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Long-Term Vibration Monitoring Interim Report No.4

North Kent Wind 1, Chatham-Kent, Ontario

Submitted to:

Mr. Jonathan Miranda, Facility Manager
North Kent Wind LP
Operations & Maintenance Building
9525 Eberts Line
Chatham, ON, N7M 5J2

Submitted by:

Golder Associates Ltd.
309 Exeter Road, Unit #1, London, Ontario, N6L 1C1, Canada

+1 519 652 0099

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1.0 INTRODUCTION

This report summarizes the results of fourteen months of vibration monitoring carried out between February 1, 2020 to April 1, 2021 for the North Kent 1 project (NK1) completed as part of Section H1 of the Renewable Energy Approval (REA) document issued by the Ontario Ministry of the Environment and Climate Change (MOECC) issued in 2016. The vibration monitoring program documented in this report addresses long-term data collection and interpretation of ground-borne vibrations described in three separate work plans that were reviewed and approved by MOECC (now the Ministry of the Environment, Conservation and Parks, (MECP)) on November 24, 2017, December 22, 2017 and February 21, 2018 as described in the following plans:

- Phase 3a: Operational Vibration Monitoring Program Instrumentation Design, North Kent Wind 1 Project, Chatham-Kent, Ontario, 1668031-1000-L02, dated November 17, 2017;
- Phase 3a: Operational Vibration Monitoring Program Instrumentation Design, North Kent Wind 1 Project – Addendum, Chatham-Kent, Ontario, 1668031-1000-L04, dated December 14, 2017; and
- Phase 3b: Operational Vibration Monitoring Program, Data Collection and Management, North Kent Wind 1 Project, Chatham-Kent, Ontario, 1668031-1000-L03, dated January 16, 2018.

The results of vibration monitoring completed during driving of test piles and during turbine foundation construction were documented in the following two reports:

- Surface and Subsurface Vibration Monitoring, Test Piles T5 and T42, North Kent 1, 1668031-2000-R01, dated June 2017; and
- Construction Vibration Monitoring Report, North Kent 1, 1668031-2000-R02, dated December 2017.

Except where relevant data is presented, these reports are not discussed further within this report.

The intent of the work described in this fourth interim report on the long-term vibration monitoring program was to provide an update of the surface and subsurface magnitudes, propagation and attenuation characteristics of ground vibrations associated with operation of the 34 wind turbines constructed at the site. Monitoring completed between January 1, 2018 to February 1, 2020 was summarized in:

- Long-Term Vibration Monitoring Interim Report No. 1, North Kent 1, 1668031-4000-R01, dated November 2018 (Report No. 1);
- Long-Term Vibration Monitoring Interim Report No. 2, North Kent 1, 1668031-4000-R02, dated June 2019 (Report No. 2); and
- Long-Term Vibration Monitoring Interim Report No. 3, North Kent 1, 1668031-4000-R03, dated April 2020 (Report No. 3).

Report No. 1 also includes detailed information regarding the vibration sources, monitoring instrumentation used, instrumented turbine locations, equipment calibrations, descriptions of the data collection and communications systems, and data analysis methodology employed. These will not be re-addressed within this report.

This report focuses on:

- vibration amplitudes and frequencies at the locations of 4 turbine towers, one of which included instrumentation within the tower itself;

- vibration amplitudes and frequencies in the subsurface rock at known distances from the turbine sources;
- vibration amplitudes and frequencies of steel casings installed to mimic local groundwater supply well casings;
- actual vibration attenuation as compared to published research; and
- comparison of these vibration levels to regulatory thresholds.

This report summarizes:

- vibration monitoring data gathered during turbine operations between February 1, 2020 to April 1, 2021; and
- interpretations of the data.

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. 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.

