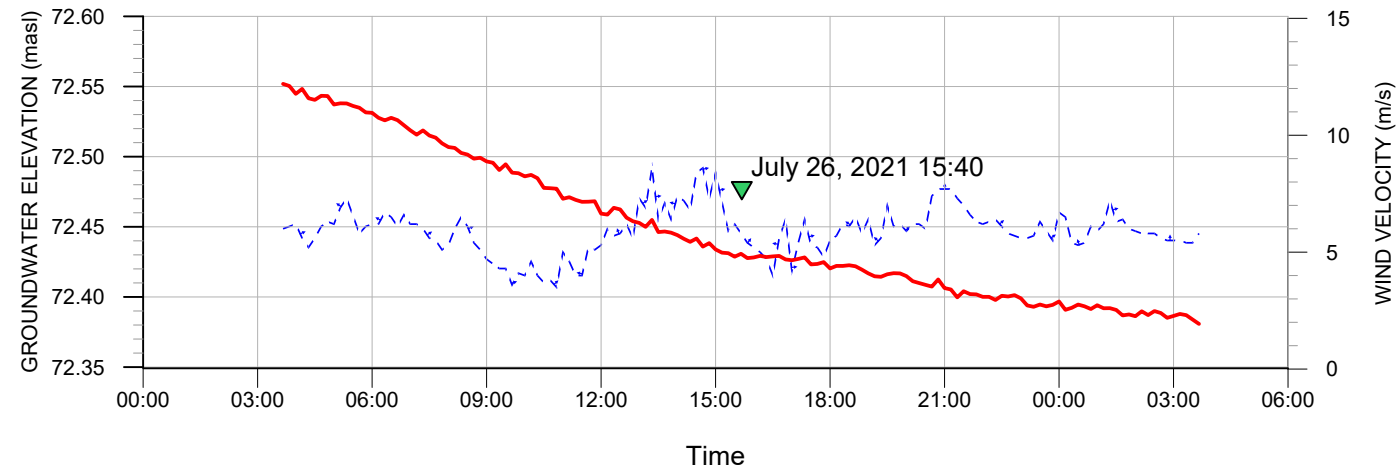
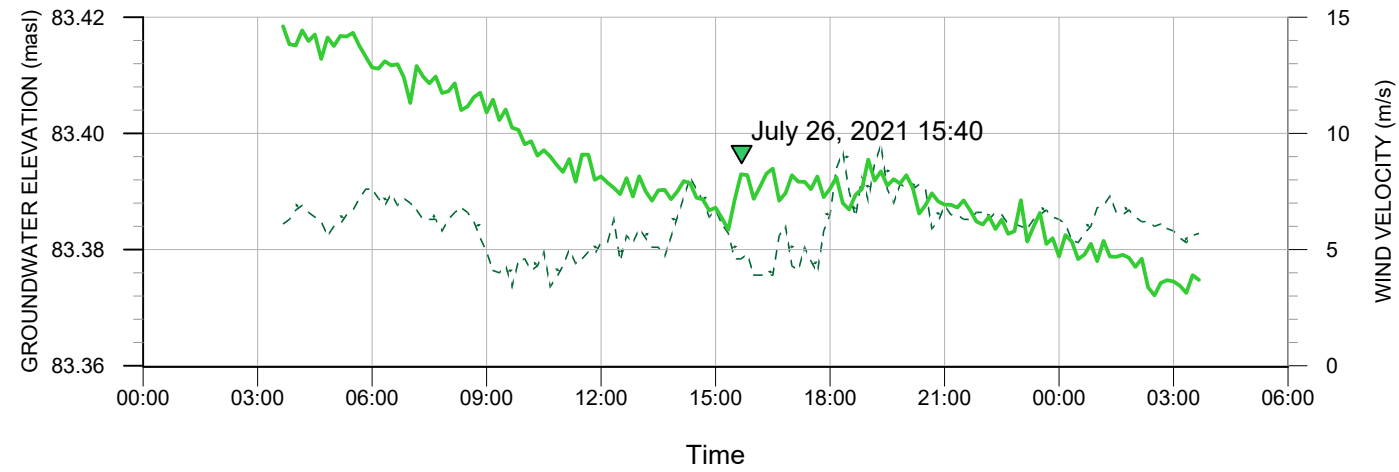
Legend	
	Daily Precipitation
	T10/11 TD-Diver logger
	T10/11 VWP logger
	T32 TD-Diver logger
	T46 TD-Diver logger
	T46 VWP logger
	T10/11 MW manual
	T46 MW manual
	T32 MW manual
	T10/11 VWP manual
	T46 VWP manual
	T32 VWP manual

Notes:
 1) Precipitation data for Ottawa International Airport station provided by Environment Canada.
 2) This graph is to be read in conjunction with accompanying text.

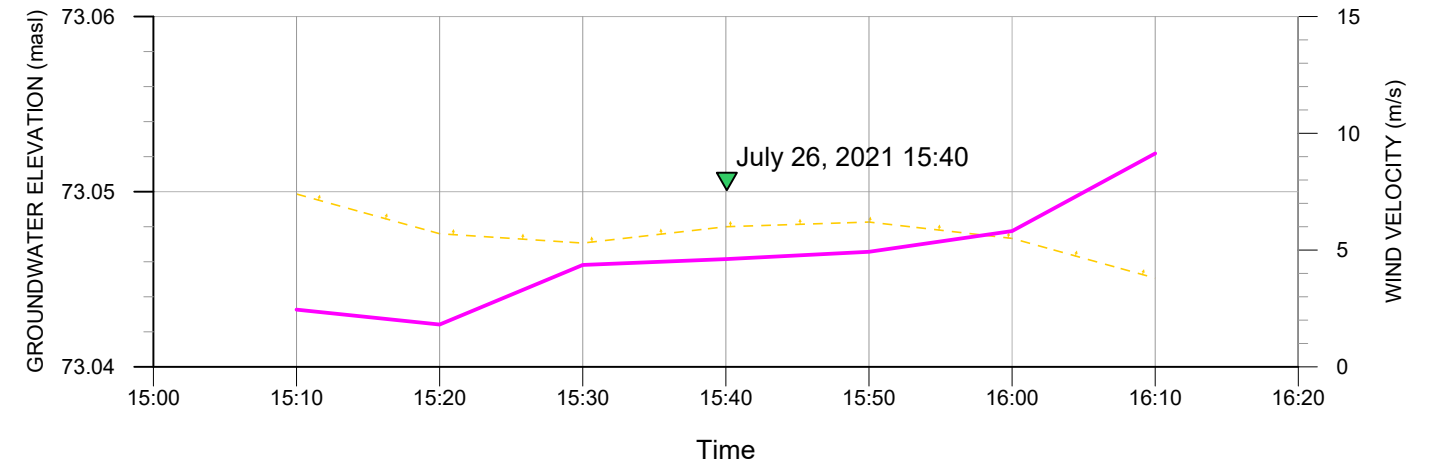
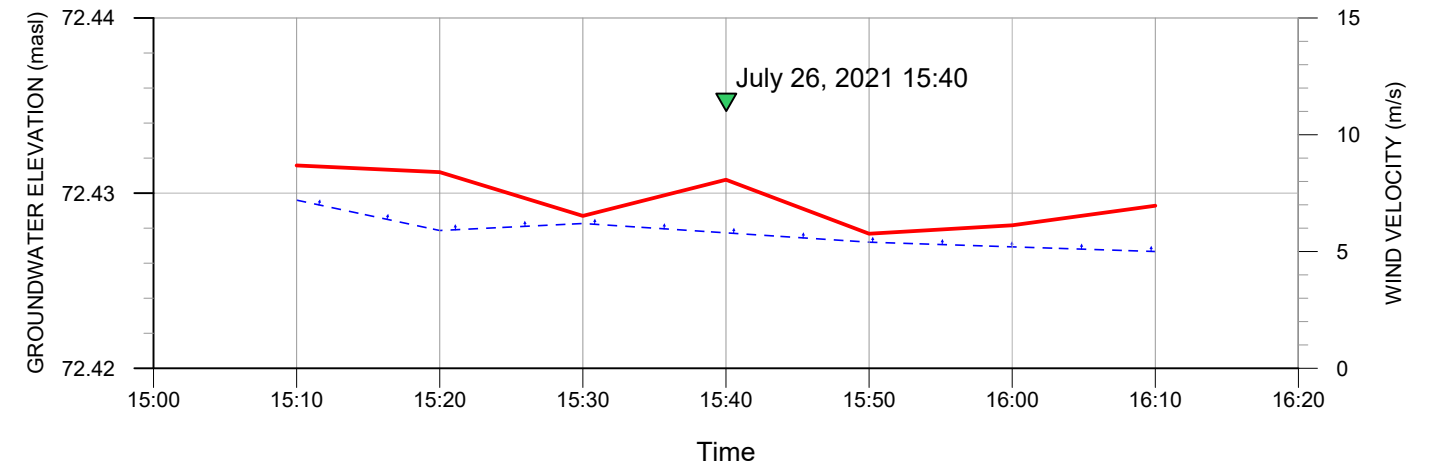
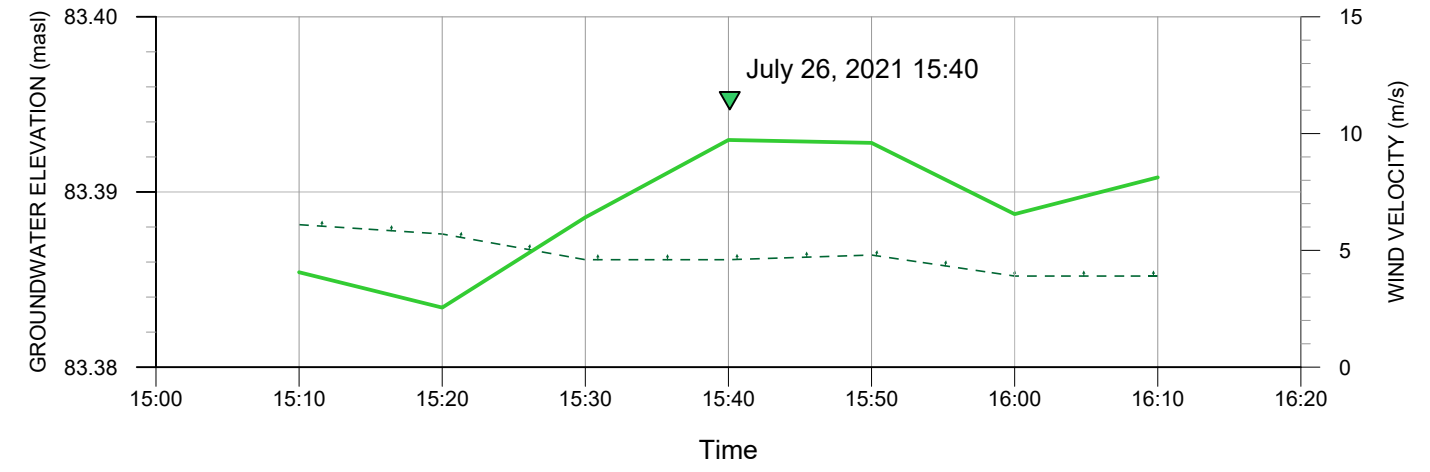
PROJECT		NATION RISE WIND FARM OPERATIONAL VIBRATION MONITORING	
TITLE		HYDROGRAPH (FEBRUARY 1, 2021 TO JANUARY 15, 2022)	
PROJECT No.	19120626-3000	FILE No.	19120626-3000-R01
		SCALE	AS SHOWN
DRAWN	JGH	July 2022	
CHECK			
			FIGURE 9

T:\Grapher_plots\Hydrograph - Nation Rise.gpj

24-Hour Groundwater Fluctuation



1-Hour Groundwater Fluctuation



Legend

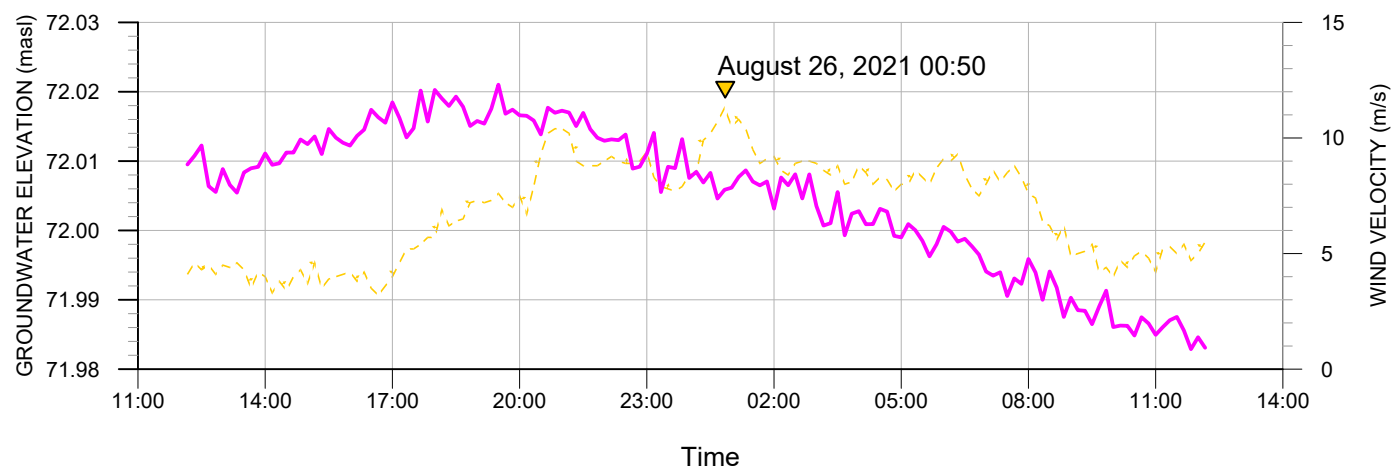
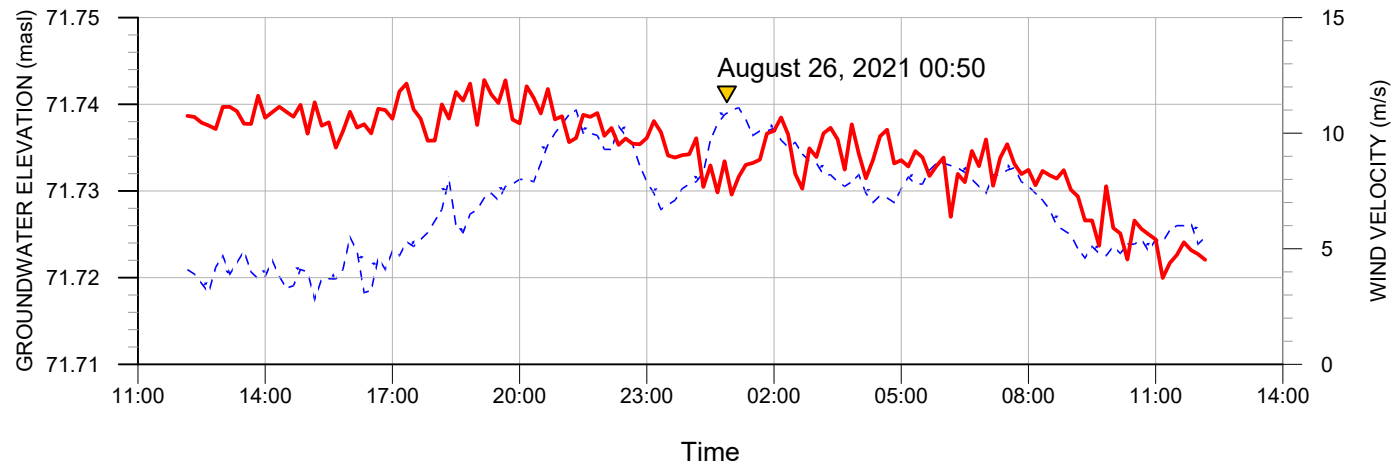
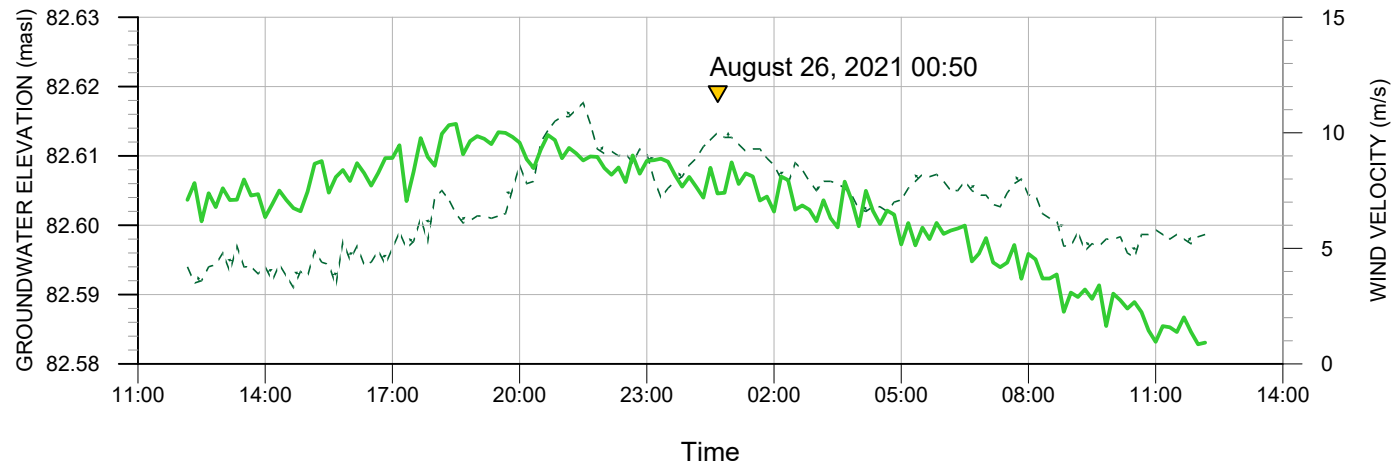
- T46 Groundwater Elevation
- T32 Groundwater Elevation
- T10/11 Groundwater Elevation
- - - Wind Velocity at T46
- - - Wind Velocity at T32
- - - Wind Velocity at T10/11
- ▼ Date for Vibration Data Analysis

Notes:

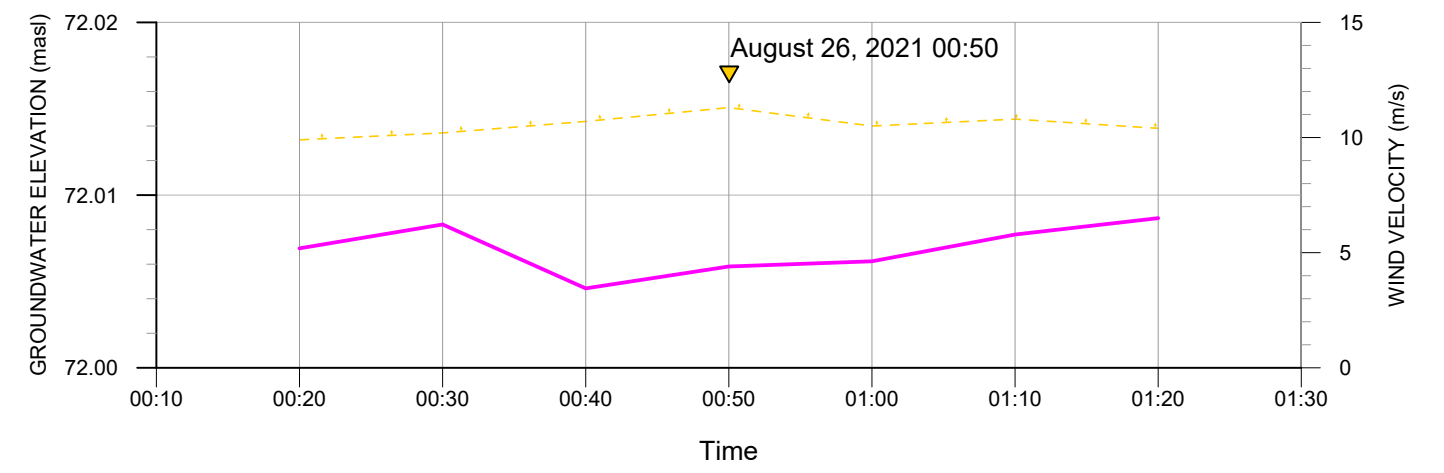
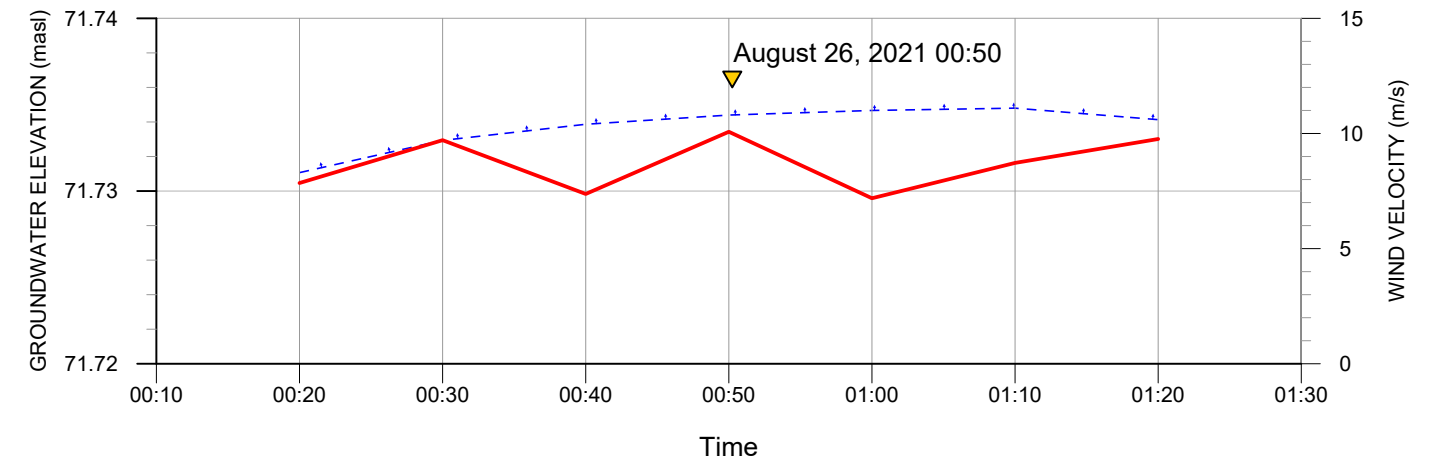
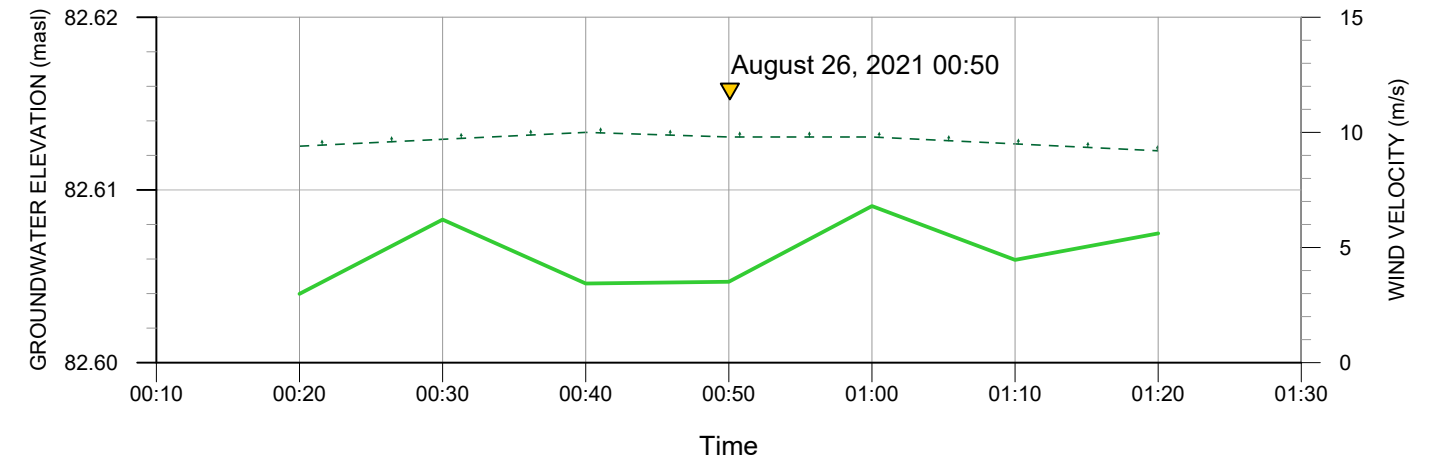
1. Graphs are to be read in conjunction with accompanying text
2. Meteorological data provided by turbine supplier
3. Low wind velocity range: 5 to 10 m/s