This report should be read in conjunction with, and is considered an addendum to, the "Long-Term Vibration Monitoring Interim Report No 1". The reader's attention is specifically drawn to this report and materials within, as it is essential for the proper use and interpretation of the information presented and discussed herein. Where applicable, the numbering of some figures and graphs within this report remain the same as in Report No. 1 (e.g., Figure 6 and Figures 9A through 9D) but have been updated or extended (in time scale) to illustrate the information gathered between February 1, 2020 to April 1, 2021.Figures 10A and 10B and Figures 11A through 11D were created using data analyses results from Reports No. 1 to 3 and this current interim report.

2.0 SUMMARY OF BACKGROUND INFORMATION

2.1 Project description

Thirty-four wind turbines were constructed for the North Kent 1 project within the Municipality of Chatham-Kent, Ontario at the locations illustrated on Figure 1. The turbines were manufactured by Siemens Energy (model SWT-3.2-113) with hub heights of 99.5 metres (m), blade lengths of 55 m and power ratings of 2.7 megawatts (MW) for turbines T19, T42 and T51, and 3.2 MW for turbines T23 and T41. Turbine specifications are provided in Appendix A of Report No. 1.

Each turbine is supported by a 17-m diameter reinforced concrete base and 18 closed-end pipe piles driven into the ground to support each turbine tower base. Half of the piles were driven at an angle of 5 degrees from vertical, outward away from the foundation, to provide additional resistance to overturning moments and sliding forces. After contacting the top of rock, grout plugs and soils within the steel pile were removed using a 355-mm diameter drilling bit. Once the plug and soils were removed from within the steel pile, an approximately 229-mm diameter hole was drilled into the rock, into which a steel reinforcing bar was to be grouted as an anchor to resist uplift. The piles were then filled with concrete to the surface. After constructing the reinforced concrete foundation into which the pile tops were integrated, the foundation excavation was backfilled with compacted on-site soils.

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 2017. 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 during the period from January through February 22, 2018. The Commercial Operating Date (COD) was granted on February 22, 2018.

2.2 Vibration Monitoring Instrumentation

Turbine sites T23, T41, T42 and T51 were selected for long-term vibration monitoring. Turbine T51, within the T19/T51 group, was specifically identified for monitoring because the access road opens onto a road less travelled (in this area) as compared to St. Clair Road and with T51 also forms a relatively close pair of turbines that were considered to possibly lend insight into the superposition of vibration characteristics pending evaluation of the data. As previously documented in the reports for this project cited above, and consistent with published research and case histories, vibration magnitudes and frequencies 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 because of the clustered locations;
- because of proximity to the more heavily instrumented T42 site; and
- to potentially reduce the influence of background conditions by selecting sites for mock wells as far as practicable from busy roads.

Monitoring of a turbine foundation and ground-borne vibrations at a site with two closely spaced turbines (T19/T51) also offers the advantage, when coupled with data from the other sites, of additional insight into the ground responses associated with two turbines operating independently as single turbines, or simultaneously, depending on operational conditions and actual magnitudes of ground-borne vibrations.

The long-term monitoring work plan included additions to the existing instrumentation at turbine T42 (the focus of the Phase 1 Test Pile Vibration Monitoring program). Instrumentation was also installed at turbine sites T23, T41 and T51. Figures 2 through 5, provided within Report No. 1, illustrate the locations of all instrumented turbine sites and the instrumentation at each turbine is discussed below in order of turbine number.

Laboratory verification of accelerometer calibrations 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. Further, field verification of accelerometer responses was completed in the field with the steel housing and internal instruments coupled to the drilling rig along with an independent accelerometer coupled to the drilling rig immediately adjacent to the housing. Field verification of accelerometer calibration of all other accelerometers was completed with a portable controlled vibration source before accelerometers were installed on well casings, turbine foundations and the turbine tower. Specifications, calibration and verification information for all of the instruments are provided in Appendix B of Report No. 1.