PROJECT			
NATION RISE WIND FARM OPERATIONAL VIBRATION MONITORING			
TITLE			
GROUNDWATER FLUCTUATION OVER 24-HOUR AND 1-HOUR PERIOD AT EACH TURBINE SITE (LOW WIND VELOCITY RANGE)			
PROJECT No.		19120626-3000	
FILE No.		19120626-3000-R01	
SCALE		AS SHOWN	
REV.		0	
DRAWN		JGH	
		July 2022	
CHECK			
FIGURE 10A			

24-Hour Groundwater Fluctuation



1-Hour Groundwater Fluctuation

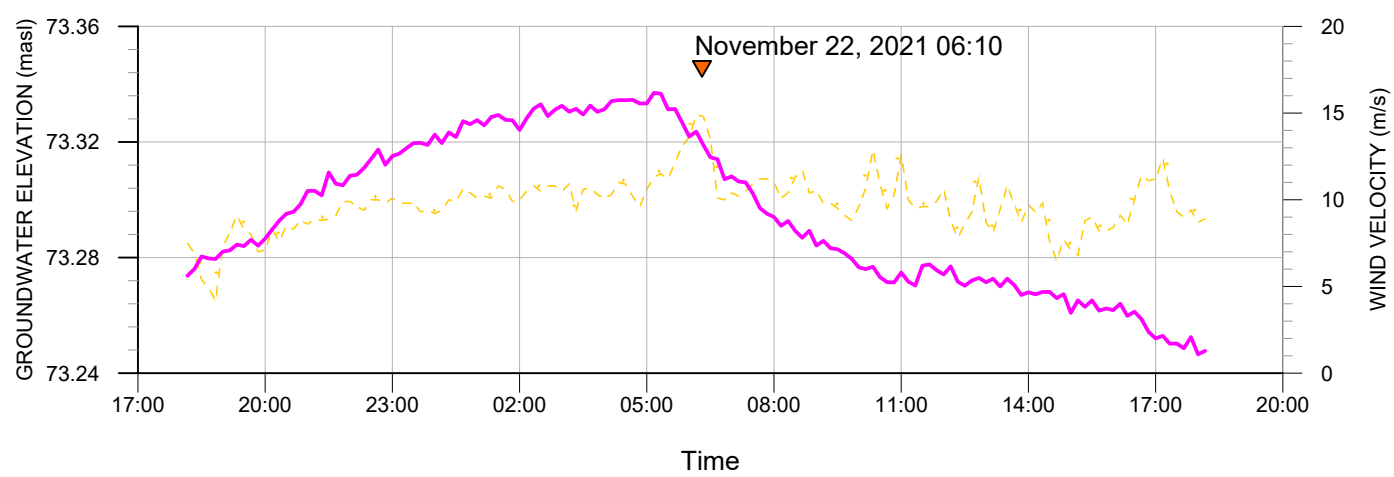
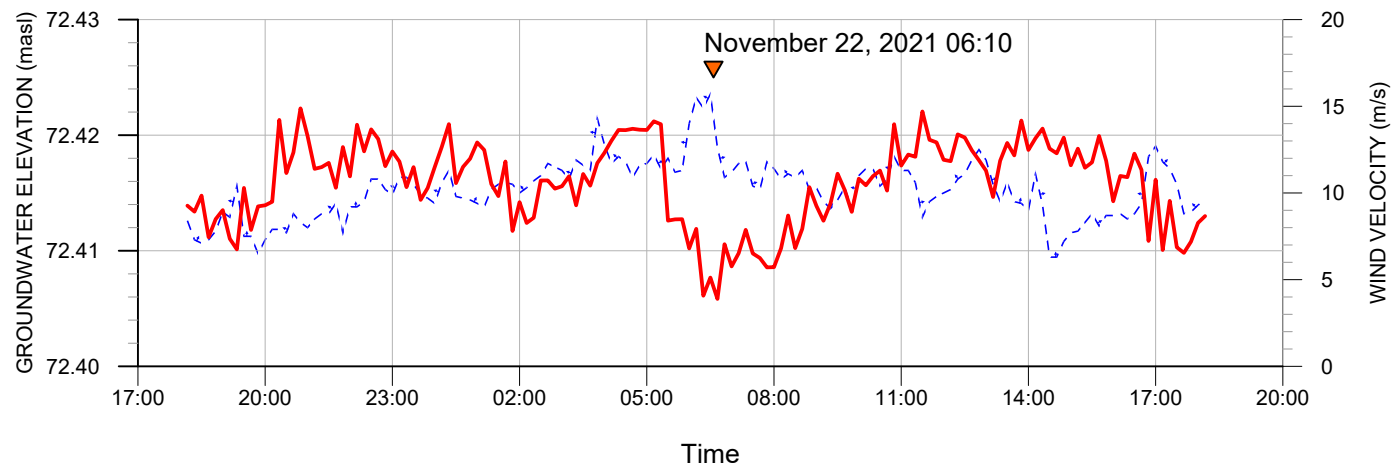
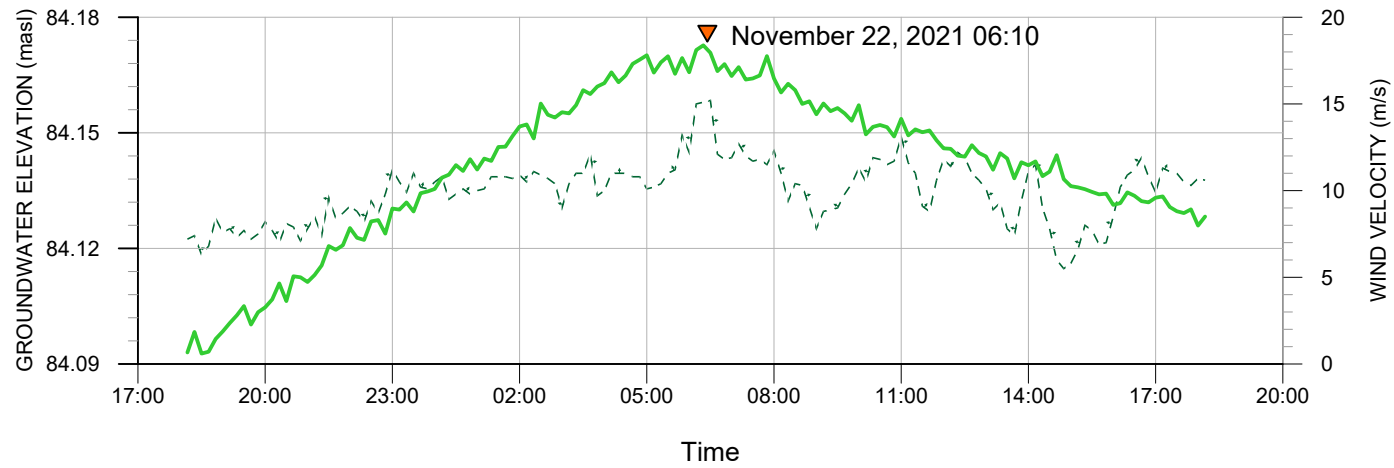


Legend			
—	T46 Groundwater Elevation	- - -	Wind Velocity at T32
—	T32 Groundwater Elevation	- - -	Wind Velocity at T10/11
—	T10/11 Groundwater Elevation	▼	Date for Vibration Data Analysis
- - -	Wind Velocity at T46		

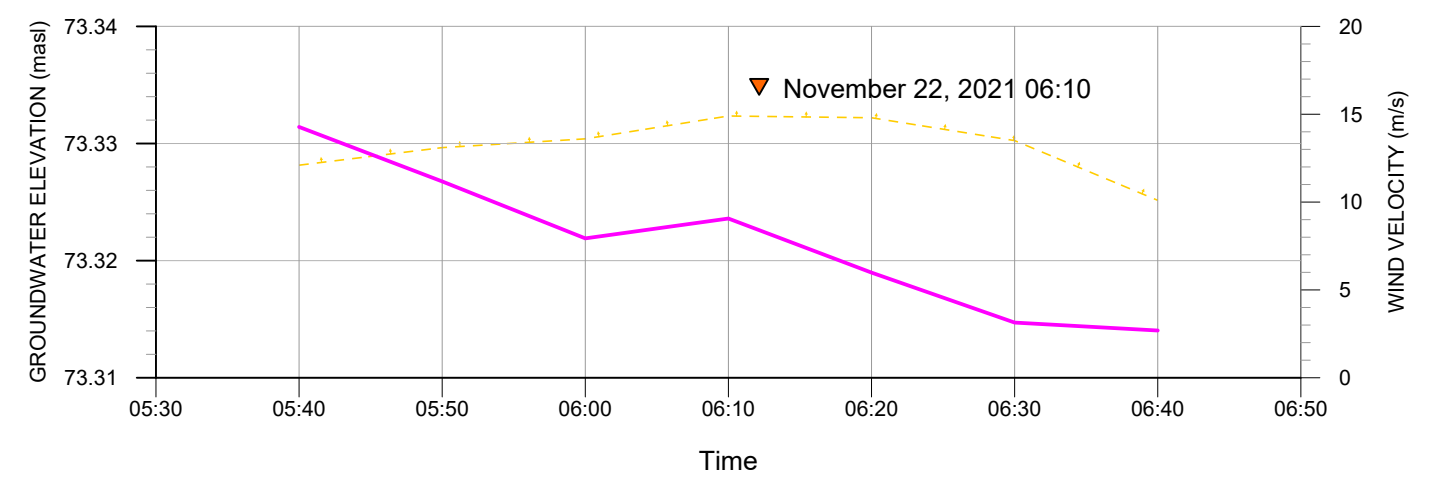
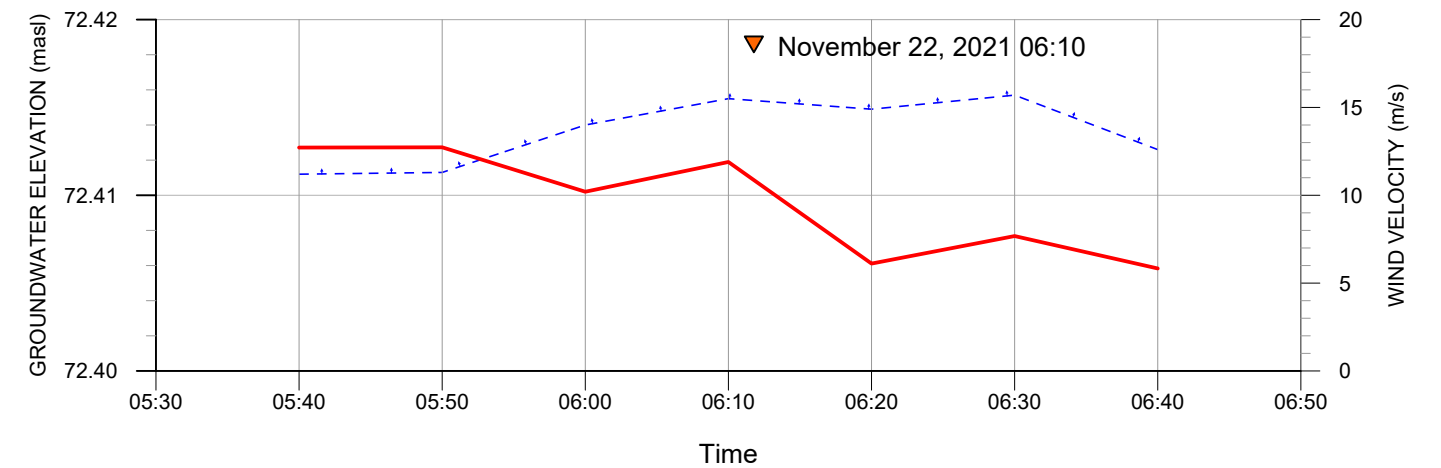
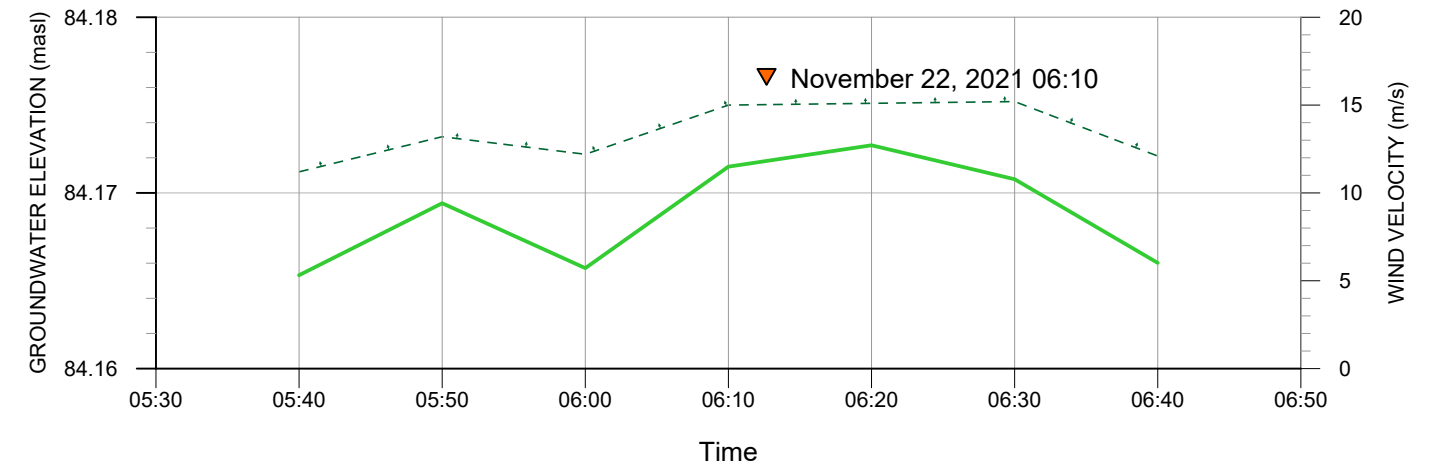
- Notes:
1. Graphs are to be read in conjunction with accompanying text
 2. Meteorological data provided by turbine supplier
 3. Moderate wind velocity range: 10 to 15 m/s

PROJECT			
NATION RISE WIND FARM OPERATIONAL VIBRATION MONITORING			
TITLE			
GROUNDWATER FLUCTUATION OVER 24-HOUR AND 1-HOUR PERIOD AT EACH TURBINE SITE (MODERATE WIND VELOCITY RANGE)			
PROJECT No. 19120626-3000		FILE No. 19120626-3000-R01	
DRAWN JGH July 2022		SCALE AS SHOWN REV. 0	
CHECK		FIGURE 10B	

24-Hour Groundwater Fluctuation



1-Hour Groundwater Fluctuation



Legend			
—	T46 Groundwater Elevation	- - -	Wind Velocity at T32
—	T32 Groundwater Elevation	- - -	Wind Velocity at T10/11
—	T10/11 Groundwater Elevation	▼	Date for Vibration Data Analysis
- - -	Wind Velocity at T46		

- Notes:
1. Graphs are to be read in conjunction with accompanying text
 2. Meteorological data provided by turbine supplier
 3. High wind velocity range: ≥ 15 m/s

PROJECT			
NATION RISE WIND FARM OPERATIONAL VIBRATION MONITORING			
TITLE			
GROUNDWATER FLUCTUATION OVER 24-HOUR AND 1-HOUR PERIOD AT EACH TURBINE LOCATION (HIGH WIND VELOCITY RANGE)			
PROJECT No. 19120626-3000		FILE No. 19120626-3000-R01	
DRAWN JGH		July 2022	
CHECK		SCALE AS SHOWN	
		REV. 0	
wsp GOLDER		FIGURE 10C	

APPENDIX A

Wind Turbine Specifications

NATION RISE WIND FARM

Specifications Report, Wind Facility

Nation Rise Wind Farm Limited Partnership

Document No.: 10021027-CAMO-R-08

Issue: E, **Status:** Final

Date: 22 May 2019



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Project name:	Nation Rise Wind Farm	DNV GL - Energy
Report title:	Specifications Report, Wind Facility	Renewables Advisory
Customer:	Nation Rise Wind Farm Limited Partnership 219 Dufferin St., Suite 217C Toronto, ON M6K 3J1	4100 Rue Molson, Suite 100, Montreal, QC, H1Y 3N1 CANADA Tel: 514 272-2175 Enterprise No.: 860480037
Contact person:	Kenneth Little	
Date of issue:	22 May 2019	
Project No.:	10021027	
Document No.:	10021027-CAMO-R-08	
Issue/Status	E/Final	

Prepared by:



Aren Nercessian, Analyst
Development and Engineering Services

Verified by:

Kristjan Varnik, Acoustic Engineer
Development and Engineering Services

Approved by:



Gabriel Constantin,
Team Leader, Environmental and
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Issue	Date	Reason for Issue	Prepared by	Verified by	Approved by
A	22 March 2017	Draft report	A. Danaitis	A. Nercessian	G. Constantin
B	13 July 2017	Update to report for REA submission	A. Danaitis	A. Nercessian	G. Constantin
C	15 September 2017	Update for completeness review	A. Danaitis	A. Nercessian	G. Constantin
D	26 September 2017	Update for completeness review	A. Danaitis	A. Nercessian	G. Constantin
E	22 May 2019	Switch to acoustically equivalent Enercon E138 turbine	A. Nercessian	K. Varnik	G. Constantin

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List of abbreviations

Abbreviation	Meaning
EPA	Ontario <i>Environmental Protection Act</i>
IESO	Independent Electricity System Operator
MECP	Ontario Ministry of Environment, Conservation and Parks
MW	Megawatt
NIA	Noise Impact Assessment
O. Reg	Ontario Regulation
REA	Renewable Energy Approval
SR	Specifications Report
TES	Trailing Edge Serrations

1 PREAMBLE

Nation Rise Wind Farm Limited Partnership (the “Proponent”) is proposing to develop the Nation Rise Wind Farm (the “Project”) which is subject to *Ontario Regulation (O. Reg.) 359/09* (Renewable Energy Approvals (REA) [1] under Part V.0.1 of the Ontario *Environmental Protection Act* (EPA)), as amended. The Proponent was awarded a contract for this Project in March 2016 from the Independent Electricity System Operator (IESO) under the Large Renewable Procurement (LRP), and has received its Renewable Energy Approval (REA) [0871-AV3TFM] from the Ontario Ministry of the Environment, Conservation and Parks (MECP, formerly the Ontario Ministry of the Environment and Climate Change) on 4 May 2018 [2]. The Project will be owned and operated by Nation Rise Wind Farm Limited Partnership, an indirectly owned of EDP Renewables Canada Ltd.

This Specifications Report, Wind Facility (SR) has been prepared in accordance with Table 1 of *O. Reg 359/09* and the Technical Guide to Renewable Energy Approvals, Chapter 9: Additional reports that may be required as part of an REA application, Section 13 Specifications Report Wind Facility (Not Class 2) [3]. Table 1-1 below presents the corresponding sections for each SR requirement.

Table 1-1: Specification Report Requirement and Corresponding Sections

Requirement	Section
Provide specifications of each wind turbine, including make, model, name plate capacity, hub height above grade, rotational speeds and acoustic emission data, including the sound power level and frequency spectrum, in terms of octave –band sound power levels.	2 and 3

2 TECHNICAL SPECIFICATIONS

This Project, with a total nameplate capacity of approximately 100 megawatts (MW), is considered to be a Class 4 wind facility. A total of 33 wind turbine locations have been permitted and the Proponent is currently evaluating different wind turbine technologies for the Project. The technology currently being considered is the Enercon E138 NR2 turbine with a capacity of 3.44 MW. This E138 model was customized for the Project with the intention of meeting the acoustically equivalent requirements of the REA (Condition A9).

The turbine rotor and nacelle will be placed on a tower with a hub-height of 131 m in height consisting of up to seven steel sections. The maximum sound power level of the proposed turbine is 104.3 dBA. A summary of technical specifications is provided below in Table 2-1.

Table 2-1: Summary of Turbine Technical Specifications

Model	Enercon E138 EP3 with Operating Mode NR2 s
Design	Steel tower or a hybrid tower made of precast concrete segments and a steel section
Rated Power	3.44 MW
Hub height	131 m
Rotor diameter	138.6 m
Number of blades	3
Blade modifications	Trailing Edge Serrations (TES)
Rotational Speed (rpm)	5 to 10.6
Cut-in wind speed	2.5 m/s
Cut-out wind speed	25 m/s
Nominal wind speed	14.5 m/s
Maximum sound power level	104.3 dBA

Additional technical information for this Enercon E138 EP3 model (mode OM NR2 s) with Trailing Edge Serrations is presented in Appendix A of this report. Moreover, an updated Wind Turbine Specifications Checklist is included in Appendix B.



3 ACOUSTIC EMISSIONS DATA

Broadband and octave-band sound power levels for all relevant noise operation modes of the Enercon E138 EP3 3.44 MW wind turbine (in operational mode OM NR2s) were provided by the manufacturer as shown in Appendix A.

The octave band sound power levels used in the updated noise model are those stated for each octave band centre frequency in Table 3-1. These are all less than or equal to those used in the Noise Impact Assessment (NIA) at all frequencies [4].