Detailed descriptions of the instrumentation used and its disposition at the turbine sites is covered in Section 3.1 of Report No. 1. These are briefly described as follows:

Turbine site T42:

- pairs of triaxial and uniaxial accelerometers were installed within the bedrock near the bedrock-till interface and at the mid-depth of the soft clay;
- borehole pairs, with one hole for deep accelerometers and another for mid-depth accelerometers, were located at approximately 10, 30 and 50 m from the turbine;
- pairs of triaxial and uniaxial accelerometers were installed within two steel pipe piles, just above the rock, at positions around the foundation perimeter separated by 90 degrees;
- pairs of triaxial and uniaxial accelerometers installed within the circular mass concrete foundation, above the instrumented piles; and
- two triaxial accelerometers installed within the turbine tower, at the approximate half-height (about 49 metres above the foundation) and about 28 m below the top of the tower (about 67 metres above the foundation).

Turbine sites T23, T41, and T51:

- pairs of triaxial and uniaxial accelerometers mounted within the concrete turbine foundations;
- pairs of triaxial and uniaxial accelerometers within the bedrock near the bedrock-till interface, installed through the overlying soft soil using a steel casing, with these wells located at distances ranging between 140 and 520 metres from the turbines; and
- three orthogonally oriented accelerometers mounted on the top of the steel casings (i.e., “mock wells”).

2.3 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 data loss remained as with any complex field instrumentation program. Equipment and data collection challenges experienced between January 1, 2018 and February 1, 2020 were summarized in Section 3.3 of Report No. 1 and in Section 2.3 of Reports No. 2 and No. 3, respectively. While several of those challenges were fully or partially mitigated, others persisted over the subsequent 14 months of data collection. These are summarized as follows:

- inability to collect data on time and perform periodical maintenance to the systems due to several province-wide lockdowns and work restrictions imposed by the provincial government due to the ongoing viral pandemic of coronavirus disease 2019 (COVID-19);
- extended periods of inclement weather and limited daylight during the winter season combined to exceed the balance of solar power generation and battery storage system capacity, despite additional batteries and solar panels, and electrical demand of the data logging and transmission systems;
- rodents continued burrowing into and nesting within mock well boxes, despite extra protection added at the end of the summers of 2018, 2019 and 2020 and repeated cleaning, this issue was exacerbated within mock

well box at the T41 turbine site where rodents chewed through the sensor and battery cables routinely after being replaced on multiple occasions between 2019 and 2021;

- EDM/RCM software continued to require multiple updates to address communications “handshaking” complications associated with power outages, restarts and internal/external data storage demands;
- EDM/RCM software programming problems persisted as related to local mass storage;
- Crystal Instruments NAS hardware-software compatibility problems persisted;
- 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 hard-drive data storage units;
- internal or on-site external data logger storage capacities were exceeded;
- the buried triaxial accelerometers responded intermittently and exhibited significant signal noise, likely associated with moisture entering the housing and wiring systems, the physical size of the accelerometer, cable lengths and other factors; and
- equipment supply problems and work interruptions associated with the COVID-19 pandemic.

Dates for which data was collected and available for analysis are illustrated on Figure 6.

3.0 METEOROLOGICAL AND TURBINE OPERATION DATA

Meteorological and turbine operation data was provided to Golder by North Kent Wind 1 in Microsoft Excel file format for the time period between February 2020 and April 2021. 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 wind velocity data provided over the specific time period is shown in Figure 6.

4.0 DATA SUMMARY AND INTERPRETATION

4.1 Ground Vibration Particle Velocity and Distance to Turbines

Data selected for analysis was processed and analysed following the procedures covered in Section 6.0 of Report No. 1. The dates picked for the analyses are shown on Figure 6. The results from the data analysis are presented on Figures 9A through 9D where the particle velocity (tower, turbine foundation, mock well casing or rock) is illustrated as related to the distance from the turbine tower centre. In this case, the data closest to the centre represent the measurements made by the accelerometers mounted within the tower (off set approximately 1.9 m from the centre). The instruments mounted on the foundations are approximately 7.9 m from the turbine tower centre. Also shown in Figures 9A to 9D are the results obtained for the first twenty-two months of vibration monitoring documented in Reports No. 1, 2 and 3 for comparison. These results are presented in grey colour scale as follows: light grey for low wind velocities (5 to 10 m/s), medium grey for moderate velocities (10 to 15 m/s), and dark grey for high velocity wind events (15 to 20 m/s). Data obtained during the period covered by this report are illustrated in full colour to facilitate comparison among the reporting periods.

The data analyses results are described below as related to each of the physical locations of accelerometers. In all cases, the data summarized in Tables 1 to 7 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 frequency bands of about 1 to about 5 Hz, approximately 5 to 10 Hz and greater than 10 Hz, as previously described in Section 6.2 of the interim report No. 1. Each table below has grouped the four peaks into these general frequency bands. Examples of these peaks in the persistence spectra can be observed in the graphs provided in Appendix D of Report No. 1. Also provided in the summary tables, in parentheses, are 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 1: Summary of largest and 95th percentile vibration velocity values for turbine tower.

Turbine T42 Tower	Turbine Tower – Particle Velocity (mm/s)			
	Equal to 1 Hz	>1 to 5 Hz (typical)	>5 to 10 Hz (typical)	>10 Hz (typical)
Top	2.8 (2.8)	3.6 (2.6)	0.2 (0.2)	0.2 (0.2)
Mid-Height	8.9 (7.1)	11.3 (4.5)	1.9 (0.8)	0.2 (0.2)

Table 2: Summary of largest and 95th percentile vibration velocity values for turbine foundations.

Turbine	Turbine Foundation – Particle Velocity (mm/s)			
	Equal to 1 Hz	>1 to 5 Hz (typical)	>5 to 10 Hz (typical)	>10 Hz (typical)
T23	0.9 (0.06)	0.1 (0.09)	0.06 (0.06)	0.02 (0.01)
T41	5.0* (0.89)	0.7 (0.3)	0.6 (0.06)	0.2 (0.06)
T42 (East)	0.1 (0.1)	0.02 (0.02)	<0.01 (<0.01)	0.04 (0.02)
T42 (West)	0.2 (0.1)	0.06 (0.02)	0.01 (<0.01)	0.01 (<0.01)
T51	0.06 (0.03)	0.02 (0.02)	0.1 (0.04)	0.04 (0.01)

*Note: Unusually large values are subject to further analysis for influence of transient vibration sources and artefacts of fast Fourier transform (FFT)-based analyses.

Table 3: Summary of largest and 95th percentile vibration velocity values for turbine T42 piles 13 and 17.

Pile	T42 Piles – Particle Velocity (mm/s)			
	Equal to 1 Hz	>1 to 5 Hz (typical)	>5 to 10 Hz (typical)	>10 Hz (typical)
East	2.8 (0.9)	1.0 (0.1)	0.09 (0.06)	0.06 (0.05)
West	2.0 (1.9)	1.78 (0.9)	0.6 (0.2)	0.06 (0.05)

Table 4: Table 6: Summary of largest and 95th percentile vibration velocity values for soil at ≈8 m depth at T42.

Turbine	Subsurface Soil at Turbine T42 site – Particle Velocity (mm/s)			
	Equal to 1 Hz	>1 to 5 Hz (typical)	>5 to 10 Hz (typical)	>10 Hz (typical)
Borehole B101	0.6 (0.5)	0.2 (<0.01)	<0.01 (<0.01)	<0.01 (<0.01)
Borehole B102	0.05 (0.05)	0.06 (0.04)	0.05 (0.02)	<0.01 (<0.01)
Borehole B103*	<0.01 (<0.01)	<0.01 (<0.01)	<0.01 (<0.01)	<0.01 (<0.01)

*Note: Instrumentation embedded in the soil in Borehole B103 included only a single uniaxial accelerometer oriented in the vertical direction and, therefore, cannot be directly compared to the data for the other two boreholes that included triaxial and uniaxial accelerometers.