Table 3-1: Enercon E138 3.44 MW (mode OM NR2s) wind turbine acoustic emission summary

Make and Model:	Enercon E138 3.44 MW (mode OMNR2s)																							
Electrical Rating:	3440 kW																							
Hub Height (m):	131																							
	Octave Band Sound Power Level (dB)																							
	Manufacturer's Emission Levels at bin centre wind speeds at hub height																					(A)	(B)	(A+B)
Wind Speeds at hub height (m/s)	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0	Manufacturer's Worst-Case Spectrum (dB)	Positive Overall Adjustment* (dB)	Maximum Sound Power Level (dB)
Frequency (Hz)																								
31.5	68.9	70.6	72.0	73.3	74.2	74.3	74.6	74.8	74.9	75.1	75.4	75.5	75.6	75.6	75.5	75.4	75.3	75.2	75.2	75.2	75.1	75.6	0	75.6
63	79.8	81.6	83.2	84.7	85.7	85.9	86.2	86.4	86.5	86.8	87.0	87.2	87.2	87.2	87.2	87.1	87.0	86.9	86.8	86.8	86.8	87.2	0	87.2
125	85.4	87.3	89.0	90.5	91.6	91.8	92.2	92.4	92.6	92.8	93.0	93.2	93.2	93.1	93.1	92.9	92.7	92.6	92.5	92.5	92.4	93.2	0	93.2
250	88.5	90.5	92.1	93.7	94.8	95.1	95.4	95.6	95.8	96.0	96.2	96.4	96.3	96.1	96.0	95.8	95.6	95.5	95.4	95.3	95.2	96.3	0.1	96.4
500	90.3	92.4	94.2	95.9	97.2	97.4	97.7	97.9	98.1	98.3	98.5	98.8	98.7	98.6	98.5	98.3	98.2	98.0	98.0	98.0	98.0	98.7	0.1	98.8
1,000	89.8	92.0	93.9	95.7	96.9	97.1	97.4	97.5	97.8	98.0	98.2	98.6	98.7	98.8	98.9	98.9	99.0	99.0	99.1	99.2	99.3	98.7	0	98.7
2,000	87.3	89.5	91.4	93.2	94.5	94.6	94.9	95.0	95.2	95.5	95.7	96.2	96.5	96.6	96.8	97.2	97.6	97.6	97.7	97.8	97.7	96.5	0	96.5
4,000	78.5	80.7	82.7	84.5	85.8	85.9	86.1	86.2	86.3	86.6	87.0	87.6	88.1	88.4	88.7	89.0	88.8	88.6	88.5	88.3	88.2	88.1	0	88.1
8,000	57.2	59.7	61.8	63.8	65.1	65.2	65.4	65.5	65.6	66.0	66.4	67.1	67.5	67.6	67.5	66.9	66.6	66.2	66.0	65.8	65.7	67.5	0	67.5
Overall A-weighted (dBA)	95.8	97.9	99.7	101.4	102.6	102.8	103.1	103.3	103.5	103.7	103.9	104.2	104.3	104.3	104.3	104.3	104.3	104.3	104.3	104.3	104.3	104.3	0	104.3

The spectrum corresponding to 11.0 m/s is the worst-case spectrum according to the definition in the 2016 Ontario Noise Guidelines.

For additional conservatism, a 0.1 dB positive adjustment has been added to the 250 Hz and 500 Hz frequencies, which represent the 10.5 m/s wind speed bin.

It can be noted that all three variants of the NR2 s model (3.5 MW, 3.45 MW and 3.44 MW) with TES have identical acoustic specifications according to [6].



3.1 Tonal audibility

Enercon states in a guarantee letter dated 15 May 2019 , that the typical tonal audibility for the E138 EP3 NR2s wind turbine generators has not exceeded 3 dBA as determined in accordance with the methods described in standard IEC 61400-11, Ed.3, 2012 [5]. This letter is shown in Appendix A.

The acoustic emissions data and technical specifications (including power curve) for the Enercon E138 EP3 3.44 MW (OM NR2s) are presented in Appendix A.



4 REFERENCES

- [1] Ontario Regulation 359/09, made under the Environmental Protection Act, Renewable Energy Approvals under Part 1.0 of the Act.
- [2] Ontario Ministry of the Environment and Climate Change, Renewable Energy Approval (0871-AV3TFM) – Nation Rise Wind Farm, 4 May 2018.
- [3] Technical Guide to Renewable Energy Approvals, Ontario Ministry of the Environment and Climate Change, 2017.
- [4] DNV GL, Noise Impact Assessment, Nation Rise Wind Farm, 26 September 2017.
- [5] IEC 61400 – 11 Ed. 3.0 Wind turbines– Part 11: Acoustic noise measurement techniques. 58 p.
- [6] Enercon. Document D0778163-1. *Data Sheet-Operating Modes E-138 EP3 / 3500 kW with TES (Nation Rise)*. December 12, 2018



APPENDIX A – ENERCON E138 EP3 NR2 S SPECIFICATIONS

This appendix contains the following supporting documentation for the Enercon E138 EP3 NR2 s 3.44 MW turbine model:

1. General specifications and power curve
2. Calculated one-third octave band sound power levels provided by Enercon
3. Enercon Guarantee letter

6 Operating mode NR2 s 3440 kW

6.1 Calculated power, c_p and c_t values – operating mode NR2 s 3440 kW

Tab. 24: Calculated power, c_p and c_t values for E-138 EP3 / 3500 kW – operating mode NR2 s 3440 kW

Wind speed v in m/s	Power P in kW	c_p value	c_t value
0.00	0	0.00	0.00
0.50	0	0.00	0.00
1.00	0	0.00	0.00
1.50	0	0.00	0.00
2.00	8	0.11	0.75
2.50	33	0.23	1.02
3.00	81	0.33	1.00
3.50	154	0.39	0.94
4.00	252	0.43	0.91
4.50	377	0.45	0.89
5.00	524	0.45	0.87
5.50	702	0.46	0.86
6.00	912	0.46	0.85
6.50	1155	0.46	0.82
7.00	1429	0.45	0.80
7.50	1726	0.44	0.76
8.00	2034	0.43	0.73
8.50	2337	0.41	0.68
9.00	2617	0.39	0.63
9.50	2858	0.36	0.57
10.00	3051	0.33	0.52
10.50	3195	0.30	0.46
11.00	3294	0.27	0.41
11.50	3359	0.24	0.36
12.00	3397	0.21	0.32
12.50	3419	0.19	0.28
13.00	3431	0.17	0.25
13.50	3436	0.15	0.22
14.00	3439	0.14	0.19

Wind speed v in m/s	Power P in kW	c_p value	c_t value
14.50	3440	0.12	0.17
15.00	3440	0.11	0.16
15.50	3440	0.10	0.14
16.00	3440	0.09	0.13
16.50	3440	0.08	0.12
17.00	3440	0.08	0.11
17.50	3440	0.07	0.10
18.00	3440	0.06	0.09
18.50	3440	0.06	0.08
19.00	3440	0.05	0.08
19.50	3438	0.05	0.07
20.00	3427	0.05	0.07
20.50	3405	0.04	0.06
21.00	3367	0.04	0.06
21.50	3305	0.04	0.05
22.00	3214	0.03	0.05
22.50	3091	0.03	0.05
23.00	2934	0.03	0.04
23.50	2746	0.02	0.04
24.00	2530	0.02	0.03
24.50	2304	0.02	0.03
25.00	1858	0.01	0.02

6.2 Calculated sound power levels – operating mode NR2 s 3440 kW

In mode NR2 s 3440 kW the wind energy converter operates with reduced power. The highest expected sound power level is 104.3 dB(A) in the nominal power range. Once nominal power has been achieved, a steady level is guaranteed.

Tab. 25: Technical specifications

Parameter	Value	Unit
Nominal power (P_n)	3440	kW
Nominal wind speed	14.5	m/s
Minimum operating speed	5.0	rpm
Speed setpoint	10.6	rpm

The following sound power levels apply, taking into account the specified uncertainties in ch. 3, p. 9.

Tab. 26: Calculated sound power level in dB(A), based on standardised wind speed v_s at a height of 10 m

Wind speed (v_s) at a height of 10 m	Sound power level in dB(A)	
	HH 131 m	
3 m/s	93.2	
3.5 m/s	96.6	
4 m/s	99.5	
4.5 m/s	101.8	
5 m/s	102.8	
5.5 m/s	103.2	
6 m/s	103.5	
6.5 m/s	103.8	
7 m/s	104.1	
7.5 m/s	104.3	
8 m/s	104.3	
8.5 m/s	104.3	
9 m/s	104.3	
9.5 m/s	104.3	
10 m/s	104.3	
10.5 m/s	104.3	
11 m/s	104.3	
11.5 m/s	104.3	
12 m/s	104.3	

Wind speed (v_{10}) at a height of 10 m	Sound power level in dB(A)
	HH 131 m
95 % P_{in}	104.3

Tab. 27: Calculated sound power level in dB(A), based on wind speed at hub height

Wind speed at hub height (v_{HH})	Sound power level in dB(A)
5 m/s	95.8
5.5 m/s	97.9
6 m/s	99.7
6.5 m/s	101.4
7 m/s	102.6
7.5 m/s	102.8
8 m/s	103.1
8.5 m/s	103.3
9 m/s	103.5
9.5 m/s	103.7
10 m/s	103.9
10.5 m/s	104.2
11 m/s	104.3
11.5 m/s	104.3
12 m/s	104.3
12.5 m/s	104.3
13 m/s	104.3
13.5 m/s	104.3
14 m/s	104.3
14.5 m/s	104.3
15 m/s	104.3

6.3 One-third octave band level at HH

In the following tables, the values at which the maximum sound power level is reached for the first time are displayed in *italics*.

Tab. 28: One-third octave band level in dB(A), based on wind speed v_H at hub height

One-third octave band level centre frequency in Hz	v_H in m/s										
	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10
20	51.6	53.1	54.3	55.4	56.2	56.3	56.6	56.7	56.8	57.1	57.3
25	57.6	59.1	60.4	61.6	62.4	62.5	62.8	62.9	63.1	63.3	63.5
31.5	62.8	64.4	65.7	67.0	67.9	68.0	68.3	68.5	68.6	68.8	69.0
40	67.3	69.0	70.4	71.7	72.7	72.8	73.1	73.3	73.4	73.6	73.9
50	71.1	72.9	74.4	75.8	76.8	77.0	77.3	77.4	77.6	77.8	78.0
63	74.5	76.3	77.8	79.3	80.3	80.5	80.8	81.0	81.1	81.4	81.6
80	77.3	79.2	80.8	82.3	83.3	83.5	83.8	84.0	84.2	84.4	84.6
100	79.4	81.3	83.0	84.5	85.6	85.8	86.1	86.3	86.5	86.7	86.9
125	80.7	82.6	84.2	85.8	86.9	87.1	87.4	87.6	87.8	88.0	88.2
160	81.6	83.5	85.1	86.7	87.8	88.0	88.4	88.6	88.8	89.0	89.2
200	82.5	84.5	86.1	87.7	88.8	89.0	89.4	89.6	89.8	90.0	90.2
250	83.7	85.7	87.3	88.9	90.0	90.3	90.6	90.8	91.0	91.2	91.4
315	84.6	86.7	88.3	89.9	91.1	91.3	91.7	91.9	92.1	92.3	92.4
400	85.4	87.4	89.1	90.8	92.0	92.2	92.5	92.8	93.0	93.2	93.3
500	85.7	87.8	89.6	91.3	92.6	92.8	93.1	93.3	93.5	93.7	93.9
630	85.6	87.8	89.7	91.4	92.7	92.9	93.2	93.4	93.6	93.8	94.0
800	85.3	87.5	89.3	91.1	92.4	92.6	92.9	93.0	93.3	93.5	93.7
1000	85.0	87.2	89.1	90.9	92.1	92.3	92.6	92.8	93.0	93.2	93.4
1250	84.8	87.0	88.9	90.7	91.9	92.1	92.3	92.5	92.7	92.9	93.1
1600	84.1	86.3	88.2	90.0	91.2	91.4	91.7	91.8	92.0	92.3	92.5
2000	82.5	84.7	86.6	88.4	89.7	89.8	90.1	90.2	90.4	90.7	90.9
2500	80.1	82.3	84.3	86.1	87.3	87.5	87.7	87.8	88.0	88.3	88.5
3150	76.9	79.1	81.1	82.9	84.2	84.3	84.5	84.6	84.7	85.0	85.4
4000	72.4	74.7	76.7	78.5	79.8	79.8	80.0	80.1	80.2	80.6	80.9
5000	66.2	68.6	70.6	72.5	73.8	73.9	74.1	74.1	74.2	74.6	75.0
6300	57.0	59.5	61.6	63.6	64.9	65.0	65.2	65.3	65.4	65.8	66.2
8000	43.4	45.9	48.0	50.1	51.5	51.6	51.8	51.9	52.1	52.5	52.8
10000	25.3	27.8	30.0	32.1	33.5	33.7	33.9	34.0	34.2	34.6	34.9

Tab. 29: One-third octave band level in dB(A), based on wind speed v_H at hub height

One-third octave band level centre frequency in Hz	v_H in m/s									
	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
20	57.3	57.4	57.4	57.4	57.3	57.2	57.1	57.1	57.0	57.0
25	63.6	63.7	63.7	63.6	63.5	63.5	63.4	63.3	63.3	63.3
31.5	69.1	69.2	69.2	69.2	69.1	69.0	68.9	68.8	68.8	68.8
40	74.0	74.1	74.1	74.0	73.9	73.8	73.7	73.7	73.7	73.6
50	78.2	78.3	78.2	78.2	78.1	78.0	77.9	77.9	77.8	77.8
63	81.8	81.8	81.8	81.8	81.7	81.6	81.5	81.4	81.4	81.4
80	84.8	84.9	84.8	84.8	84.7	84.6	84.5	84.5	84.4	84.4
100	87.1	87.1	87.1	87.1	86.9	86.8	86.7	86.7	86.6	86.6
125	88.4	88.4	88.4	88.3	88.1	88.0	87.9	87.8	87.8	87.7
160	89.4	89.4	89.3	89.2	89.0	88.8	88.7	88.6	88.6	88.5
200	90.4	90.3	90.2	90.1	89.9	89.7	89.5	89.5	89.4	89.3
250	91.6	91.5	91.3	91.2	91.0	90.8	90.7	90.6	90.5	90.4
315	92.6	92.5	92.3	92.2	92.0	91.8	91.6	91.6	91.4	91.4
400	93.5	93.4	93.2	93.1	92.9	92.7	92.5	92.5	92.4	92.3
500	94.1	94.1	93.9	93.8	93.6	93.4	93.3	93.3	93.2	93.2
630	94.3	94.3	94.3	94.2	94.1	94.0	93.9	93.9	93.9	93.9
800	94.0	94.1	94.1	94.2	94.1	94.1	94.1	94.1	94.2	94.2
1000	93.8	94.0	94.0	94.1	94.1	94.2	94.3	94.4	94.5	94.5
1250	93.6	93.8	93.9	94.0	94.1	94.3	94.4	94.6	94.7	94.8
1600	92.9	93.2	93.3	93.5	93.7	94.1	94.2	94.4	94.5	94.5
2000	91.4	91.7	91.9	92.1	92.5	92.9	93.0	93.1	93.1	93.1
2500	89.1	89.4	89.7	89.9	90.5	90.8	90.7	90.6	90.5	90.4
3150	85.9	86.4	86.7	87.0	87.5	87.4	87.2	87.1	86.9	86.8
4000	81.6	82.1	82.5	82.7	82.8	82.5	82.2	82.0	81.9	81.7
5000	75.7	76.3	76.5	76.6	76.2	75.8	75.6	75.4	75.2	75.0
6300	66.9	67.3	67.4	67.3	66.7	66.4	66.0	65.8	65.6	65.5
8000	53.5	53.7	53.7	53.6	53.0	52.6	52.2	52.0	51.8	51.6
10000	35.5	35.7	35.7	35.5	34.9	34.4	34.0	33.7	33.5	33.3



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May 15, 2019

Enercon Canada Inc.
700 rue de la Gauchetière, Suite 1200
Montreal, Quebec
H3B 5M2

Re: Tonal Audibility Level Warranty and Maximum Sound Power Level

Dear Sir/Madam,

With respect to the Nation Rise wind farm project, ENERCON Canada Inc. warrants that the E-138 EP3 E1 wind energy converter using the operating mode (OM) NR2, with a maximum rated power level of 3.44 MW and a maximum sound power level of 104.3 dB(A) will have a tonal audibility level of less than or equal to 3 dB, when measured according to the methods described in standard IEC 61400-11, Ed. 3, 2012.

Kind regards,

Michael Weidemann
Executive Vice-President
ENERCON Canada Inc.

700, De La Gauchetière Street West, Suite 1200, Montreal, Quebec H3B 5M2
Telephone: (514) 363-7266 • Fax: (514) 687-2536

APPENDIX B – WIND TURBINE SPECIFICATIONS CHECKLIST

Specifications	Details
Wind Turbine Information	
Manufacturer	Enercon GmbH
Model	E138 EP3 3500kW
Hub Height (m)	130.54 m
Operation Information	
Speed regulation	Pitch Control – Pitch regulated with variable speed
Rotational Speed per wind speed bin	At 6.0 m/s: 8.9 rpm
	At 6.5 m/s: 9.5 rpm
	At 7.0 m/s: 9.8 rpm
	At 7.5 m/s: 9.9 rpm
	At 8.0 m/s: 10.0 rpm
	At 8.5 m/s: 10.1 rpm
	At 9.0 m/s: 10.1 rpm
	At 9.5 m/s: 10.2 rpm
	At 10.0 m/s: 10.2 rpm
	At 10.5 m/s: 10.4 rpm
	At 11.0 m/s: 10.7 rpm
	At 11.5 m/s: 10.7 rpm
	At 12.0 m/s: 10.7 rpm
	At 12.5 m/s: 10.7 rpm
At 13.0 m/s: 10.8 rpm	
At 13.5 m/s: 10.8 rpm	
At 14.0 m/s: 10.9 rpm	
At 14.5 m/s: 11.0 rpm	
Version Software for control of wind turbine	EP3-CS-02-a-01 / E-138 EP3 3500kW - OMNR2s 3440kW Rev 0.0
Rotor Information	
Type (Default is a 3 blade, horizontal, upwind turbine)	3 blade, horizontal, upwind turbine
Horizontal Distance from rotor centre to tower axis (m)	5.99 m
Diameter of Rotor (m)	138.25 m
Rotor Control Devices	Electrical pitch system
Blade Modifications	<input checked="" type="checkbox"/> Trailing Edge Serrations <input checked="" type="checkbox"/> Vortex Generators
Blade Length (m)	66.89 m
Gearbox Information	
Type	Direct Drive
Manufacturer	Not Applicable
Model Number	Not Applicable

Generator Information	
Manufacturer	Enercon GmbH
Model Number	E-138 EP3-GE-01
Nominal Power (MW)	3.44 MW
Sound Data for tested wind turbine	
Overall sound power level IEC61400-11 test at hub height	Mode OM NR2 s
	At 6.0 m/s: 98.4 dBA
	At 6.5 m/s: 99.7 dBA
	At 7.0 m/s: 100.6 dBA
	At 7.5 m/s: 101.5 dBA
	At 8.0 m/s: 102.0 dBA
	At 8.5 m/s: 102.2 dBA
	At 9.0 m/s: 102.3 dBA
	At 9.5 m/s: 102.4 dBA
	At 10.0 m/s: 102.6 dBA
	At 10.5 m/s: 103.0 dBA
	At 11.0 m/s: 103.3 dBA
	At 11.5 m/s: 103.3 dBA
	At 12.0 m/s: 103.4 dBA
	At 12.5 m/s: 103.6 dBA
At 13.0 m/s: 103.8 dBA	
At 13.5 m/s: 103.9 dBA	
At 14.0 m/s: 104.1 dBA	
At 14.5 m/s: 104.2 dBA	
Measurement Uncertainty (dB)	Max 0.8 dB
Grid Terminal Frequency of Tester	50 Hz
Additional Specifications	Details
Operating Information	
Swept Area (m ²)	15,011 m ²
Rated Power Output (MW)	3.44 MW
Aerodynamic Brakes	No
Cut-in Wind Speed (m/s)	2.5 m/s
Cut-out Wind Speed (m/s)	25.0 m/s
Nominal Power Wind Speed (m/s)	14.5 m/s
Rotor Information	
Aerodynamic Profile of Blade	EC1
Sound Data for tested wind turbine	
Maximum tonal audibility (dB)	-2.5
Provide a Power Curve for each wind turbine proposed for the Project	See Appendix A



ABOUT DNV GL

Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification, technical assurance, software and independent expert advisory services to the maritime, oil & gas and energy industries. We also provide certification services to customers across a wide range of industries. Combining leading technical and operational expertise, risk methodology and in-depth industry knowledge, we empower our customers' decisions and actions with trust and confidence. We continuously invest in research and collaborative innovation to provide customers and society with operational and technological foresight. Operating in more than 100 countries, our professionals are dedicated to helping customers make the world safer, smarter and greener.

APPENDIX B

**Monitoring Instrument
Specifications and Calibrations**

Sensor Information

Model Number: 393B31
Serial Number: 55540
Manufacturer: PCB
ID Number:

Calibration Data

Sensitivity @ 10 Hz: 9,979 mV/g
1,018 mV/m/s²
Phase @ 10 Hz: -0.86 deg.
Test Level: 0.30 g

Transducer Specifications

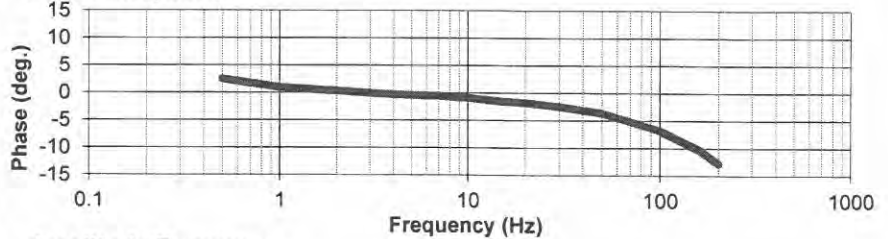
Amp. Range: ± 0.5 g
Resolution: 0.000001 g
Resonant Freq: ≥ 700 Hz
Temp. Range: -18 to 66 °C
0 to 150 °F
Axis: Uni-Axial

Description: ICP® Accelerometer

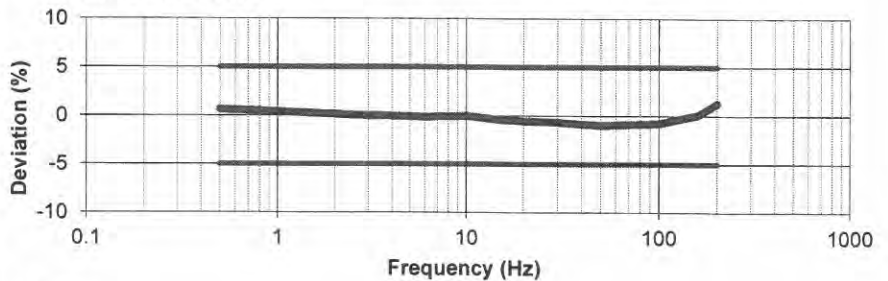
Data Table

Freq. (Hz)	Deviation (%)	Phase (deg)
0.5	0.6386	2.4666
1	0.4364	0.9773
2	0.1400	0.3106
3	0.0005	-0.0777
4	-0.0248	-0.2986
5	-0.0679	-0.4273
6.3	-0.1242	-0.5541
7	-0.0704	-0.5674
8	-0.0778	-0.7239
10	0.0000	-0.8636
15	-0.4183	-1.5373
20	-0.5502	-1.7457
30	-0.6582	-2.4851
50	-0.9701	-3.6197
100	-0.7636	-6.7661
160	0.1090	-10.3285
200	1.3003	-12.7336

Phase Response



Amplitude Response



Notes

Results relate only to the items calibrated.
This certificate may not be reproduced except in full, without written permission.
Method: Back-to-Back Comparison Calibration per ISO 16063 Part 21
This calibration was performed with TMS 9155 Calibration Workstation 1 version 6.0.0
Proficiency in calibration traceable to PTB (17014/17004) and NIST (683/287323).
Back-to-Back Comparison Calibration per ISO 16063-21
Procedures Used: PRD-P220 and PRD-P214, or PRD-P239
Measurement uncertainty (95% confidence level with coverage factor 2) for frequency ranges tested during calibration are as follows: 0.5-1 Hz; 1.1%; >1-10 Hz; ± 0.8%, 11-99 Hz; ± 1.2%, 100 Hz; ± 0.75%, 101-920 Hz; ± 1.0%, 921-5000 Hz; ± 1.4%, 5001-10,000 Hz; ± 1.9%, 10,001-15,000 Hz; ± 2.2%, 15,001-20,000 Hz; ± 2.8%.