Table 5: Summary of largest and 95th percentile vibration velocity values for bedrock at T42.

Turbine	Subsurface Rock at Turbine T42 site – Particle Velocity (mm/s)			
	Equal to 1 Hz	>1 to 5 Hz (typical)	>5 to 10 Hz (typical)	>10 Hz (typical)
Borehole B101	0.5 (0.2)	0.03 (0.02)	0.1 (0.04)	0.03 (0.02)
Borehole B102	0.06 (0.06)	0.01 (0.01)	0.02 (0.01)	0.01 (<0.01)
Borehole B103	0.05 (0.04)	0.01 (0.01)	<0.01 (<0.01)	0.01 (<0.01)

Table 6: Summary of largest and 95th percentile vibration velocity values for mock well casings.

Turbine	Mock Well Casings – Particle Velocity (mm/s)			
	Equal to 1 Hz	>1 to 5 Hz (typical)	>5 to 10 Hz (typical)	>10 Hz (typical)
T23	1.3×10^{-2} (1.3×10^{-2})	2.2×10^{-3} (2.2×10^{-3})	4.2×10^{-4} (3.6×10^{-4})	1.8×10^{-4} (1.8×10^{-4})
T41	4.5×10^{-2} (4.1×10^{-2})	6.3×10^{-3} (5.5×10^{-3})	3.3×10^{-3} (3.1×10^{-3})	1.3×10^{-3} (1.2×10^{-3})
T51	3.2×10^{-2} (2.9×10^{-2})	1.3×10^{-2} (8.3×10^{-3})	2.4×10^{-3} (2.1×10^{-3})	2.5×10^{-3} (8.5×10^{-4})

Table 7: Summary of largest and 95th percentile vibration velocity values in rock at mock wells.

Turbine	Rock at Mock Well Locations – Particle Velocity (mm/s)			
	Equal to 1 Hz	>1 to 5 Hz (typical)	>5 to 10 Hz (typical)	>10 Hz (typical)
T23	6.3×10^{-4} (6.3×10^{-4})	1.8×10^{-4} (1.7×10^{-4})	6.7×10^{-5} (6.1×10^{-5})	1.4×10^{-5} (1.4×10^{-5})
T41	4.5×10^{-3} (4.5×10^{-3})	1.4×10^{-3} (1.4×10^{-3})	2.0×10^{-4} (2.0×10^{-4})	1.3×10^{-4} (1.2×10^{-4})
T51	2.5×10^{-4} (2.5×10^{-4})	7.1×10^{-5} (6.8×10^{-5})	1.3×10^{-5} (1.3×10^{-5})	4.9×10^{-6} (4.8×10^{-6})

Figures 9A through 9D illustrate the analysis of data collected from the uniaxial accelerometers at the mock wells. As illustrated on these figures and as summarized in Tables 6 and 7, the vibration magnitudes at the top of the mock well casings (i.e., near ground surface) were greater than those within the rock. Typically, vertical responses in the rock were about 1/5th to less than 1/100th of those at the mock well casing tops and less than 1/5th, 95 per cent of the time. Vibration magnitudes measured in the horizontal direction were also greater than those in the vertical direction. As described in Reports No.1, No.2 and No.3, these observed relationships are attributed to the following factors:

1) the greater stiffness and density of the bedrock, as compared to the overlying soft soil, result in greater inertial resistance to vibrations caused by transient human activities at the ground surface (e.g., farming, vehicles entering and leaving the sites, nearby road traffic);
2) the soft soil amplifies ground-borne vibrations transmitted long distances through the bedrock (e.g., earthquakes, construction pile driving), consistent with known seismic amplification factors[1] and site hazard classifications that form part of the National Building Code of Canada[2] and other building codes;
3) near the energy source, vertical or horizontal ground motions may, in some cases, be dominant whereas horizontal ground motions will tend to dominate at large distances from the energy source;
4) vibrations at, and on, the foundations should not be interpreted to be representative of ground motions; and
5) magnitude attenuation patterns should not be based on an assumed propagation of the motions of the turbine tower, foundation or piles but should be based on the measurements made of ground responses at different distances.