Customer

Golder Associates

User Notes

Lab Conditions

Temperature: 72 (22) °F (°C)
Humidity: 57 %

Unit Condition

As Found: In Tolerance
As Left: In Tolerance

Cal Date: 27-Aug-20

Due Date:

Approval Information

Technician: William Moses

Approval: *William Moses*



Equipment Used

Description	Manufacturer	Model	Serial	Due Date
Data Acquisition Card	NI	PCI-4461	1D83333	11/5/2020
Ref Std Conditioner	NI	PCI-6251	136F2A3	2/14/2021
Reference Std	PCB	080A200	110553	1/9/2021
Air Bearing Shaker	PCB	396C11	603	n/a
Ref Std Conditioner	PCB	442A102	305	1/9/2021
SUT Signal Conditioner	PCB	443B101	373	10/15/2020
Power Amplifier	TMS	2100E21-C	50002	n/a
Reference Std	TMS	2129E025 Sys	111	2/14/2021
Long Stroke Shaker	TMS	2129E025-779	111	n/a

~ Calibration Certificate ~

Per ISO 16063-21

Model Number: 393B31

Serial Number: 60743

Description: ICP® Accelerometer

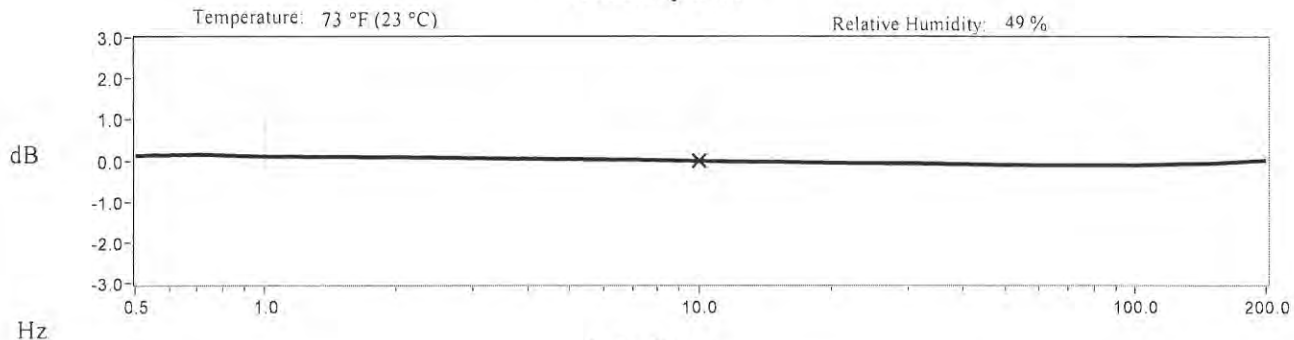
Manufacturer: PCB

Method: Back-to-Back Comparison AT401-12

Calibration Data

Sensitivity @ 10 Hz 9.74 V/g Output Bias 11.5 VDC
(0.993 V/m/s²) Transverse Sensitivity 3.1 %
Resonant Frequency 860 Hz

Sensitivity Plot



Data Points

Frequency (Hz)	Dev. (%)	Frequency (Hz)	Dev. (%)	Frequency (Hz)	Dev. (%)
0.5	1.4	REF. FREQ.	0.0	70	-1.2
1	1.2	15	-0.4	100	-1.3
2	1.0	20	-0.6	200	0.2
5	0.4	30	-0.8		
7	0.2	50	-1.2		

Mounting Surface: Stainless Steel w/Silicone Grease Fastener: 1/4-28 Female Fixture Orientation: Vertical

Acceleration Level (pk): 0.100 g (0.981 m/s²)

The acceleration level may be limited by shaker displacement at low frequencies. If the listed level cannot be obtained, the calibration system uses the following formula to set the vibration amplitude: Acceleration Level (g) = 0.207 x (freq)^{1.5}. The gravitational constant used for calculations by the calibration system is: 1 g = 9.80665 m/s².

Condition of Unit

As Found: n/a

As Left: New Unit, In Tolerance

Notes

1. Calibration is traceable to one or more of the following; PTB 10065, PTB 10066 and NIST 683/283498.
2. This certificate shall not be reproduced, except in full, without written approval from PCB Piezotronics, Inc.
3. Calibration is performed in compliance with ISO 10012-1, ANSI Z540.3 and ISO 17025.
4. See Manufacturer's Specification Sheet for a detailed listing of performance specifications.
5. Measurement uncertainty (95% confidence level with coverage factor of 2) for frequency ranges tested during calibration are as follows: 0.5-0.99 Hz; +/- 1.8%, 1-30 Hz; +/- 1.0%, 30.01-199 Hz; +/- 1.5%, 200-1 kHz; +/- 3.0%.

Technician: _____

Jonathan Harmon

Date: _____

10/1/2020



HEADQUARTERS: 3425 WALDEN AVENUE - DEPEW, NY 14043
CALIBRATION PERFORMED AT: 10869 HIGHWAY 903, HALIFAX, NC 27839
TEL: 888-684-0013 - FAX: 716-685-3886 - www.pcb.com

CAL143-3684404150.297-0



~ Calibration Certificate ~

Per ISO 16063-21

Model Number: 393B31

Serial Number: 60746

Description: ICP® Accelerometer

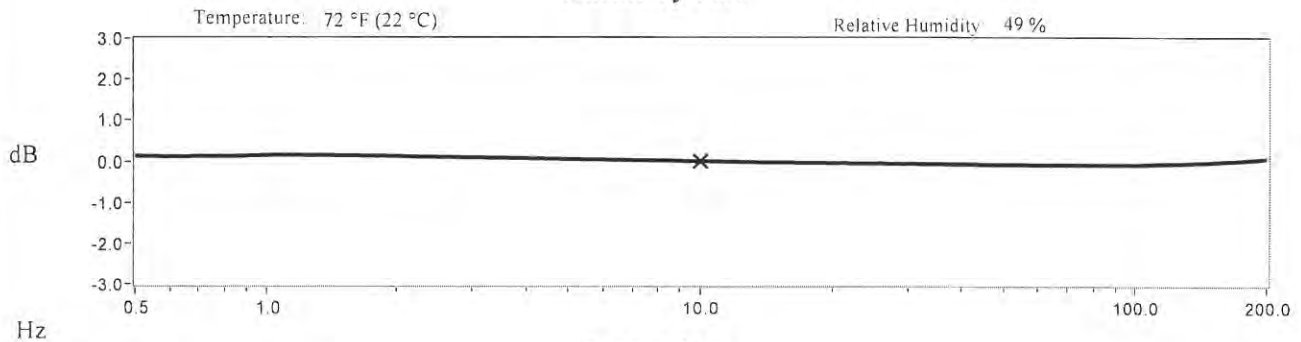
Manufacturer: PCB

Method: Back-to-Back Comparison AT401-12

Calibration Data

Sensitivity @ 10 Hz 9.94 V/g Output Bias 11.5 VDC
(1.014 V/m/s²) Transverse Sensitivity 4.5 %
Resonant Frequency 850 Hz

Sensitivity Plot



Data Points

Frequency (Hz)	Dev. (%)	Frequency (Hz)	Dev. (%)	Frequency (Hz)	Dev. (%)
0.5	1.4	REF. FREQ.	0.0	70	-1.1
1	1.7	15	-0.4	100	-1.0
2	1.3	20	-0.5	200	0.6
5	0.6	30	-0.7		
7	0.3	50	-1.0		

Mounting Surface: Stainless Steel w/Silicone Grease Fastener: 1/4-28 Female Fixture Orientation: Vertical

Acceleration Level (pk): 0.100 g (0.981 m/s²)

*The acceleration level may be limited by shaker displacement at low frequencies. If the listed level cannot be obtained, the calibration system uses the following formula to set the vibration amplitude: Acceleration Level (g) = 0.207 x (freq)². *The gravitational constant used for calculations by the calibration system is: 1 g = 9.80665 m/s²


Condition of Unit

As Found: n/a

As Left: New Unit, In Tolerance

Notes

1. Calibration is traceable to one or more of the following; PTB 10065, PTB 10066 and NIST 683/283498.
2. This certificate shall not be reproduced, except in full, without written approval from PCB Piezotronics, Inc.
3. Calibration is performed in compliance with ISO 10012-1, ANSI Z540.3 and ISO 17025.
4. See Manufacturer's Specification Sheet for a detailed listing of performance specifications.
5. Measurement uncertainty (95% confidence level with coverage factor of 2) for frequency ranges tested during calibration are as follows: 0.5-0.99 Hz; +/- 1.8%, 1-30 Hz; +/- 1.0%, 30.01-199 Hz; +/- 1.5%, 200-1 kHz; +/- 3.0%.

Technician: Jonathan Harmon 

Date: 10/1/2020



HEADQUARTERS: 3425 WALDEN AVENUE - DEPEW, NY 14043
CALIBRATION PERFORMED AT: 10869 HIGHWAY 903, HALIFAX, NC 27839
TEL: 888-684-0013 - FAX: 716-685-3886 - www.pcb.com

CAL143-3684395725-449-01



~ Calibration Certificate ~

Per ISO 16063-21

Model Number: 393B31

Serial Number: 60744

Description: ICP® Accelerometer

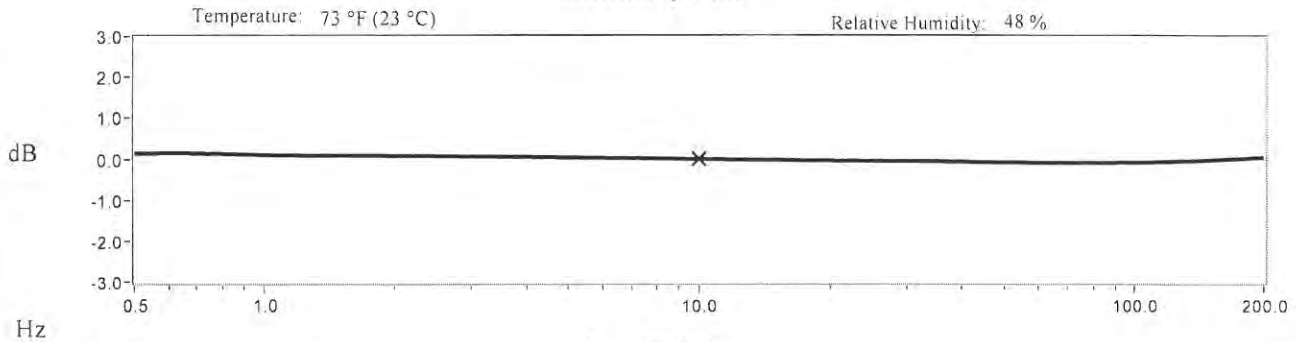
Manufacturer: PCB

Method: Back-to-Back Comparison AT401-12

Calibration Data

Sensitivity @ 10 Hz	9.80 V/g (1.000 V/m/s ²)	Output Bias	11.6 VDC
Resonant Frequency	850 Hz	Transverse Sensitivity	1.5 %

Sensitivity Plot



Data Points

Frequency (Hz)	Dev. (%)	Frequency (Hz)	Dev. (%)	Frequency (Hz)	Dev. (%)
0.5	1.5	REF. FREQ.	0.0	70	-1.1
1	1.1	15	-0.4	100	-1.1
2	0.8	20	-0.5	200	0.4
5	0.4	30	-0.7		
7	0.2	50	-1.0		

Mounting Surface: Stainless Steel w/Silicone Grease Fastener: 1/4-28 Female Fixture Orientation: Vertical
Acceleration Level (pk): 0.100 g (0.981 m/s²)

*The acceleration level may be limited by shaker displacement at low frequencies. If the listed level cannot be obtained, the calibration system uses the following formula to set the vibration amplitude: Acceleration Level (g) = 0.207 * (freq)^{1.5}. *The gravitational constant used for calculations by the calibration system is: 1 g = 9.80665 m/s².

Condition of Unit

As Found: n/a

As Left: New Unit, In Tolerance

Notes

1. Calibration is traceable to one or more of the following: PTB 10065, PTB 10066 and NIST 683/283498.
2. This certificate shall not be reproduced, except in full, without written approval from PCB Piezotronics, Inc.
3. Calibration is performed in compliance with ISO 10012-1, ANSI Z540.3 and ISO 17025.
4. See Manufacturer's Specification Sheet for a detailed listing of performance specifications.
5. Measurement uncertainty (95% confidence level with coverage factor of 2) for frequency ranges tested during calibration are as follows: 0.5-0.99 Hz: +/- 1.8%, 1-30 Hz: +/- 1.0%, 30.01-199 Hz: +/- 1.5%, 200-1 kHz: +/- 3.0%.

Technician: Jonathan Harmon *JH*

Date: 10/1/2020



HEADQUARTERS: 3425 WALDEN AVENUE - DEPEW, NY 14043
CALIBRATION PERFORMED AT: 10869 HIGHWAY 903, HALIFAX, NC 27839
TEL: 888-684-0013 - FAX: 716-685-3886 - www.pcb.com

CAL143-3684405196 668+0



Sensor Information

Model Number: 393B31
Serial Number: 52108
Manufacturer: PCB
ID Number:

Calibration Data

Sensitivity @ 10 Hz: 10,022 mV/g
1,022 mV/m/s²
Phase @ 10 Hz: -1.01 deg.
Test Level: 0.30 g

Transducer Specifications

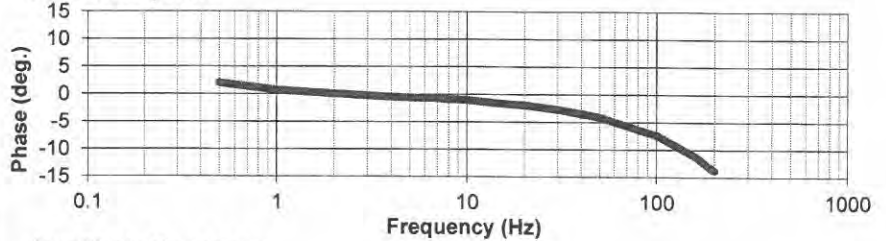
Amp. Range: ± 0.5 g
Resolution: 0.000001 g
Resonant Freq: ≥ 700 Hz
Temp. Range: -18 to 66 °C
0 to 150 °F
Axis: Uni-Axial

Description: ICP® Accelerometer

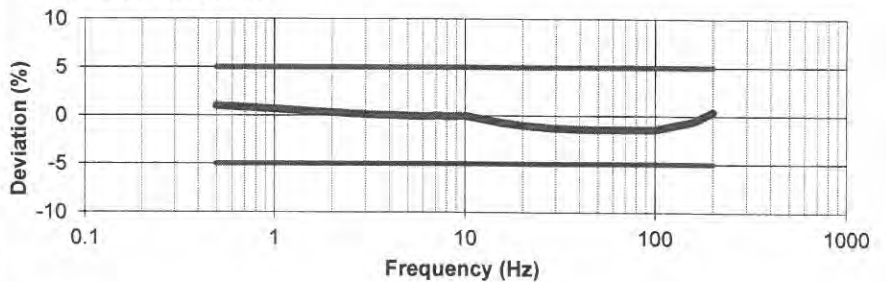
Data Table

Freq. (Hz)	Deviation (%)	Phase (deg)
0.5	1.0115	2.0283
1	0.6974	0.7411
2	0.3239	0.1223
3	0.1246	-0.2388
4	0.0590	-0.4568
5	-0.0153	-0.5832
6.3	-0.0878	-0.7364
7	0.0242	-0.7320
8	-0.0630	-0.8780
10	0.0000	-1.0091
15	-0.6535	-1.6274
20	-0.9914	-1.9448
30	-1.3023	-2.6688
50	-1.4408	-4.0740
100	-1.3998	-7.3691
160	-0.5230	-11.1546
200	0.4396	-13.7527

Phase Response



Amplitude Response



Notes

Results relate only to the items calibrated.
This certificate may not be reproduced except in full, without written permission.
Method: Back-to-Back Comparison Calibration per ISO 16063 Part 21
This calibration was performed with TMS 9155 Calibration Workstation 1 version 6.0.0
Proficiency in calibration traceable to PTB (17014/17004) and NIST (683/287323).
Back-to-Back Comparison Calibration per ISO 16063-21
Procedures Used: PRD-P220 and PRD-P214, or PRD-P239
Measurement uncertainty (95% confidence level with coverage factor 2) for frequency ranges tested during calibration are as follows: 0.5-1 Hz; 1.1%; >1-10 Hz; ± 0.8%, 11-99 Hz; ± 1.2%, 100 Hz; ± 0.75%, 101-920 Hz; ± 1.0%, 921-5000 Hz; ± 1.4%, 5001-10,000 Hz; ± 1.9%, 10,001-15,000 Hz; ± 2.2%, 15,001-20,000 Hz; ± 2.8%.

Customer

Golder Associates

User Notes

Lab Conditions

Temperature: 73 (23) °F (°C)
Humidity: 55 %

Unit Condition

As Found: In Tolerance
As Left: In Tolerance

Cal Date: 27-Aug-20

Due Date:

Equipment Used

Description	Manufacturer	Model	Serial	Due Date
Data Acquisition Card	NI	PCI-4461	1D83333	11/5/2020
Ref Std Conditioner	NI	PCI-6251	136F2A3	2/14/2021
Reference Std	PCB	080A200	110553	1/9/2021
Air Bearing Shaker	PCB	396C11	603	n/a
Ref Std Conditioner	PCB	442A102	305	1/9/2021
SUT Signal Conditioner	PCB	443B101	373	10/15/2020
Power Amplifier	TMS	2100E21-C	50002	n/a
Reference Std	TMS	2129E025 Sys	111	2/14/2021
Long Stroke Shaker	TMS	2129E025-779	111	n/a

Approval Information

Technician: William Moses

Approval: *William Moses*



William Moses

~ Calibration Certificate ~

Per ISO 16063-21

Model Number: 393B31

Serial Number: 60741

Description: ICP® Accelerometer

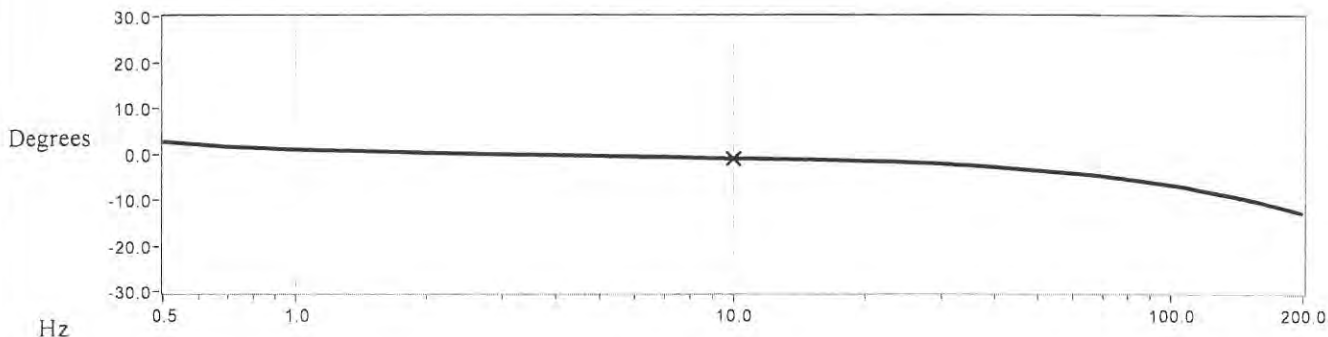
Manufacturer: PCB

Method: Back-to-Back Comparison AT401-12

Calibration Data

Sensitivity @ 10 Hz 9.84 V/g (1.003 V/m/s²)

Phase Plot



Data Points

Frequency (Hz)	Phase (°)	Frequency (Hz)	Phase (°)
0.5	2.6	30	-2.2
1	0.9	50	-3.7
2	0.2	70	-4.9
5	-0.5	100	-6.8
7	-0.7	200	-12.9
REF. FREQ.	-1.0		
15	-1.3		
20	-1.6		

Notes

1. Calibration is traceable to one or more of the following; PTB 10065, PTB 10066 and NIST 683/283498.
2. This certificate shall not be reproduced, except in full, without written approval from PCB Piezotronics, Inc.
3. Calibration is performed in compliance with ISO 10012-1, ANSI Z540.3 and ISO 17025.
4. See Manufacturer's Specification Sheet for a detailed listing of performance specifications.
5. Measurement uncertainty for Phase (95% confidence level with coverage factor of 2) for frequency ranges tested during calibration are as follows: = 0.5 to < 10 Hz; +/- 2.5°, = 10 to < 200 Hz; +/- 0.75°, = 200 Hz to = 1 kHz; +/- 1.5°.

Technician: Jonathan Harmon

Date: 10/1/2020



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~ Calibration Certificate ~

Per ISO 16063-21

Model Number: 393B31

Serial Number: 59305

Description: ICP® Accelerometer

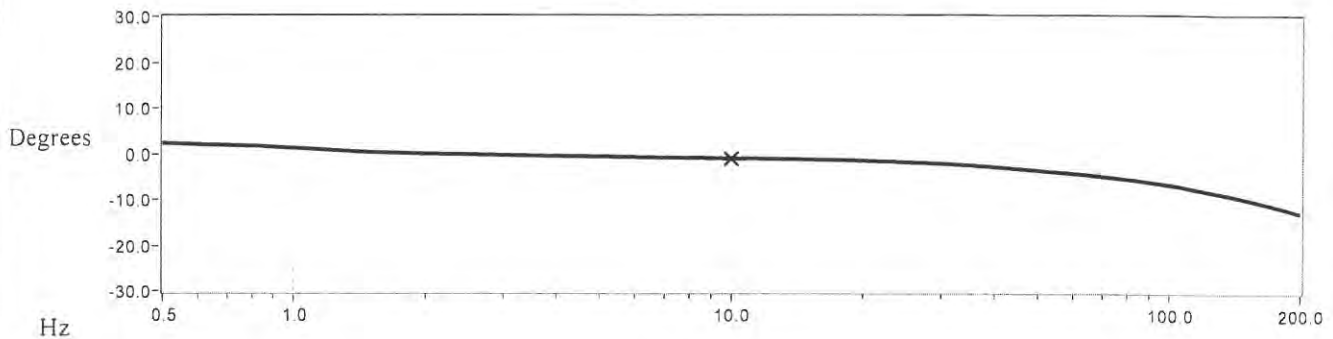
Manufacturer: PCB

Method: Back-to-Back Comparison AT401-12

Calibration Data

Sensitivity @ 10 Hz 9.65 V/g (0.984 V/m/s²)

Phase Plot



Data Points

Frequency (Hz)	Phase (°)	Frequency (Hz)	Phase (°)
0.5	2.3	30	-2.2
1	1.2	50	-3.7
2	-0.0	70	-5.0
5	-0.7	100	-6.8
7	-0.9	200	-13.0
REF. FREQ.	-1.2		
15	-1.3		
20	-1.6		

Notes

1. Calibration is traceable to one or more of the following; PTB 10065, PTB 10066 and NIST 683/283498.
2. This certificate shall not be reproduced, except in full, without written approval from PCB Piezotronics, Inc.
3. Calibration is performed in compliance with ISO 10012-1, ANSI Z540.3 and ISO 17025.
4. See Manufacturer's Specification Sheet for a detailed listing of performance specifications.
5. Measurement uncertainty for Phase (95% confidence level with coverage factor of 2) for frequency ranges tested during calibration are as follows: = 0.5 to < 10 Hz; +/- 2.5°, = 10 to < 200 Hz; +/- 0.75°, = 200 Hz to = 1 kHz; +/- 1.5°.

Technician: Jonathan Harmon *JH*

Date: 10/1/2020



HEADQUARTERS: 3425 WALDEN AVENUE - DEPEW, NY 14043
 CALIBRATION PERFORMED AT: 10869 HIGHWAY 903, HALIFAX, NC 27839
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~ Calibration Certificate ~

Per ISO 16063-21

Model Number: 393B31

Serial Number: 60742

Description: ICP® Accelerometer

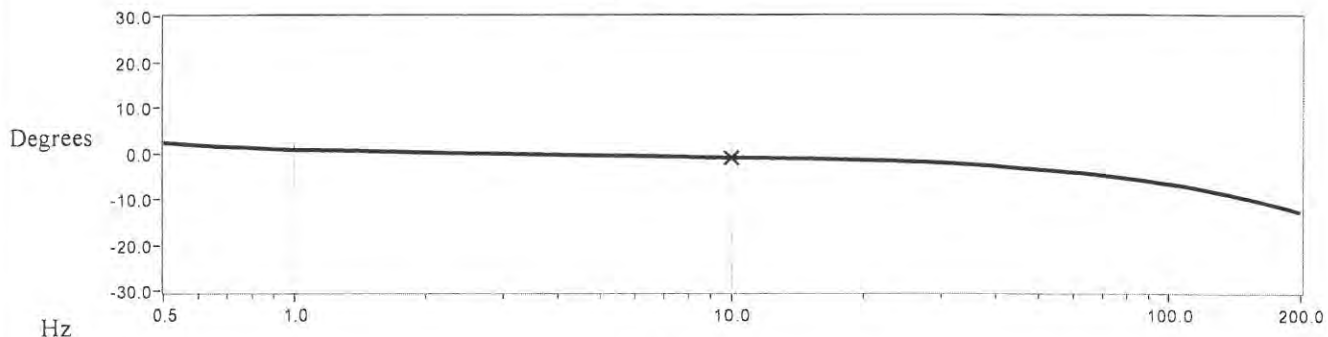
Manufacturer: PCB

Method: Back-to-Back Comparison AT401-12

Calibration Data

Sensitivity @ 10 Hz 9.72 V/g (0.991 V/m/s²)

Phase Plot




Data Points

Frequency (Hz)	Phase (°)	Frequency (Hz)	Phase (°)
0.5	2.3	30	-2.2
1	0.7	50	-3.6
2	0.1	70	-4.8
5	-0.5	100	-6.8
7	-0.8	200	-12.9
REF. FREQ.	-1.1		
15	-1.3		
20	-1.6		

Notes

1. Calibration is traceable to one or more of the following; PTB 10065, PTB 10066 and NIST 683/283498.
2. This certificate shall not be reproduced, except in full, without written approval from PCB Piezotronics, Inc.
3. Calibration is performed in compliance with ISO 10012-1, ANSI Z540.3 and ISO 17025.
4. See Manufacturer's Specification Sheet for a detailed listing of performance specifications.
5. Measurement uncertainty for Phase (95% confidence level with coverage factor of 2) for frequency ranges tested during calibration are as follows: = 0.5 to < 10 Hz; +/- 2.5°, = 10 to < 200 Hz; +/- 0.75°, = 200 Hz to = 1 kHz; +/- 1.5°.

Technician: Jonathan Harmon 

Date: 10/1/2020



HEADQUARTERS: 3425 WALDEN AVENUE - DEPEW, NY 14043
CALIBRATION PERFORMED AT: 10869 HIGHWAY 903, HALIFAX, NC 27839
TEL: 888-684-0013 - FAX: 716-685-3886 - www.pcb.com



~ Calibration Certificate ~

Per ISO 16063-21

Model Number: 393B31

Serial Number: 60749

Description: ICP® Accelerometer

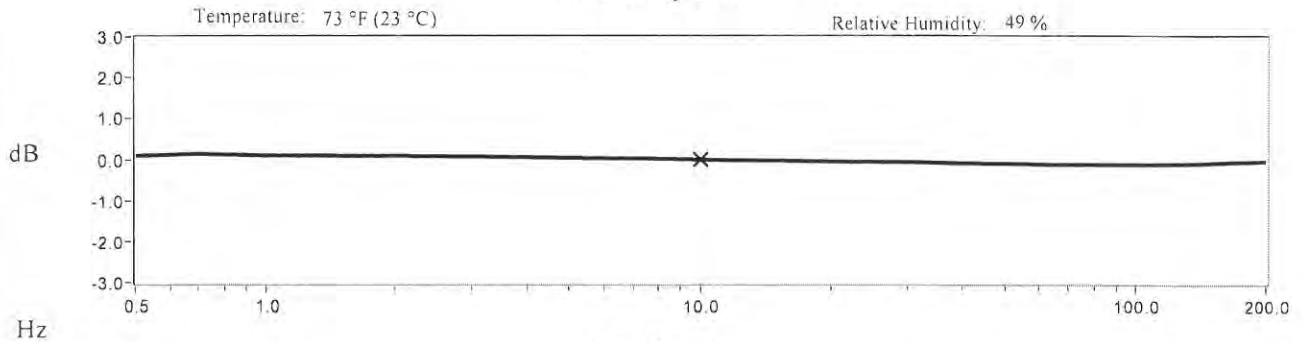
Manufacturer: PCB

Method: Back-to-Back Comparison AT401-12

Calibration Data

Sensitivity @ 10 Hz	9.69 V/g (0.988 V/m/s ²)	Output Bias	11.4 VDC
Resonant Frequency	890 Hz	Transverse Sensitivity	4.6 %

Sensitivity Plot



Data Points

Frequency (Hz)	Dev. (%)	Frequency (Hz)	Dev. (%)	Frequency (Hz)	Dev. (%)
0.5	1.0	REF. FREQ.	0.0	70	-1.4
1	1.2	15	-0.4	100	-1.4
2	1.0	20	-0.6	200	-0.5
5	0.5	30	-0.8		
7	0.2	50	-1.2		

Mounting Surface: Stainless Steel w/Silicone Grease Fastener: 1/4-28 Female Fixture Orientation: Vertical

Acceleration Level (pk): 0.100 g (0.981 m/s²)

*The acceleration level may be limited by shaker displacement at low frequencies. If the listed level cannot be obtained, the calibration system uses the following formula to set the vibration amplitude: Acceleration Level (g) = 0.207 x (freq)^{1.35} The gravitational constant used for calculations by the calibration system is: 1 g = 9.80665 m/s²

Condition of Unit

As Found: n/a

As Left: New Unit, In Tolerance

Notes

1. Calibration is traceable to one or more of the following; PTB 10065, PTB 10066 and NIST 683/283498.
2. This certificate shall not be reproduced, except in full, without written approval from PCB Piezotronics, Inc.
3. Calibration is performed in compliance with ISO 10012-1, ANSI Z540.3 and ISO 17025.
4. See Manufacturer's Specification Sheet for a detailed listing of performance specifications.
5. Measurement uncertainty (95% confidence level with coverage factor of 2) for frequency ranges tested during calibration are as follows: 0.5-0.99 Hz; +/- 1.8%, 1-30 Hz; +/- 1.0%, 30.01-199 Hz; +/- 1.5%, 200-1 kHz; +/- 3.0%.

Technician: Jonathan Harmon *JH*

Date: 10/1/2020



HEADQUARTERS: 3425 WALDEN AVENUE - DEPEW, NY 14043
 CALIBRATION PERFORMED AT: 10869 HIGHWAY 903, HALIFAX, NC 27839
 TEL: 888-684-0013 - FAX: 716-685-3886 - www.pcb.com

CAL143-3684398307.593-0



~ Calibration Certificate ~

Per ISO 16063-21

Model Number: 393B31

Serial Number: 60748

Description: ICP® Accelerometer

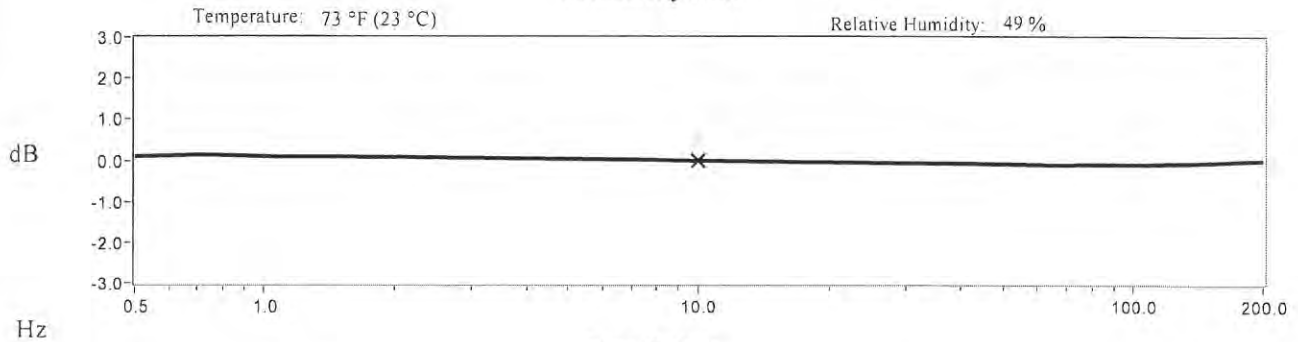
Manufacturer: PCB

Method: Back-to-Back Comparison AT401-12

Calibration Data

Sensitivity @ 10 Hz	9.83 V/g (1.002 V/m/s ²)	Output Bias	11.6 VDC
Resonant Frequency	880 Hz	Transverse Sensitivity	1.3 %

Sensitivity Plot



Data Points

Frequency (Hz)	Dev. (%)	Frequency (Hz)	Dev. (%)	Frequency (Hz)	Dev. (%)
0.5	1.1	REF. FREQ.	0.0	70	-1.1
1	1.1	15	-0.3	100	-1.1
2	0.9	20	-0.5	200	0.0
5	0.4	30	-0.7		
7	0.3	50	-0.9		

Mounting Surface: Stainless Steel w/Silicone Grease Fastener: 1/4-28 Female Fixture Orientation: Vertical
Acceleration Level (pk): 0.100 g (0.981 m/s²)

*The acceleration level may be limited by shaker displacement at low frequencies. If the listed level cannot be obtained, the calibration system uses the following formula to set the vibration amplitude: Acceleration Level (g) = 0.207 x (freq)^{1.35} *The gravitational constant used for calculations by the calibration system is: 1 g = 9.80665 m/s².

Condition of Unit

As Found: n/a

As Left: New Unit, In Tolerance

Notes

1. Calibration is traceable to one or more of the following; PTB 10065, PTB 10066 and NIST 683/283498.
2. This certificate shall not be reproduced, except in full, without written approval from PCB Piezotronics, Inc.
3. Calibration is performed in compliance with ISO 10012-1, ANSI Z540.3 and ISO 17025.
4. See Manufacturer's Specification Sheet for a detailed listing of performance specifications.
5. Measurement uncertainty (95% confidence level with coverage factor of 2) for frequency ranges tested during calibration are as follows: 0.5-0.99 Hz; +/- 1.8%, 1-30 Hz; +/- 1.0%, 30.01-199 Hz; +/- 1.5%, 200-1 kHz; +/- 3.0%.

Technician: Jonathan Harmon *JH*

Date: 10/1/2020



HEADQUARTERS: 3425 WALDEN AVENUE - DEPEW, NY 14043
CALIBRATION PERFORMED AT: 10869 HIGHWAY 903, HALIFAX, NC 27839
TEL: 888-684-0013 - FAX: 716-685-3886 - www.pcb.com

CAL143-3684396932 598-01



~ Calibration Certificate ~

Per ISO 16063-21

Model Number: 393B31

Serial Number: 60750

Description: ICP® Accelerometer

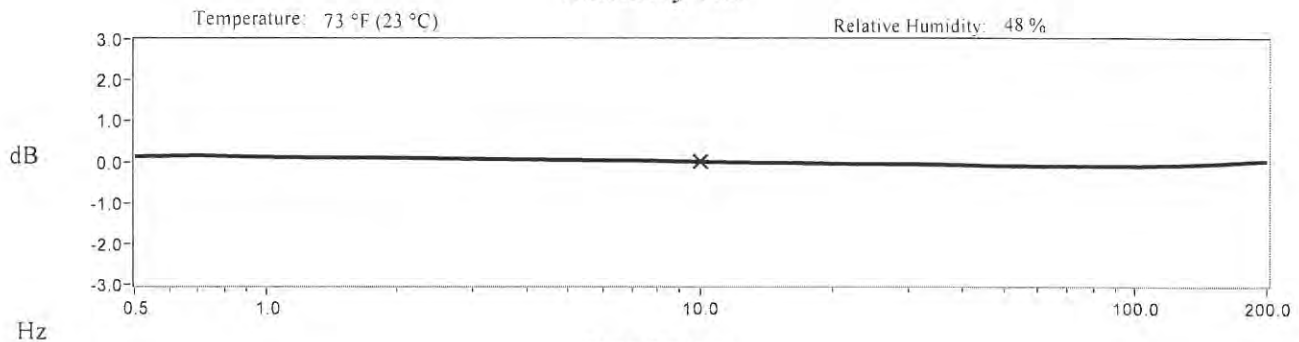
Manufacturer: PCB

Method: Back-to-Back Comparison AT401-12

Calibration Data

Sensitivity @ 10 Hz	9.63 V/g (0.982 V/m/s ²)	Output Bias	10.8 VDC
Resonant Frequency	810 Hz	Transverse Sensitivity	4.7 %

Sensitivity Plot



Data Points

Frequency (Hz)	Dev. (%)	Frequency (Hz)	Dev. (%)	Frequency (Hz)	Dev. (%)
0.5	1.4	REF. FREQ.	0.0	70	-1.3
1	1.2	15	-0.4	100	-1.3
2	1.0	20	-0.6	200	0.1
5	0.4	30	-0.8		
7	0.2	50	-1.2		

Mounting Surface: Stainless Steel w/Silicone Grease Fastener: 1/4-28 Female Fixture Orientation: Vertical

Acceleration Level (pk): 0.100 g (0.981 m/s²)

*The acceleration level may be limited by shaker displacement at low frequencies. If the listed level cannot be obtained, the calibration system uses the following formula to set the vibration amplitude: Acceleration Level (g) = 0.207 x (freq)^{1.5}. *The gravitational constant used for calculations by the calibration system is: 1 g = 9.80665 m/s²

Condition of Unit

As Found: n/a

As Left: New Unit, In Tolerance

Notes

1. Calibration is traceable to one or more of the following; PTB 10065, PTB 10066 and NIST 683/283498.
2. This certificate shall not be reproduced, except in full, without written approval from PCB Piezotronics, Inc.
3. Calibration is performed in compliance with ISO 10012-1, ANSI Z540.3 and ISO 17025.
4. See Manufacturer's Specification Sheet for a detailed listing of performance specifications.
5. Measurement uncertainty (95% confidence level with coverage factor of 2) for frequency ranges tested during calibration are as follows: 0.5-0.99 Hz; +/- 1.8%, 1-30 Hz; +/- 1.0%, 30.01-199 Hz; +/- 1.5%, 200-1 kHz; +/- 3.0%.

Technician: Jonathan Harmon *JH*

Date: 10/1/2020



HEADQUARTERS: 3425 WALDEN AVENUE - DEPEW, NY 14043
CALIBRATION PERFORMED AT: 10869 HIGHWAY 903, HALIFAX, NC 27839
TEL: 888-684-0013 - FAX: 716-685-3886 - www.pcb.com

CAL 143-3684399084 333-0



The Modal Shop, Inc.
(513) 351-9919

Manufacturer: PCB
Model: 393B31
Serial: 56259
ID:

Sens: 10114.4330 mV/g @ 10Hz
Cal Date: 8/27/2020
Due Date:

The Modal Shop, Inc.
(513) 351-9919

Manufacturer: PCB
Model: 393B31
Serial: 32001
ID:

Sens: 10093.1768 mV/g @ 10Hz
Cal Date: 8/27/2020
Due Date:

The Modal Shop, Inc.
(513) 351-9919

Manufacturer: PCB
Model: 393B31
Serial: 56258
ID:

Sens: 10263.3288 mV/g @ 10Hz
Cal Date: 8/27/2020
Due Date:

Calibration Data Card

SHEAR ACCELEROMETER

MODEL #: 393B31

SERIAL #: 60750

SENSITIVITY: 9.63 V/g
(0.982 V/m/s²)

OUTPUT BIAS: 10.8 VDC

Date: 10/01/2020 By: Jonathan Harmon



3425 WALDEN AVE DEERFIELD, IL 60015 (815) 938-1000

For further information, please refer to the accompanying Calibration Certificate.

Calibration Data Card

SHEAR ACCELEROMETER

MODEL #: 393B31

SERIAL #: 60748

SENSITIVITY: 9.83 V/g
(1.002 V/m/s²)

OUTPUT BIAS: 11.6 VDC

Date: 10/01/2020 By: Jonathan Harmon



3425 WALDEN AVE DEERFIELD, IL 60015 (815) 938-1000

For further information, please refer to the accompanying Calibration Certificate.

Calibration Data Card

SHEAR ACCELEROMETER

MODEL #: 393B31

SERIAL #: 60749

SENSITIVITY: 9.69 V/g
(0.988 V/m/s²)

OUTPUT BIAS: 11.4 VDC

Date: 10/01/2020 By: Jonathan Harmon



3425 WALDEN AVE DEERFIELD, IL 60015 (815) 938-1000

For further information, please refer to the accompanying Calibration Certificate.

The Modal Shop, Inc.
(513) 351-9919

Manufacturer: PCB
Model: 393B31
Serial: 52107
ID: 65141

Sens: 9796.2974 mV/g @ 10Hz
Cal Date: 8/27/2020
Due Date:

The Modal Shop, Inc.
(513) 351-9919

Manufacturer: PCB
Model: 393B31
Serial: 47528
ID:

Sens: 9668.7987 mV/g @ 10Hz
Cal Date: 8/27/2020
Due Date:

The Modal Shop, Inc.
(513) 351-9919

Manufacturer: PCB
Model: 393B31
Serial: 52108
ID:

Sens: 10022.4127 mV/g @ 10Hz
Cal Date: 8/27/2020
Due Date:

The Modal Shop, Inc.
(513) 351-9919
Manufacturer: PCB
Model: 393B31
Serial: 56317
ID:
Sens: 9780.2790 mV/g @ 10Hz
Cal Date: 8/27/2020
Due Date:

The Modal Shop, Inc.
(513) 351-9919
Manufacturer: PCB
Model: 393B31
Serial: 56315
ID:
Sens: 10128.7845 mV/g @ 10Hz
Cal Date: 8/27/2020
Due Date:

The Modal Shop, Inc.
(513) 351-9919
Manufacturer: PCB
Model: 393B31
Serial: 55540
ID:
Sens: 9978.7129 mV/g @ 10Hz
Cal Date: 8/27/2020
Due Date:

Calibration Data Card
SHEAR ACCELEROMETER

MODEL #: 393B31
SERIAL #: 60744
SENSITIVITY: 9.80 V/g
(1.000 V/m/s²)

OUTPUT BIAS: 11.6 VDC
Date: 10/01/2020 By: Jonathan Harmon



For further information, please refer to the accompanying Calibration Certificate.

Calibration Data Card
SHEAR ACCELEROMETER

MODEL #: 393B31
SERIAL #: 60746
SENSITIVITY: 9.94 V/g
(1.014 V/m/s²)

OUTPUT BIAS: 11.5 VDC
Date: 10/01/2020 By: Jonathan Harmon



For further information, please refer to the accompanying Calibration Certificate.

Calibration Data Card
SHEAR ACCELEROMETER

MODEL #: 393B31
SERIAL #: 60743
SENSITIVITY: 9.74 V/g
(0.993 V/m/s²)

OUTPUT BIAS: 11.5 VDC
Date: 10/01/2020 By: Jonathan Harmon



For further information, please refer to the accompanying Calibration Certificate.

Calibration Data Card
SHEAR ACCELEROMETER

MODEL #: 393B31
SERIAL #: 60741
SENSITIVITY: 9.84 V/g
(1.003 V/m/s²)

OUTPUT BIAS: 11.8 VDC
Date: 10/01/2020 By: Jonathan Harmon



For further information, please refer to the accompanying Calibration Certificate.

Calibration Data Card
SHEAR ACCELEROMETER

MODEL #: 393B31
SERIAL #: 60742
SENSITIVITY: 9.72 V/g
(0.991 V/m/s²)

OUTPUT BIAS: 11.9 VDC
Date: 10/01/2020 By: Jonathan Harmon



For further information, please refer to the accompanying Calibration Certificate.



Discover the all new TD-Diver



Meet the difference

DISCOVER THE **NEW** DIVER



We are very excited to introduce the new TD-Diver as the Mini-Diver's successor! The new TD-Diver is a totally new design which combines over 75 years of groundwater monitoring experience with the most recent technologies and components available in the market today.

When developing the TD-Diver the focus on long term reliability and stability has remained unwavering. The enclosure has been redesigned to optimize the protection of the pressure sensor and electronics and by making the TD-Diver heavier than its predecessor, users will experience a simpler and smoother deployment down a bore-hole.

The electronics for the TD-Diver have been designed to use state of the art components, which has allowed us to incorporate more memory and additional logging schemes.

By adding more memory and processor capacity, compensation and calibration of the pressure sensor has been improved. This gives the TD-Diver the features to guarantee the best linearity, accuracy and stability.

Benefits of the new Diver

- Spend less time waiting for your data to be retrieved
- Choose your own data logging method, continuous memory or fixed length memory
- With 72,000 records you can record a sample every 15 minutes for more than 2 years
- More efficient electronics allow 2 times more samples without compromising the battery lifetime
- After restart of your Diver a backup of previous data is still available; 72,000 backup records
- Increased corrosion resistance by additional surface treatment of the housing
- Easy connection with SDI-12, Modbus protocols
- Twice the weight so easier deployment of the Diver
- The new TD-Diver and Baro-Diver can be used with all existing Diver accessories

The TD-Diver is based on an ingenious and proven concept and is acknowledged as the most reliable instrument for the autonomous measuring and recording of groundwater level and temperature. Its internal working memory of 72,000 measurements per parameter provides sufficient capacity to perform one measurement every 15 minutes for over 2 years. For each measurement, the Diver registers the date and time, groundwater level, and temperature.

Technical specifications TD-Diver

	Metric (M)	Imperial (I)
Length	110 mm	4.33 in
Diameter	22 mm	0.87 in
Weight	104 g	3.67 oz
Memory	72,000 measurements (and 72,000 as backup) continuous and fixed length memory	
Battery life	up to 10 years (dependent on usage)	
Sample interval	½ second to 99 hours	
Sample method	fixed interval	
Communication	RS232	

Wetted parts

Housing	stainless steel (316L)
O-rings	Viton®
Pressure sensor	piezo resistive ceramic (Al ₂ O ₃) with thermal compensation
Cap	Nylon PA6 30% glass fiber
Nose cone	ABS

Pressure

Article number	11110402		11110404		11110406		11110408		M	I
	M	I	M	I	M	I	M	I		
Range	10	33	20	66	50	164	100	328	mH ₂ O	ftH ₂ O
Accuracy*	± 0.5	± 0.2	± 1.0	± 0.4	± 2.5	± 1.0	± 5.0	± 2.0	cmH ₂ O	inH ₂ O
Resolution	0.06	0.02	0.09	0.04	0.19	0.07	0.36	0.14	cmH ₂ O	inH ₂ O

Temperature

	Metric	Imperial
Range	-20 to 80 °C	-4 to 176 °F
Calibrated	0 to 50 °C	32 to 122 °F
Accuracy*	± 0.1 °C	± 0.18 °F
Resolution	0.01 °C	0.01 °C / 0.018 °F

* = typical



Actual size

The conveniently priced Baro-Diver water level logger has also been equipped with the new technologies. The Baro-Diver ensures that you accurately capture changes in atmospheric pressure. Conveniently priced and easy to deploy, one Baro-Diver covers a radius of up to 15 km, depending on the topography. The Baro-Diver can also be used for measuring shallow water levels up to approximately 0.9 meter. The Baro-Diver has an internal working memory capable of storing 72,000 measurements per parameter. For each measurement, the Baro-Diver simultaneously registers barometric pressure, air temperature, date and time.

Technical specifications Baro-Diver

	Metric	Imperial
Length	110 mm	4.33 in
Diameter	22 mm	0.87 in
Weight	104 g	3.67 oz
Memory	72,000 measurements (and 72,000 as backup) continuous and fixed length memory	
Battery life	up to 10 years (dependent on usage)	
Sample interval	1/2 second to 99 hours	
Sample method	fixed interval	
Communication	RS232	

Wetted parts

Housing	stainless steel (316L)
O-rings	Viton®
Pressure sensor	piezo resistive ceramic (Al ₂ O ₃) with thermal compensation
Cap	Nylon PA6 30% glass fiber
Nose cone	ABS

Pressure

Article number 11115601

	Metric	Imperial
Range	1.5 mH ₂ O	4.9 ftH ₂ O
Accuracy*	± 0.5 cmH ₂ O	0.2 inH ₂ O
Resolution	0.03 cmH ₂ O	0.01 inH ₂ O

Temperature

	Metric	Imperial
Range	-20 to 80 °C	-4 to 176 °F
Calibrated	-10 to 50 °C	14 to 122 °F
Accuracy*	± 0.1 °C	± 0.18 °F
Resolution	0.01 °C	0.018 °F

* = typical



Actual size

CERTIFICATE OF CALIBRATION

Certificate No. #: MO-200834C

CALIBRATION CONDITIONS

Calibration Date: 9/22/2020

Due Date: 9/22/2021

Calibration Cycle: 12 Mo.

Temperature: 23 ± 5°C

Relative Humidity: 50 ± 30% RH

Cal Procedure: CI User's Manual (Version 1.0)

INSTRUMENT/ID

Model: Spider-80X


Serial No: 2616000

Description: Dynamic Signal Analyzer

This certifies that the above instrument was calibrated in compliance with the quality system registered to ISO 9001:2015 in accordance with referenced procedures. Standards used to perform this calibration are certified by or traceable to NIST, natural physical constants, consensus standards or derived by ratio type calibrations. Expanded uncertainties are determined as required with a distribution that corresponds to a probability of approximately 95% (k=2sigma), no sampling plan or other process was used for this calibration, the results reported herein apply only to the item described above.

Standard Utilized

Serial Number	Manufacturer	Model No.	Calib. Date	Due Date	Traceability Cert. No.
3177003	FLUKE	8845A	1/10/2020	1/10/2021	TSV-0-188885

TECHNICIAN: 

QC: 

Manufacturer's Certificate of Conformance

Inspected by: Robert Yu Serial #: 2616000 Type: Spider-80X	Date: October 1, 2020 M.O. #: 200834 P.O. #: 89779
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	Test Performed	Compliant	Note
1	Digital Signal Processor	Yes	
2	System Memory	Yes	
3	Analog Input Channels	Yes	
4	Analog Output Channels	Yes	
5	Isolated Digital Input	Yes	
6	Isolated Digital Output	Yes	
7	Network Connection	Yes	
8	Power Supply	Yes	
9	RS-485	Yes	
10	Data Port	Yes	
11	External Enclosure Visual Inspection	Yes	

Notes:

This document certifies that the Dynamic Signal Analyzer System has been manufactured, repaired (if applicable), tested, or inspected in accordance with referenced purchase order and conform(s) to the applicable specifications per Crystal Instruments quality and standards. The final test has been performed using calibrated equipment, traceable to NIST standards.

This document is not a replacement for a calibration certificate. For calibration services please contact an authorized representative or distributor.

Materials supplied are in full compliance with the requirements of the purchase order, including invoked specifications and drawings.

Approved by: 
 Yao Liang, Manufacturing Dept.

Date: October 1, 2020

CERTIFICATE OF CALIBRATION

Certificate No. #: MO-200834A

CALIBRATION CONDITIONS

Calibration Date: 9/22/2020

Due Date: 9/22/2021

Calibration Cycle: 12 Mo.

Temperature: 23 ± 5°C

Relative Humidity: 50 ± 30% RH

Cal Procedure: CI User's Manual (Version 1.0)

INSTRUMENT/ID

Model: Spider-80X

Serial No: 2615872

Description: Dynamic Signal Analyzer

This certifies that the above instrument was calibrated in compliance with the quality system registered to ISO 9001:2015 in accordance with referenced procedures. Standards used to perform this calibration are certified by or traceable to NIST, natural physical constants, consensus standards or derived by ratio type calibrations. Expanded uncertainties are determined as required with a distribution that corresponds to a probability of approximately 95% (k=2sigma), no sampling plan or other process was used for this calibration, the results reported herein apply only to the item described above.

Standard Utilized

Serial Number	Manufacturer	Model No.	Calib. Date	Due Date	Traceability Cert. No.
3177003	FLUKE	8845A	1/10/2020	1/10/2021	TSV-0-188885

TECHNICIAN: _____



QC: _____



Manufacturer's Certificate of Conformance

Inspected by: **Robert Yu**
 Serial #: **2615872**
 Type: **Spider-80X**

Date: **October 1, 2020**
 M.O. #: **200834**
 P.O. #: **89779**

	Test Performed	Compliant	Note
1	Digital Signal Processor	Yes	
2	System Memory	Yes	
3	Analog Input Channels	Yes	
4	Analog Output Channels	Yes	
5	Isolated Digital Input	Yes	
6	Isolated Digital Output	Yes	
7	Network Connection	Yes	
8	Power Supply	Yes	
9	RS-485	Yes	
10	Data Port	Yes	
11	External Enclosure Visual Inspection	Yes	

Notes:

This document certifies that the Dynamic Signal Analyzer System has been manufactured, repaired (if applicable), tested, or inspected in accordance with referenced purchase order and conform(s) to the applicable specifications per Crystal Instruments quality and standards. The final test has been performed using calibrated equipment, traceable to NIST standards.

This document is not a replacement for a calibration certificate. For calibration services please contact an authorized representative or distributor.

Materials supplied are in full compliance with the requirements of the purchase order, including invoked specifications and drawings.

Approved by: _____



Yao Liang, Manufacturing Dept.

Date: October 1, 2020

CERTIFICATE OF CALIBRATION

Certificate No. #: MO-200834B

CALIBRATION CONDITIONS

Calibration Date: 9/22/2020

Due Date: 9/22/2021

Calibration Cycle: 12 Mo.

Temperature: 23 ± 5°C

Relative Humidity: 50 ± 30% RH

Cal Procedure: CI User's Manual (Version 1.0)

INSTRUMENT/ID

Model: Spider-80X

Serial No: 2615904

Description: Dynamic Signal Analyzer

This certifies that the above instrument was calibrated in compliance with the quality system registered to ISO 9001:2015 in accordance with referenced procedures. Standards used to perform this calibration are certified by or traceable to NIST, natural physical constants, consensus standards or derived by ratio type calibrations. Expanded uncertainties are determined as required with a distribution that corresponds to a probability of approximately 95% ($k=2\sigma$), no sampling plan or other process was used for this calibration, the results reported herein apply only to the item described above.

Standard Utilized

Serial Number	Manufacturer	Model No.	Calib. Date	Due Date	Traceability Cert. No.
3177003	FLUKE	8845A	1/10/2020	1/10/2021	TSV-0-188885

TECHNICIAN: _____



QC: _____



Manufacturer's Certificate of Conformance

Inspected by: **Robert Yu**
 Serial #: **2615904**
 Type: **Spider-80X**

Date: **October 1, 2020**
 M.O. #: **200834**
 P.O. #: **89779**


	Test Performed	Compliant	Note
1	Digital Signal Processor	Yes	
2	System Memory	Yes	
3	Analog Input Channels	Yes	
4	Analog Output Channels	Yes	
5	Isolated Digital Input	Yes	
6	Isolated Digital Output	Yes	
7	Network Connection	Yes	
8	Power Supply	Yes	
9	RS-485	Yes	
10	Data Port	Yes	
11	External Enclosure Visual Inspection	Yes	

Notes:

This document certifies that the Dynamic Signal Analyzer System has been manufactured, repaired (if applicable), tested, or inspected in accordance with referenced purchase order and conform(s) to the applicable specifications per Crystal Instruments quality and standards. The final test has been performed using calibrated equipment, traceable to NIST standards.

This document is not a replacement for a calibration certificate. For calibration services please contact an authorized representative or distributor.

Materials supplied are in full compliance with the requirements of the purchase order, including invoked specifications and drawings.

Approved by: 
 Yao Liang, Manufacturing Dept.

Date: October 1, 2020

CERTIFICATE OF CALIBRATION

Certificate No. #: MO-210585

CALIBRATION CONDITIONS

Calibration Date: 5/26/2021

Due Date: 5/26/2022

Calibration Cycle: 12 Mo.

Temperature: 23 ± 5°C

Relative Humidity: 50 ± 30%RH

Cal Procedure: CI User's Manual (Version1.0)

INSTRUMENT/ID

Model: Spider-80X

Serial No: 2612736

Description: Vibration Controller

This certifies that the above instrument was calibrated in compliance with the quality system registered to ISO 9001:2008 in accordance with referenced procedures. Standards used to perform this calibration are certified by or traceable to NIST, natural physical constants, consensus standards or derived by ratio type calibrations. Expanded uncertainties are determined as required with a distribution that corresponds to a probability of approximately 95% (k=2sigma), no sampling plan or other process was used for this calibration, the results reported herein apply only to the item described above.

Standard Utilized

Serial Number	Manufacturer	Model No.	Calib.Date	Due Date	Traceability Cert.No.
3177003	FLUKE	8845A	1/15/2021	1/15/2022	TSV-0-286773

TECHNICIAN: 

QC: 

Manufacturer's Certificate of Conformance

Inspected by: Adam Thao Serial #: 2612736 Type: Spider-80X	Date: May 28, 2021 M.O. #: 210585
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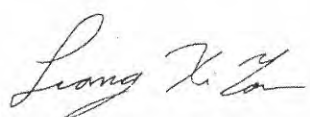
	Test Performed	Compliant	Note
1	Digital Signal Processor	Yes	
2	System Memory	Yes	
3	Analog Input Channels	Yes	
4	Analog Output Channels	Yes	
5	Isolated Digital Input	Yes	
6	Isolated Digital Output	Yes	
7	Network Connection	Yes	
8	Power Supply	Yes	
9	RS-485	Yes	
10	Data Port	Yes	
11	External Enclosure Visual Inspection	Yes	

Notes:

This document certifies that the Dynamic Signal Analyzer System has been manufactured, repaired (if applicable), tested, or inspected in accordance with referenced purchase order and conform(s) to the applicable specifications per Crystal Instruments quality and standards. The final test has been performed using calibrated equipment, traceable to NIST standards.

This document is not a replacement for a calibration certificate. For calibration services please contact an authorized representative or distributor.

Materials supplied are in full compliance with the requirements of the purchase order, including invoked specifications and drawings.

Approved by: 
 Yao Liang, Manufacturing Dept.

Date: May 28, 2021

Manufacturer's Certificate of Conformance

Inspected by: **Thue Thao**
Serial #: **3542912**
Type: **Spider-NAS**

Date: **June 11, 2021**
M.O. #: **210637**
P.O. #: **N/A**

	Test Performed	Compliant	Note
1	Network Connection	Yes	
2	Data Ports	Yes	
3	SSD Storage	Yes	
4	Power Supply	Yes	
5	External Enclosure Visual Inspection	Yes	

Notes:

This document certifies that the High Speed Network Storage Device has been manufactured, repaired (if applicable), tested, or inspected in accordance with referenced purchase order and conform(s) to the applicable specifications per Crystal Instruments quality and standards. The final test has been performed using calibrated equipment, traceable to NIST standards.

This document is not a replacement for a calibration certificate. For calibration services please contact an authorized representative or distributor.

Approved by: _____



Yao Liang, Manufacturing Dept.

Date: June 11, 2021

Manufacturer's Certificate of Conformance

Inspected by: **Robert Yu**
Serial #: **3543008**
Type: **Spider-NAS**

Date: **October 1, 2020**
M.O. #: **200834**
P.O. #: **89779**

	Test Performed	Compliant	Note
1	Network Connection	Yes	
2	Data Ports	Yes	
3	SSD Storage	Yes	
4	Power Supply	Yes	
5	External Enclosure Visual Inspection	Yes	

Notes:

This document certifies that the hardware has been manufactured, repaired (if applicable), tested, or inspected in accordance with referenced purchase order and conform(s) to the applicable specifications per Crystal Instruments quality and standards. The final test has been performed using calibrated equipment, traceable to NIST standards.

This document is not a replacement for a calibration certificate. For calibration services please contact an authorized representative or distributor.

Approved by: _____



Yao Liang, Manufacturing Dept.

Date: October 1, 2020

Manufacturer's Certificate of Conformance

Inspected by: **Robert Yu**
Serial #: **3543040**
Type: **Spider-NAS**


Date: **October 1, 2020**
M.O. #: **200834**
P.O. #: **89779**

	Test Performed	Compliant	Note
1	Network Connection	Yes	
2	Data Ports	Yes	
3	SSD Storage	Yes	
4	Power Supply	Yes	
5	External Enclosure Visual Inspection	Yes	

Notes:

This document certifies that the hardware has been manufactured, repaired (if applicable), tested, or inspected in accordance with referenced purchase order and conform(s) to the applicable specifications per Crystal Instruments quality and standards. The final test has been performed using calibrated equipment, traceable to NIST standards.

This document is not a replacement for a calibration certificate. For calibration services please contact an authorized representative or distributor.

Approved by: 
Yao Liang, Manufacturing Dept.

Date: October 1, 2020

Manufacturer's Certificate of Conformance

Inspected by: **Robert Yu**
Serial #: **3543072**
Type: **Spider-NAS**

Date: **October 1, 2020**
M.O. #: **200834**
P.O. #: **89779**

	Test Performed	Compliant	Note
1	Network Connection	Yes	
2	Data Ports	Yes	
3	SSD Storage	Yes	
4	Power Supply	Yes	
5	External Enclosure Visual Inspection	Yes	

Notes:

This document certifies that the hardware has been manufactured, repaired (if applicable), tested, or inspected in accordance with referenced purchase order and conform(s) to the applicable specifications per Crystal Instruments quality and standards. The final test has been performed using calibrated equipment, traceable to NIST standards.

This document is not a replacement for a calibration certificate. For calibration services please contact an authorized representative or distributor.

Approved by: _____



Yao Liang, Manufacturing Dept.

Date: **October 1, 2020**

CERTIFICATION OF CONFORMANCE

Title Page of Calibration Certificate Documentation

CUSTOMER:

Golder Associates
Unit 1
309 Exeter Road
London, ON N6L 1C1
CANADA

PURCHASE ORDER #: 89791/19120626-04

PCB ORDER #: I000292571

QTY	ITEM	DESCRIPTION
3	691A50/12	BNC ENCLOSURE BOX, 12 CH 00049436, 00049440, 00049441

Notes:

1. This document certifies that the subject item(s) have been manufactured, repaired (if applicable), tested, or inspected in accordance with referenced purchase order and conform(s) to applicable specifications per PCB Quality Policy Manual Rev. M 10/03/2018.
2. Equipment used in validation is traceable to NIST and appropriate records are on file.
3. Calibrations comply with ISO 17025 and ANSI/NCSL Z540.3-2006 except as noted on associated calibration certificate(s). Order placement is an acknowledgement and acceptance of measurement capability. Product is compliant with specification if measured value is within or equal to the specification tolerance. Product is not compliant with specification if measured value falls outside the specification tolerance.
4. Calibrations are performed using processes having a test uncertainty ratio (TUR) of four or more times greater than the unit calibrated, unless otherwise noted on the calibration certificate. Calibration at 4:1 TUR provides reasonable confidence that the instrument is within product specifications.

Logistics Associate: _____



Date: 10/22/20

- ISO 9001 Certified / ISO 17025 Accredited / AS9100 Certified -

PCB PIEZOTRONICS, INC.

3425 WALDEN AVENUE, DEPEW, NY 14043 UNITED STATES

Phone: (716) 684-0001, Fax: (716) 684-0987

CERTIFICATION OF CONFORMANCE

Title Page of Calibration Certificate Documentation

CUSTOMER:

Golder Associates
Unit 1
309 Exeter Road
London, ON N6L 1C1
CANADA

PURCHASE ORDER #: 89698/19120626-02

PCB ORDER #: I000291134

QTY	ITEM	DESCRIPTION
9	393B31	ACCELEROMETER 00059305, 00060741, 00060742, 00060743, 00060744, 00060746, 00060748, 00060749, 00060750

Notes:

1. This document certifies that the subject item(s) have been manufactured, repaired (if applicable), tested, or inspected in accordance with referenced purchase order and conform(s) to applicable specifications per PCB Quality Policy Manual Rev. M 10/03/2018.
2. Equipment used in validation is traceable to NIST and appropriate records are on file.
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4. Calibrations are performed using processes having a test uncertainty ratio (TUR) of four or more times greater than the unit calibrated, unless otherwise noted on the calibration certificate. Calibration at 4:1 TUR provides reasonable confidence that the instrument is within product specifications.

Logistics Associate: _____

Date: 10/02/20

- ISO 9001 Certified / ISO 17025 Accredited / AS9100 Certified -

PCB PIEZOTRONICS, INC.

3425 WALDEN AVENUE, DEPEW, NY 14043 UNITED STATES

Phone: (716) 684-0001, Fax: (716) 684-0987

CERTIFICATION OF CONFORMANCE

Title Page of Calibration Certificate Documentation

CUSTOMER:

Golder Associates
Unit 1
309 Exeter Road
London, ON N6L 1C1
CANADA

PURCHASE ORDER #: 89778/19120626-03

PCB ORDER #: 1000292469

QTY	ITEM	DESCRIPTION
2	052BSAD-0002	CUSTOM CABLE, 052BS065AD
2	052BSAD-0003	CUSTOM CABLE, 052BS035AD
2	052BSAD-0004	CUSTOM CABLE, 052BS050AD
1	052BRAD-0031	CUSTOM CABLE, 052BR065AD
1	052BRAD-0032	CUSTOM CABLE, 052BR035AD
1	052BRAD-0002	CUSTOM CABLE, 052BR050AD

Notes:

1. This document certifies that the subject item(s) have been manufactured, repaired (if applicable), tested, or inspected in accordance with referenced purchase order and conform(s) to applicable specifications per PCB Quality Policy Manual Rev. M 10/03/2018.
2. Equipment used in validation is traceable to NIST and appropriate records are on file.
3. Calibrations comply with ISO 17025 and ANSI/NC SL Z540.3-2006 except as noted on associated calibration certificate(s). Order placement is an acknowledgement and acceptance of measurement capability. Product is compliant with specification if measured value is within or equal to the specification tolerance. Product is not compliant with specification if measured value falls outside the specification tolerance.
4. Calibrations are performed using processes having a test uncertainty ratio (TUR) of four or more times greater than the unit calibrated, unless otherwise noted on the calibration certificate. Calibration at 4:1 TUR provides reasonable confidence that the instrument is within product specifications.

Logistics Associate: _____



Date: 11/30/20

- ISO 9001 Certified / ISO 17025 Accredited / AS9100 Certified -

PCB PIEZOTRONICS, INC.

3425 WALDEN AVENUE, DEPEW, NY 14043 UNITED STATES

Phone: (716) 684-0001, Fax: (716) 684-0987

CERTIFICATION OF CONFORMANCE

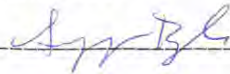
Title Page of Calibration Certificate Documentation

9	048APAC-0001	CUSTOM CABLE, 048AP010AC
9	048APAD-0002	CUSTOM CABLE, 048AP010AD
3	691B35/691000	12-CHANNEL INTERFACE BOX 00049675, 00049676, 00049677

Notes:

1. This document certifies that the subject item(s) have been manufactured, repaired (if applicable), tested, or inspected in accordance with referenced purchase order and conform(s) to applicable specifications per PCB Quality Policy Manual Rev. M 10/03/2018.
2. Equipment used in validation is traceable to NIST and appropriate records are on file.
3. Calibrations comply with ISO 17025 and ANSI/NCSL Z540.3-2006 except as noted on associated calibration certificate(s). Order placement is an acknowledgement and acceptance of measurement capability. Product is compliant with specification if measured value is within or equal to the specification tolerance. Product is not compliant with specification if measured value falls outside the specification tolerance.
4. Calibrations are performed using processes having a test uncertainty ratio (TUR) of four or more times greater than the unit calibrated, unless otherwise noted on the calibration certificate. Calibration at 4:1 TUR provides reasonable confidence that the instrument is within product specifications.

Logistics Associate: _____



Date: 11/30/20

- ISO 9001 Certified / ISO 17025 Accredited / AS9100 Certified -

PCB PIEZOTRONICS, INC.

3425 WALDEN AVENUE, DEPEW, NY 14043 UNITED STATES

Phone: (716) 684-0001, Fax: (716) 684-0987

CERTIFICATION OF CONFORMANCE

Title Page of Calibration Certificate Documentation

CUSTOMER:

Golder Associates
Unit 1
309 Exeter Road
London, ON N6L 1C1
CANADA

PURCHASE ORDER #: 90219/19120626-05

PCB ORDER #: I000299392

QTY	ITEM	DESCRIPTION
3	052BQBZ-0004	CUSTOM CABLE, 052BQ050BZ
4	052BQBZ-0003	CUSTOM CABLE, 052BQ030BZ
2	508BQBZ-0005	CUSTOM CABLE, 508BQ100BZ

Notes:

1. This document certifies that the subject item(s) have been manufactured, repaired (if applicable), tested, or inspected in accordance with referenced purchase order and conform(s) to applicable specifications per PCB Quality Policy Manual Rev. M 10/03/2018.
2. Equipment used in validation is traceable to NIST and appropriate records are on file.
3. Calibrations comply with ISO 17025 and ANSI/NCSL Z540.3-2006 except as noted on associated calibration certificate(s). Order placement is an acknowledgement and acceptance of measurement capability. Product is compliant with specification if measured value is within or equal to the specification tolerance. Product is not compliant with specification if measured value falls outside the specification tolerance.
4. Calibrations are performed using processes having a test uncertainty ratio (TUR) of four or more times greater than the unit calibrated, unless otherwise noted on the calibration certificate. Calibration at 4:1 TUR provides reasonable confidence that the instrument is within product specifications.

Logistics Associate: 

Date: 01/22/21

- ISO 9001 Certified / ISO 17025 Accredited / AS9100 Certified -

PCB PIEZOTRONICS, INC.

3425 WALDEN AVENUE, DEPEW, NY 14043 UNITED STATES

Phone: (716) 684-0001, Fax: (716) 684-0987

VW MiniLogger

MiniLogger Advantages

Economical: It is possible to deploy four or five MiniLoggers for less than the cost of a full-size logger. Cable costs are also reduced, since the MiniLogger can be placed near each sensor.

Simple to Use: Learn how to use the MiniLogger in minutes, not hours. There are no programs to write, no switches to set, and only four wires to connect.

Reliable: The MiniLogger is rated for temperatures from -20 to $+50^{\circ}\text{C}$. Its encapsulated electronics are impervious to humidity and condensation. Readings are stored in secure, non-volatile memory.

Spreadsheet Friendly: Logger Manager software retrieves readings and applies calibration factors, if present, to generate data files that contain both raw and processed readings. Thus data can be used immediately in the spreadsheet.

Wireless Option: The wireless option provides easy data retrieval when access to the logger is difficult or when frequent retrieval is required.



VW MiniLogger Applications

The VW MiniLogger is a reliable, low-cost data logger designed to monitor a single vibrating wire sensor, such as a VW piezometer or crackmeter. Typical applications include:

- Monitoring small projects, where only a few sensors are installed. Note that one MiniLogger is required for each sensor.
- Monitoring single sensors that are too far away to connect to a centralized data acquisition system.
- Monitoring single sensors in areas where heavy traffic or electrical noise prevents use of long cables.
- Monitoring single sensors during early phase of construction when centralized data acquisition system is not ready.

Overview of Operation

The MiniLogger is simple to use and takes only a few minutes to set up.

Connect the MiniLogger to your PC and run Logger Manager software to specify a start time and reading interval for data logging.

On site, connect the sensor signal cable to the MiniLogger and walk away. D-cell batteries provide power for up to six months in temperatures as low as -20°C .

Return to the site with your PC and run Logger Manager to retrieve the readings and save them in a file that is ready for your spreadsheet.

Finally, open the file with your spreadsheet for processing and plotting.



VW MINILOGGER

VW MiniLogger 52613310

VW MiniLogger includes interface cable and two D-cell batteries.

Sensor Compatibility: Reads VW sensors operating in the range of 450 to 6000 Hz. Also reads temperature sensors (RTD and thermistor).

Data Storage: Stores 8,000 records in secure, non-volatile memory. Each record includes a VW reading, a temperature reading, and the time and date. When memory is full, recording either stops or continues by overwriting the earliest readings, according to user preference.

Logger Settings: Assign a logger ID, specify whether to stop when memory is full or to overwrite earliest readings.

Sensor Settings: Assign a sensor ID, set sweep range for excitation, store calibration factors, and set temperature sensor to RTD or thermistor.

Reading Schedule Starts recording on power up or at specified date and time. Records readings at intervals from one reading every two seconds to one reading per week.

Logging Schedule: Set logger to start recording on power up or at a specific date and time (to synchronize readings with other MiniLoggers or data loggers). Set reading intervals to day, hour, minute, and second.

Power: Two D-cell batteries provide power for approximately six months at temperatures from -20 to +50°C, assuming readings are taken every half-hour.

Weatherproofing: MiniLogger electronics are completely encapsulated in waterproof resin. Polycarbonate box has O-ring seal and cable gland for signal cable.

Dimensions: 100 x 100 x 90 mm high (4 x 4 x 3.5").

Data Retrieval: Readings are retrieved via RS-232 serial connection or by wireless link to computer running Logger Manager.

VW MINILOGGER ACCESORIES

USB-RS232 Adapter 50310959

The USB-RS232 Adapter is used with the included interface cable to allow communication between the VW Minilogger and a computer that does not have a serial port.

2.4 GHZ WIRELESS OPTION

Radio Lid, 2.4 Ghz 52613360

Radio Base Station, 2.4 Ghz 52613455

Radio lid replaces standard lid of MiniLogger and includes spread-spectrum radio, interface cable, and half-wave antenna.

Base station works with PC and includes spread-spectrum radio, USB cable, half-wave antenna, and CD.

Frequency: 2.4 Ghz.

Radio Type: Spread Spectrum.

Transmission Power: 40 mW.

Range: Up to 0.6 km (0.4 miles) line of sight.

Power: Powered from MiniLogger's batteries. Average life is about 2 months, assuming 4-daily downloads. Base station is powered by computer's USB port.

WIRELESS ACCESSORIES

Advanced Programming Cable. . . 52613340

Optional cable allows user to change configuration of radio lid. Works with both 900 Mhz and 2.4Ghz radios.

LOGGER MANAGER SOFTWARE

Logger Manager Software Download

Logger Manager is used to set MiniLogger's reading schedule and to retrieve recorded readings. Readings can be stored in a Campbell Scientific compatible format or in a spreadsheet-ready format.

@ T10/11

SLOPE INDICATOR

VW Piezometer Calibration Certificate

Serial #: 1903622 ✓
Range : 700 kPa
Cable Length: 30 m ✓
Date of Calibration: 10/26/2019

Part #: 52611033 ✓
Cable Part #: 50613824
Calibrated by: SH
Note:

ABC Calibration Factors

	A	B	C
kPa	-1.678371E-4	-9.594610E-3	1.551662E+3
psi	-2.434271E-5	-1.391581E-3	2.250496E+2

Pressure in kPa/psi = (A x Hz²) + (B x Hz) + C, where Hz is frequency in Hertz.

TI Calibration Factors

	C0	C1	C2	C3	C4	C5
kPa	1.548000E+3	-8.424191E-3	8.915533E-2	-1.683421E-4	8.429483E-5	-2.852633E-3
psi	2.245105E+2	-1.221783E-3	1.293043E-2	-2.441510E-5	1.222550E-5	-4.137249E-4

Pressure in kPa/psi = C0 + (C1 x Hz) + (C2 x T) + (C3 x Hz²) + (C4 x Hz x T) + (C5 x T²)

Where Hz is the frequency reading in Hertz and T is the Thermistor reading in degrees C.

TI factors are calculated from temperatures at 5.0, 15.0 and 25.0 degrees C.

Applied pressure and temperature are NIST traceable.

Summary of Test Results at 15°C

Thermistor reading is 15.4 °C.

Applied Pressure is referenced to 1 atm. Calculated Pressure uses ABC Calibration factors.

Applied (kPa)	Equivalent (psi)	Frequency (Hz)	Calculated (kPa)	(psi)	Error (%FS)
0.0	0.00	3011.9	0.2	0.03	-0.03
70.0	10.15	2942.9	69.8	10.13	0.02
140.0	20.31	2871.8	139.9	20.29	0.01
210.0	30.46	2799.0	209.9	30.44	0.01
280.0	40.61	2724.3	279.9	40.59	0.02
350.0	50.76	2647.3	350.0	50.77	0.00
420.0	60.92	2568.2	420.0	60.92	0.00
490.0	71.07	2486.5	490.1	71.09	-0.02
560.0	81.22	2402.1	560.2	81.25	-0.03
630.0	91.37	2314.9	630.0	91.38	-0.01
700.0	101.53	2224.5	699.8	101.50	0.03

© T46

SLOPE INDICATOR

VW Piezometer Calibration Certificate

Serial #: 1903706
 Range : 700 kPa
 Cable Length: 45 m
 Date of Calibration: 10/29/2019

Part #: 52611034
 Cable Part # : 50613824
 Calibrated by: SH
 Note:

ABC Calibration Factors

	A	B	C
kPa	-1.829750E-4	9.342799E-2	1.334970E+3
psi	-2.653828E-5	1.355058E-2	1.936210E+2

Pressure in kPa/psi = (A x Hz²) + (B x Hz) + C, where Hz is frequency in Hertz.

TI Calibration Factors

	C0	C1	C2	C3	C4	C5
kPa	1.333160E+3	9.241154E-2	1.709090E-1	-1.829304E-4	5.218881E-5	-2.322290E-3
psi	1.933517E+2	1.340269E-2	2.478738E-2	-2.653088E-5	7.569080E-6	-3.368078E-4

Pressure in kPa/psi = C0 + (C1 x Hz) + (C2 x T) + (C3 x Hz²) + (C4 x Hz x T) + (C5 x T²)

Where Hz is the frequency reading in Hertz and T is the Thermistor reading in degrees C.

TI factors are calculated from temperatures at 5.0, 15.0 and 25.0 degrees C.

Applied pressure and temperature are NIST traceable.

Summary of Test Results at 15°C

Thermistor reading is 15.3 °C.

Applied Pressure is referenced to 1 atm. Calculated Pressure uses ABC Calibration factors.

Applied (kPa)	Equivalent (psi)	Frequency (Hz)	Calculated (kPa)	(psi)	Error (%FS)
0.0	0.00	2968.4	0.0	0.01	-0.01
70.0	10.15	2897.0	70.0	10.15	0.00
140.0	20.31	2823.6	140.0	20.30	0.00
210.0	30.46	2747.9	210.1	30.47	-0.01
280.0	40.61	2669.9	280.1	40.63	-0.01
350.0	50.76	2589.4	350.1	50.77	-0.01
420.0	60.92	2506.1	419.9	60.91	0.01
490.0	71.07	2419.5	489.9	71.05	0.02
560.0	81.22	2329.1	560.0	81.22	0.00
630.0	91.37	2234.5	630.1	91.39	-0.02
700.0	101.53	2135.7	699.9	101.51	0.01

@ T32 ?

SLOPE INDICATOR

VW Piezometer Calibration Certificate

Serial #: 1903701
Range : 700 kPa
Cable Length: 45 m
Date of Calibration: 10/29/2019

Part #: 52611034
Cable Part # : 50613824
Calibrated by: SH
Note:

ABC Calibration Factors

	A	B	C
kPa	-1.331362E-4	-1.716332E-1	1.649268E+3
psi	-1.930977E-5	-2.489329E-2	2.392061E+2

Pressure in kPa/psi = (A x Hz²) + (B x Hz) + C, where Hz is frequency in Hertz.

TI Calibration Factors

	C0	C1	C2	C3	C4	C5
kPa	1.652688E+3	-1.743762E-1	1.672156E-2	-1.334263E-4	1.968939E-4	-1.059707E-2
psi	2.396937E+2	-2.529024E-2	2.425172E-3	-1.935117E-5	2.855604E-5	-1.536921E-3

Pressure in kPa/psi = C0 + (C1 x Hz) + (C2 x T) + (C3 x Hz²) + (C4 x Hz x T) + (C5 x T²)

Where Hz is the frequency reading in Hertz and T is the Thermistor reading in degrees C.

TI factors are calculated from temperatures at 5.0, 15.0 and 25.0 degrees C.

Applied pressure and temperature are NIST traceable.

Summary of Test Results at 15°C

Thermistor reading is 15.3°C.

Applied Pressure is referenced to 1 atm. Calculated Pressure uses ABC Calibration factors.

Applied (kPa)	Equivalent (psi)	Frequency (Hz)	Calculated (kPa)	(psi)	Error (%FS)
0.0	0.00	2933.2	0.4	0.05	-0.05
70.0	10.15	2859.2	70.1	10.17	-0.02
140.0	20.31	2783.9	139.6	20.25	0.05
210.0	30.46	2706.4	209.6	30.40	0.06
280.0	40.61	2627.0	279.6	40.55	0.06
350.0	50.76	2545.2	350.0	50.76	0.00
420.0	60.92	2461.4	420.2	60.95	-0.03
490.0	71.07	2375.4	490.4	71.12	-0.05
560.0	81.22	2287.0	560.4	81.28	-0.06
630.0	91.37	2196.2	630.2	91.40	-0.02
700.0	101.53	2103.0	699.5	101.46	0.07

APPENDIX C

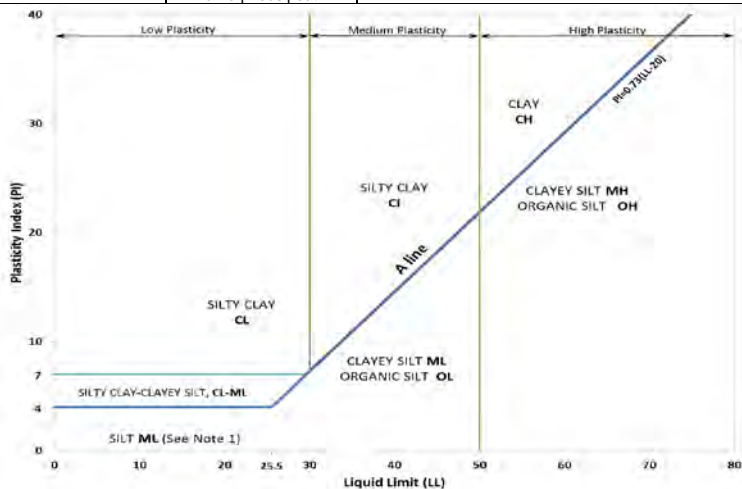
Record of Boreholes (Mock Wells)

METHOD OF SOIL CLASSIFICATION

The Golder Associates Ltd. Soil Classification System is based on the Unified Soil Classification System (USCS)

Organic or Inorganic	Soil Group	Type of Soil	Gradation or Plasticity	$Cu = \frac{D_{60}}{D_{10}}$	$Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$	Organic Content	USCS Group Symbol	Group Name	
									INORGANIC (Organic Content ≤30% by mass)
Well Graded	≥4	1 to 3	GW	GRAVEL					
GRAVELS with >12% fines (by mass)	Below A Line	n/a		GM	SILTY GRAVEL				
	Above A Line	n/a		GC	CLAYEY GRAVEL				
SANDS (≥50% by mass of coarse fraction is smaller than 4.75 mm)	SANDS with ≤12% fines (by mass)	Poorly Graded	<6	≤1 or ≥3	SP	SAND			
		Well Graded	≥6	1 to 3	SW	SAND			
	SANDS with >12% fines (by mass)	Below A Line	n/a		SM	SILTY SAND			
		Above A Line	n/a		SC	CLAYEY SAND			

Organic or Inorganic	Soil Group	Type of Soil	Laboratory Tests	Field Indicators					Organic Content	USCS Group Symbol	Primary Name
				Dilatancy	Dry Strength	Shine Test	Thread Diameter	Toughness (of 3 mm thread)			
INORGANIC (Organic Content ≤30% by mass)	FINE-GRAINED SOILS (≥50% by mass is smaller than 0.075 mm)	SILTS (Non-Plastic or PI and LL plot below A-Line on Plasticity Chart below)	Liquid Limit <50	Rapid	None	None	>6 mm	N/A (can't roll 3 mm thread)	<5%	ML	SILT
				Slow	None to Low	Dull	3mm to 6 mm	None to low	<5%	ML	CLAYEY SILT
			Liquid Limit ≥50	Slow to very slow	Low to medium	Dull to slight	3mm to 6 mm	Low	5% to 30%	OL	ORGANIC SILT
				Slow to very slow	Low to medium	Slight	3mm to 6 mm	Low to medium	<5%	MH	CLAYEY SILT
		CLAYS (PI and LL plot above A-Line on Plasticity Chart below)	Liquid Limit <30	None	Low to medium	Slight to shiny	~ 3 mm	Low to medium	0% to 30% (see Note 2)	CL	SILTY CLAY
			Liquid Limit 30 to 50	None	Medium to high	Slight to shiny	1 mm to 3 mm	Medium		CI	SILTY CLAY
			Liquid Limit ≥50	None	High	Shiny	<1 mm	High		CH	CLAY
HIGHLY ORGANIC SOILS (Organic Content >30% by mass)	Peat and mineral soil mixtures						30% to 75%	PT	SILTY PEAT, SANDY PEAT		
		Predominantly peat, may contain some mineral soil, fibrous or amorphous peat					75% to 100%		PEAT		



Note 1 – Fine grained materials with PI and LL that plot in this area are named (ML) SILT with slight plasticity. Fine-grained materials which are non-plastic (i.e. a PL cannot be measured) are named SILT.
Note 2 – For soils with <5% organic content, include the descriptor “trace organics” for soils with between 5% and 30% organic content include the prefix “organic” before the Primary name.

Dual Symbol — A dual symbol is two symbols separated by a hyphen, for example, GP-GM, SW-SC and CL-ML. For non-cohesive soils, the dual symbols must be used when the soil has between 5% and 12% fines (i.e. to identify transitional material between “clean” and “dirty” sand or gravel. For cohesive soils, the dual symbol must be used when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart (see Plasticity Chart at left).

Borderline Symbol — A borderline symbol is two symbols separated by a slash, for example, CL/CI, GM/SM, CL/ML. A borderline symbol should be used to indicate that the soil has been identified as having properties that are on the transition between similar materials. In addition, a borderline symbol may be used to indicate a range of similar soil types within a stratum.

ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

PARTICLE SIZES OF CONSTITUENTS

Soil Constituent	Particle Size Description	Millimetres	Inches (US Std. Sieve Size)
BOULDERS	Not Applicable	>300	>12
COBBLES	Not Applicable	75 to 300	3 to 12
GRAVEL	Coarse	19 to 75	0.75 to 3
	Fine	4.75 to 19	(4) to 0.75
SAND	Coarse	2.00 to 4.75	(10) to (4)
	Medium	0.425 to 2.00	(40) to (10)
	Fine	0.075 to 0.425	(200) to (40)
SILT/CLAY	Classified by plasticity	<0.075	< (200)

MODIFIERS FOR SECONDARY AND MINOR CONSTITUENTS

Percentage by Mass	Modifier
>35	Use 'and' to combine major constituents (i.e., SAND and GRAVEL)
> 12 to 35	Primary soil name prefixed with "gravelly, sandy, SILTY, CLAYEY" as applicable
> 5 to 12	some
≤ 5	trace

PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) split-spoon sampler for a distance of 300 mm (12 in.). Values reported are as recorded in the field and are uncorrected.

Cone Penetration Test (CPT)

An electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (q_t), porewater pressure (u) and sleeve frictions are recorded electronically at 25 mm penetration intervals.

Dynamic Cone Penetration Resistance (DCPT); N_d:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

SAMPLES

AS	Auger sample
BS	Block sample
CS	Chunk sample
DD	Diamond Drilling
DO or DP	Seamless open ended, driven or pushed tube sampler – note size
DS	Denison type sample
GS	Grab Sample
MC	Modified California Samples
MS	Modified Shelby (for frozen soil)
RC	Rock core
SC	Soil core
SS	Split spoon sampler – note size
ST	Slotted tube
TO	Thin-walled, open – note size (Shelby tube)
TP	Thin-walled, piston – note size (Shelby tube)
WS	Wash sample

SOIL TESTS

w	water content
PL , w _p	plastic limit
LL , w _L	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D _R	relative density (specific gravity, G _s)
DS	direct shear test
GS	specific gravity
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO ₄	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V (FV)	field vane (LV-laboratory vane test)
γ	unit weight

1. Tests anisotropically consolidated prior to shear are shown as CAD, CAU.

NON-COHESIVE (COHESIONLESS) SOILS

Compactness²

Term	SPT 'N' (blows/0.3m) ¹
Very Loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	>50

1. SPT 'N' in accordance with ASTM D1586, uncorrected for the effects of overburden pressure.

2. Definition of compactness terms are based on SPT 'N' ranges as provided in Terzaghi, Peck and Mesri (1996). Many factors affect the recorded SPT 'N' value, including hammer efficiency (which may be greater than 60% in automatic trip hammers), overburden pressure, groundwater conditions, and grain size. As such, the recorded SPT 'N' value(s) should be considered only an approximate guide to the soil compactness. These factors need to be considered when evaluating the results, and the stated compactness terms should not be relied upon for design or construction.

Field Moisture Condition

Term	Description
Dry	Soil flows freely through fingers.
Moist	Soils are darker than in the dry condition and may feel cool.
Wet	As moist, but with free water forming on hands when handled.

COHESIVE SOILS

Consistency

Term	Undrained Shear Strength (kPa)	SPT 'N' ^{1,2} (blows/0.3m)
Very Soft	<12	0 to 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	>200	>30

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.

2. SPT 'N' values should be considered ONLY an approximate guide to consistency; for sensitive clays (e.g., Champlain Sea clays), the N-value approximation for consistency terms does NOT apply. Rely on direct measurement of undrained shear strength or other manual observations.

Water Content

Term	Description
w < PL	Material is estimated to be drier than the Plastic Limit.
w ~ PL	Material is estimated to be close to the Plastic Limit.
w > PL	Material is estimated to be wetter than the Plastic Limit.

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
$\ln x$	natural logarithm of x
$\log_{10} x$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta \sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index = $(w_l - w_p)$
NP	non-plastic
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_C	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_α	secondary compression index
m_v	coefficient of volume change
C_v	coefficient of consolidation (vertical direction)
C_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = $\tan \delta$
c'	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

* Density symbol is ρ . Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

Notes: 1
2

$$\tau = c' + \sigma' \tan \phi'$$

$$\text{shear strength} = (\text{compressive strength})/2$$

PROJECT: 19120626-3000

RECORD OF BOREHOLE BH20-1A

SHEET 1 OF 1

LOCATION: N 4993205.0 , E 487934.0

BORING DATE: January 19 - 22, 2021

DATUM: GEODETIC

HAMMER TYPE: Auto Hammer

DRILLING CONTRACTOR: Orbit Excavating & Sanitization

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES			ELEVATION	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	INSTALLATION AND GROUNDWATER OBSERVATIONS	
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE		BLOWS/0.3m	SHEAR STRENGTH Cu, kPa				WATER CONTENT PERCENT					
									20	40	60	80	10 ⁻⁶	10 ⁻⁵	10 ⁻⁴			10 ⁻³
0	HOLLOW STEM AUGER 168mm ID HOLLOW STEM AUGERS	GROUND SURFACE		85.28												0.76 m Above Ground		
		TOPSOIL; black		84.68												Air Gap Within Casing		
1	TRICONE 6.5" MUD ROTARY DRILLING PQ CASING	SILTY SAND (SM), some gravel, some clay, cobbles; brown; very dense		0.60	1	SS	>50										257mm O.D. Casing	
2				2	SS	>50												
3				3	SS	>50												
4				4	SS	>50												
5				5	SS	>50												
6	PQ ROCK CORE PQ CASING	SANDY SILT (ML), some gravel, trace clay, cobbles; grey; very dense		2.90	4	SS	>50									Bentonite Grout 128mm O.D. Casing		
7				6	SS	>50												
8				7	SS	>50												
9				8	SS	>50												
7	PQ ROCK CORE PQ CASING	Gravelly SILTY SAND (SM), some clay, cobbles; grey		3.80	5	SS	>50								Cement Grout			
8				6	SS	>50												
7	PQ ROCK CORE PQ CASING	Gravelly SILTY SAND (SM), some clay, cobbles; grey		4.42	6	SS	>50								Cement Grout			
8				7	SS	>50												
7	PQ ROCK CORE PQ CASING	---Spoon refusal at 6.9 m		5.33	7	SS	>50								Cement Grout			
8				8	SS	>50												
8	PQ ROCK CORE PQ CASING	LIMESTONE		6.90	9	SS	>50								Instrument Cluster Cement With No Casing			
9				8	SS	>50												
9	PQ ROCK CORE PQ CASING	END OF BOREHOLE		8.11											Instrument Cluster Cement With No Casing			
				76.47														

LDN_BHS_07 NATION_RISE.GPJ_GLDPR_LON.GDT 21-07-22 13:13 DATA INPUT:

DEPTH SCALE
1 : 50



LOGGED: LK
CHECKED:

PROJECT: 19120626-3000

RECORD OF BOREHOLE BH20-1B

SHEET 1 OF 1

LOCATION: N 4993205.0 , E 487934.0

BORING DATE: January 23, 2021

DATUM: GEODETIC

HAMMER TYPE: Auto Hammer

DRILLING CONTRACTOR: Orbit Excavating & Sanitization

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES			ELEVATION	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	INSTALLATION AND GROUNDWATER OBSERVATIONS	
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE		BLOWS/0.3m	SHEAR STRENGTH				WATER CONTENT PERCENT					
									20 40 60 80		nat V. + Q - rem V. ⊕ U -		10 ⁻⁶ 10 ⁻⁵ 10 ⁻⁴ 10 ⁻³		Wp — W — WI			
		Soil Description From 0 to 6.9m Inferred From BH20-1A					86									<p>Top of Pipe Elev. 86.12m</p> <p>Jan 24/2021</p> <p>Bentonite Seal</p> <p>Filter Sand</p> <p>51mm Diam. PVC Screen</p> <p>Water level measured in well at Elev. 83.69 m on January 24 2021</p>		
0	HOLLOW STEM AUGER 168mm ID HOLLOW STEM AUGERS	GROUND SURFACE		85.27														
		TOPSOIL; black		0.00														
1	TRICONE 6.5" MUD ROTARY DRILLING PQ CASING			84.67														
				0.60														
2		SILTY SAND (SM), some gravel, some clay, cobbles; brown; very dense																
3				82.37														
				2.90														
4		SANDY SILT (ML), some gravel, some clay, cobbles; grey; very dense																
5			81.47															
			3.80															
6	Gravelly SILTY SAND (SM), some clay, cobbles; grey; very dense																	
			80.85															
			4.42															
7	SANDY SILT (ML), some gravel, trace clay, cobbles; grey; very dense																	
			79.94															
			5.33															
8	Gravelly SILTY SAND (SM), some clay, cobbles; grey																	
			78.72															
			6.55															
9	END OF BOREHOLE																	

LDN_BHS_07 NATION_RISE.GPJ_GLDPR_LON.GDT 21-07-22 13:13 DATA INPUT:

DEPTH SCALE
1 : 50



LOGGED: LK
CHECKED:

PROJECT: 19120626-3000

RECORD OF BOREHOLE BH20-1C

SHEET 1 OF 1

LOCATION: N 4993205.0 , E 487934.0

BORING DATE: January 19, 2021

DATUM: GEODETIC

HAMMER TYPE: Auto Hammer

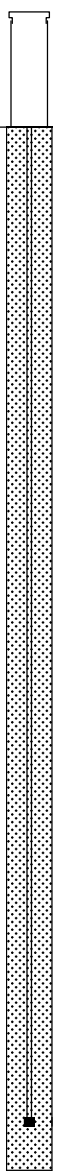
DRILLING CONTRACTOR: Orbit Excavating & Sanitization

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES			ELEVATION	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	INSTALLATION AND GROUNDWATER OBSERVATIONS	
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE		BLOWS/0.3m	SHEAR STRENGTH Cu, kPa				WATER CONTENT PERCENT					
									20	40	60	80	10 ⁻⁶	10 ⁻⁵	10 ⁻⁴			10 ⁻³
		Soil Description 0 to 6.9m Inferred from BH20-1A																
0		GROUND SURFACE																
	HOLLOW STEM AUGER 168mm ID HOLLOW STEM AUGERS	TOPSOIL; black																
1		SILTY SAND (SM), some gravel, some clay, cobbles; brown; very dense																
2		SANDY SILT (ML), some gravel, some clay, cobbles; grey; very dense																
3		Gravelly SILTY SAND (SM), some clay, cobbles; grey; very dense																
4	TRICONE 6.5" MUD ROTARY DRILLING PQ CASING	SANDY SILT (ML), some gravel, trace clay, cobbles; grey; very dense																
5		Gravelly SILTY SAND (SM), some clay, cobbles; grey																
6		Gravelly SILTY SAND (SM), some clay, cobbles; grey																
7		END OF BOREHOLE																

Top of Pipe Elev. 86.20m

Cement Grout Mix

VWP



LDN_BHS_07 NATION_RISE.GPJ_GLDPR_LON.GDT 21-07-22 13:13 DATA INPUT:

DEPTH SCALE
1 : 50



LOGGED: LK
CHECKED:

PROJECT: 19120626-3000

RECORD OF BOREHOLE BH20-2A

SHEET 1 OF 1

LOCATION: N 5000091.9 , E 488784.0

BORING DATE: January 29, 2021

DATUM: GEODETIC

HAMMER TYPE: Auto Hammer

DRILLING CONTRACTOR: Orbit Excavating & Sanitization

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES			ELEVATION	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	INSTALLATION AND GROUNDWATER OBSERVATIONS	
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE		BLOWS/0.3m	SHEAR STRENGTH Cu, kPa				WATER CONTENT PERCENT					
									20	40	60	80	nat V. rem V.	+ ⊕	- ⊖			Q - U
0		GROUND SURFACE		72.93			73									0.83 m Above Ground		
1	HOLLOW STEM AUGER 168mm ID HOLLOW STEM AUGERS	SILTY CLAY (CL), with organic seams; grey; soft to firm		0.00			72									Air Gap Within Casing		
2				1	SS	9												
3	TRICONE 6.5" MUD ROTARY DRILLING PQ CASING	Gravelly SILTY SAND (SM), trace clay, cobbles; grey; compact		70.72			71									257mm O.D. Casing		
4				2	SS	5										MH		
5		Silty GRAVELLY SAND (SM); grey; compact		69.96			70									Bentonite Grout		
6				3	SS	13												
7		LIMESTONE		68.18			69									128mm O.D. Casing		
8				4	SS	11										MH		
9		END OF BOREHOLE		68.18			68									Cement Grout		
10				5	SS	29											Instrument Cluster	
11				67.83			67											
12				6.10			66											

LDN_BHS_07 NATION_RISE.GPJ_GLDPR_LON.GDT 21-07-22 13:13 DATA INPUT:

DEPTH SCALE
1 : 50



LOGGED: RA
CHECKED:

PROJECT: 19120626-3000

RECORD OF BOREHOLE BH20-2B

SHEET 1 OF 1

LOCATION: N 5000091.9 , E 488784.0

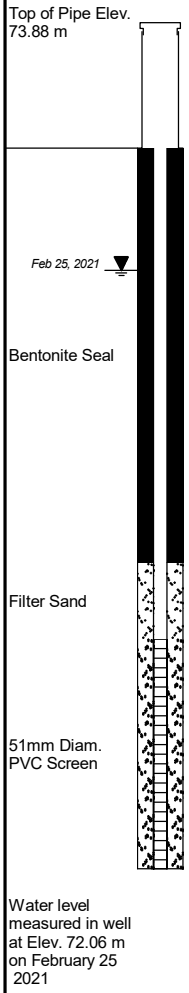
BORING DATE: February 2, 2021

DATUM: GEODETIC

HAMMER TYPE: Auto Hammer

DRILLING CONTRACTOR: Orbit Excavating & Sanitization

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES			ELEVATION	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	INSTALLATION AND GROUNDWATER OBSERVATIONS	
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE		BLOWS/0.3m	SHEAR STRENGTH Cu, kPa				WATER CONTENT PERCENT					
									20	40	60	80	nat. rem.	V. V.	+ ⊕			Q - U -
		Soil Description From 0 to 4.75m Inferred From BH20-2A																
0		GROUND SURFACE				72.87												
1	HOLLOW STEM AUGER 168mm ID HOLLOW STEM AUGERS	SILTY CLAY (CL), with organic seams; grey; soft to firm				0.00												
2								70.66										
3	TRICONE 6.5" MUD ROTARY DRILLING PO CASING	Gravelly SILTY SAND (SM), trace clay, cobbles; grey; compact				2.21												
4								69.90										
5		Silty GRAVELLY SAND (SM); grey; compact				2.97												
6								68.12										
7		END OF BOREHOLE				4.75												



LDN_BHS_07 NATION_RISE.GPJ_GLDPR_LON.GDT 21-07-22 13:13 DATA INPUT:

DEPTH SCALE
1 : 50



LOGGED: RA
CHECKED:

PROJECT: 19120626-3000

RECORD OF BOREHOLE BH20-2C

SHEET 1 OF 1

LOCATION: N 5000091.9 , E 488784.0

BORING DATE: February 3, 2021

DATUM: GEODETIC

HAMMER TYPE: Auto Hammer

DRILLING CONTRACTOR: Orbit Excavating & Sanitization

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES			ELEVATION	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	INSTALLATION AND GROUNDWATER OBSERVATIONS	
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE		BLOWS/0.3m	SHEAR STRENGTH Cu, kPa				WATER CONTENT PERCENT					
									20	40	60	80	10 ⁻⁶	10 ⁻⁵	10 ⁻⁴			10 ⁻³
		Soil Description From 0 to 4.75m Inferred From BH20-2A																
0		GROUND SURFACE					72.91											
1	HOLLOW STEM AUGER 168mm ID HOLLOW STEM AUGERS	SILTY CLAY (CL), with organic seams; grey; soft to firm					0.00											
2							70.70											
3	TRICONE 6.5" MUD ROTARY DRILLING PO CASING	Gravelly SILTY SAND (SM), trace clay, cobbles; grey; compact					2.21											
4		Silty GRAVELLY SAND; grey; compact					69.94											
5		END OF BOREHOLE					68.16											
							4.75											

Top of Pipe Elev. 73.78 m

Cement Grout Mix

VWP

LDN_BHS_07 NATION_RISE.GPJ_GLDPR_LON.GDT 21-07-22 13:13 DATA INPUT:

DEPTH SCALE



LOGGED: RA

CHECKED:

1 : 50

PROJECT: 19120626-3000

RECORD OF BOREHOLE BH20-3A

SHEET 1 OF 2

LOCATION: N 5003448.1 , E 483149.9

BORING DATE: February 4, 2021

DATUM: GEODETIC

HAMMER TYPE: Auto Hammer

DRILLING CONTRACTOR: Orbit Excavating & Sanitization

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES			ELEVATION	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	INSTALLATION AND GROUNDWATER OBSERVATIONS	
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE		BLOWS/0.3m	SHEAR STRENGTH Cu, kPa				WATER CONTENT PERCENT					
									20	40	60	80	10 ⁻⁶	10 ⁻⁵	10 ⁻⁴			10 ⁻³
0		GROUND SURFACE		74.55														
0.00	HOLLOW STEM AUGER 168mm ID HOLLOW STEM AUGERS			0.00	1	SS	12									0.76 m Above Ground		
1		Gravelly SILTY SAND (SM), some clay, cobble; brown; compact to dense ---Turning grey at 2.29 m			2	SS	45									MH		
2					3	SS	36									257mm O.D. Casing		
3					4	SS	22	72										
4					5	SS	25	71								128mm O.D. Casing Bentonite Grout		
5	TRICONE 6.5" MUD ROTARY DRILLING PQ CASING			70.13	6	SS	29	70								MH		
6		Silty SANDY GRAVEL, some clay, cobbles; grey; dense to very dense		4.42	7	SS	33	69								MH		
7					8	SS	40	68										
8					9	SS	87	67										
9					10	SS	50/152mm	66										
7.32		---Spoon refusal at 7.32 m		67.23												Cement Grout		
8	PQ ROCK CORE PQ CASING	WEATHERED LIMESTONE		66.38												Instrument Cluster		
8.17		LIMESTONE		8.17														
9		--- CONTINUED NEXT PAGE ---																

LDN_BHS_07 NATION_RISE.GPJ GLDR_LON.GDT 21-07-22 13:13 DATA INPUT:

DEPTH SCALE

1 : 50



LOGGED: RA

CHECKED:

PROJECT: 19120626-3000

RECORD OF BOREHOLE BH20-3A

SHEET 2 OF 2


LOCATION: N 5003448.1 , E 483149.9

BORING DATE: February 4, 2021

DATUM: GEODETIC

HAMMER TYPE: Auto Hammer

DRILLING CONTRACTOR: Orbit Excavating & Sanitization

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES		ELEVATION	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	INSTALLATION AND GROUNDWATER OBSERVATIONS T10/11 Mock Well	
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE		BLOWS/0.3m	SHEAR STRENGTH Cu, kPa				WATER CONTENT PERCENT					
									20	40	60	80	nat V. + rem V. ⊕	Q - U - ○	10 ⁻⁶			10 ⁻⁵
9		--- CONTINUED FROM PREVIOUS PAGE ---																
		LIMESTONE															Cement Grout 	
		END OF BOREHOLE															No Casing No Casing	
10							65											
11																		
12																		
13																		
14																		
15																		
16																		
17																		
18																		
19																		

LDN_BHS_07 NATION_RISE.GPJ_GLDR_LON.GDT 21-07-22 13:13 DATA INPUT:

DEPTH SCALE



LOGGED: RA

1 : 50

CHECKED:

PROJECT: 19120626-3000

RECORD OF BOREHOLE BH20-3B

SHEET 1 OF 1

LOCATION: N 5003448.1 , E 483149.9

BORING DATE: February 4, 2021

DATUM: GEODETIC

HAMMER TYPE: Auto Hammer

DRILLING CONTRACTOR: Orbit Excavating & Sanitization

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES			ELEVATION	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	INSTALLATION AND GROUNDWATER OBSERVATIONS	
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE		BLOWS/0.3m	SHEAR STRENGTH Cu, kPa				WATER CONTENT PERCENT					
									20	40	60	80	10 ⁻⁶	10 ⁻⁵	10 ⁻⁴			10 ⁻³
		Soil Description From 0 to 7.3 m Inferred From BH20-3A																
0		GROUND SURFACE		74.57														
0	HOLLOW STEM AUGER 168mm ID HOLLOW STEM AUGERS	Gravelly SILTY SAND (SM), some clay, cobble; brown; compact to dense ---Turning grey at 2.29 m		0.00														
1																		
2																		
3																		
4																		
4	TRICONE 6.5" MUD ROTARY DRILLING PQ CASING	Silty SANDY GRAVEL, some clay, cobbles; grey; dense to very dense		70.15														
5					4.42													
6																		
7		END OF BOREHOLE		67.56														
7				7.01														
8																		
9																		

Top of Pipe Elev. 75.75 m

Feb 12, 2021

Bentonite Seal

Filter Sand

51mm Diam. PVC Screen

Water level measured in well at Elev. 72.51 m on February 12 2021



LDN_BHS_07 NATION_RISE.GPJ_GLDPR_LON.GDT 21-07-22 13:13 DATA INPUT:

DEPTH SCALE
1 : 50



LOGGED: RA
CHECKED:

PROJECT: 19120626-3000

RECORD OF BOREHOLE BH20-3C

SHEET 1 OF 1

LOCATION: N 5003448.1 , E 483149.9

BORING DATE: February 4, 2021

DATUM: GEODETIC

HAMMER TYPE: Auto Hammer

DRILLING CONTRACTOR: Orbit Excavating & Sanitization

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES			ELEVATION	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	INSTALLATION AND GROUNDWATER OBSERVATIONS	
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE		BLOWS/0.3m	SHEAR STRENGTH Cu, kPa				WATER CONTENT PERCENT					
									20	40	60	80	10 ⁻⁶	10 ⁻⁵	10 ⁻⁴			10 ⁻³
0	HOLLOW STEM AUGER 168mm ID HOLLOW STEM AUGERS	Soil Description From 0 to 7.3 m Inferred From BH20-3A		74.63												Top of Pipe Elev. 74.96 m		
		GROUND SURFACE		0.00														
1	TRICONE 6.5" MUD ROTARY DRILLING PQ CASING	Gravelly SILTY SAND (SM), some clay, cobble; brown; compact to dense ---Turning grey at 2.29 m														Cement Grout Mix		
2																		
3																		
4																		
5		Silty SANDY GRAVEL, some clay, cobbles; grey; dense to very dense		70.21												VWP		
6																		
7																		
7		END OF BOREHOLE		67.62														
				7.01														
8																		
9																		

LDN_BHS_07 NATION_RISE.GPJ_GLDPR_LON.GDT 21-07-22 13:13 DATA INPUT:

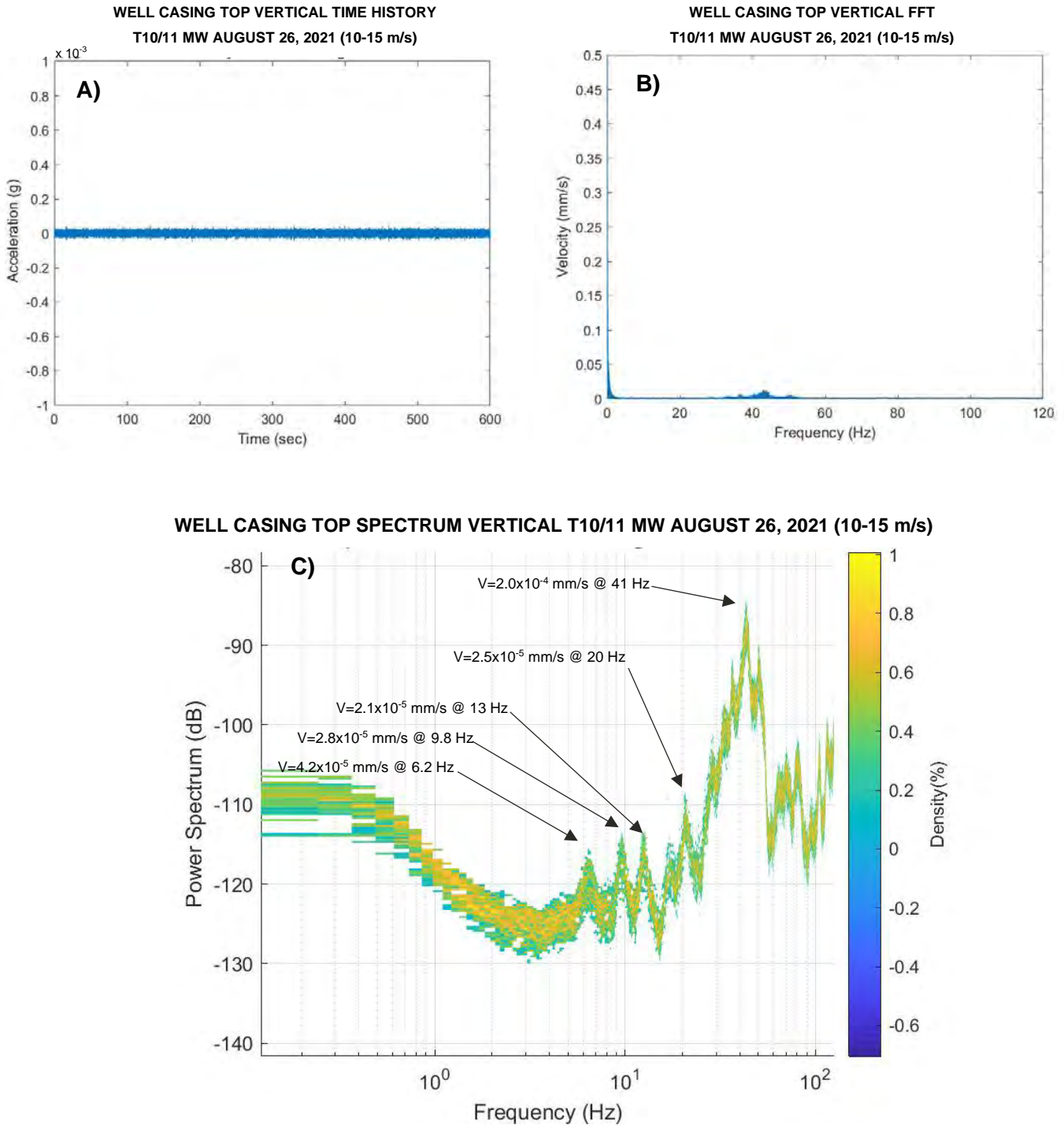
DEPTH SCALE
1 : 50



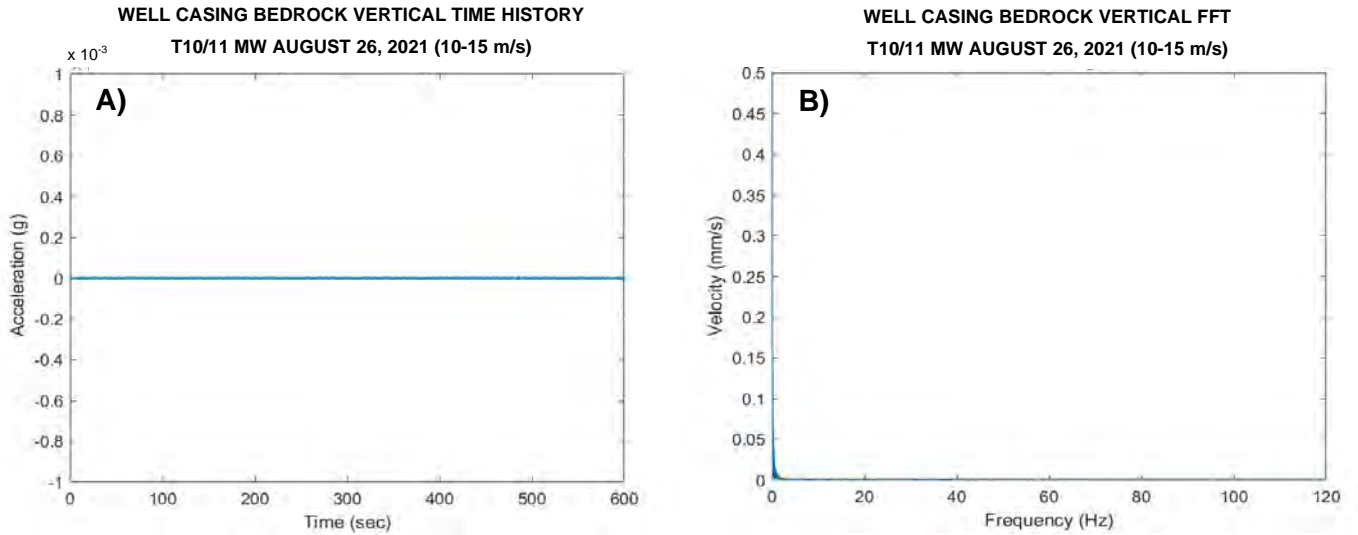
LOGGED: RA
CHECKED:

APPENDIX D

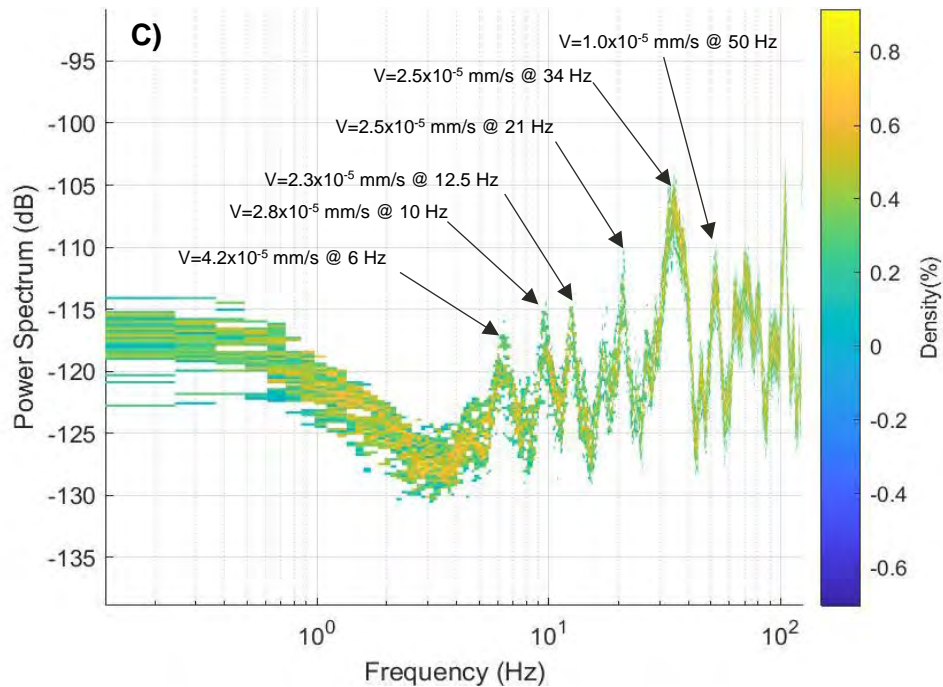
**Example Acceleration Time
Histories and Persistence Spectra**



D-1: Well Casing Top – Example of: A) Acceleration Time Histories; B) Fast Fourier Transform (FFT); and Persistence Spectra Graph. (This figure is schematic only and is to be read in conjunction with accompanying text, Wind velocity showed in parentheses)



WELL CASING BEDROCK SPECTRUM VERTICAL T10/11 MW AUGUST 26, 2021 (10-15 m/s)



D-2: Well Casing Bedrock – Example of: A) Acceleration Time Histories; B) Fast Fourier Transform (FFT); and Persistence Spectra Graph. (This figure is schematic only and is to be read in conjunction with accompanying text, Wind velocity showed in parentheses)

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