In this case, vibrations measured by the accelerometers mounted on the mock well casings, near the ground surface, will always exhibit greater responses to transient vibrations originating at the ground surface and vibrations originating through bedrock transmission as compared to the responses of the accelerometers grouted into bedrock.

Results of monitoring during pile driving for the 2017 construction of the wind power facility are documented in the report titled “Construction Vibration Monitoring Report”, dated December 7, 2017. The largest measured well casing acceleration and velocity induced by pile driving (regardless of direction) were about 7.8×10^{-3} m/s^2 and 0.037 mm/s (3.7×10^{-2} mm/s), respectively. These values were measured at about 687 m from the pile. The largest measured

[1] Kramer, S. 1995. Geotechnical Earthquake Engineering, Chapter 8. Pearson, 635 pp.

[2] National Research Council Canada. 2015. National Building Code of Canada. https://www.nrc-cnrc.gc.ca/eng/publications/codes_centre/2015_national_building_code.html

velocity values (horizontal or vertical) of the mock well casings associated with turbine operation were similar, being on the order of about 3.6×10^{-2} mm/s.

4.2 Ground Vibration Magnitudes and Environmental Factors

As part of the monitoring program, the available data was evaluated to understand whether there may be a meaningful relationship between wind velocity, wind direction and ground vibration particle velocity. As discussed in the initial report on the long-term vibration monitoring program (Section 6.2 of the November 2018 report), wind velocity, turbine orientation and wind direction (azimuth) and turbine power were all recorded in 10-minute intervals. Therefore, each measurement in the data collection system represented one instantaneous measurement at the pre-set recording interval. Vibration characteristics, however, were measured in 10-minute-long files with data collected at 250 Hz (i.e., 9×10^{6} measurements). Further, to eliminate or reduce the influence of transient sources of ground vibrations (e.g., farm equipment, road traffic, animal interference), the maximum values of ground vibrations were judged based on magnitude persistence spectra (see discussion in November 2018 report) to capture the largest values (within given frequency bands) of repetitive ground motions that might be associated with the combined cyclic responses of turbine towers, equipment and their foundations to wind energy and transmission of these vibratory responses through the ground. Based on the data obtained throughout the previous 3 years of monitoring, ground vibration magnitudes derived from the persistence spectra also varied by several orders of magnitude. Therefore, given the differences in measurement sampling rates and broad magnitudes of ground vibration particle velocity measurements, comparing environmental data to ground vibration measurements was completed using a semi-quantitative approach, as described below.

Figures 10A and 10B illustrate histograms of particle velocity measured on the turbine foundations as compared to the wind velocity categories associated with the 10-minute interval meteorological data. Data from the triaxial accelerometers mounted on the turbine foundations was selected for this comparison since, by coupling of the foundation with the ground, the foundations would be the source of ground vibrations away from the turbine. In general, if foundation particle velocity is directly and strongly correlated to wind velocity, these histograms should show more frequent measurements (higher bars in the histograms) of stronger ground particle velocities (bins to the right in the histograms) being associated with the stronger wind velocity categories (i.e., the histogram bars would cluster toward the left for the low wind velocities – green category – and to the right for high wind velocities – orange category). While some rightward shift in the foundation particle velocity histograms can be seen, this shift and the inferred relationship between wind velocity and foundation particle velocity is not strong. While intuitively a strong relationship between wind velocity and foundation vibration magnitude might be expected, the turbine and blade dynamics are not necessarily proportional to wind velocity, particularly at higher wind speeds. Golder understands that above a wind velocity of approximately 14 to 15 meters per second, the turbine blades are feathered (the pitch of the blades is changed) to result in a constant power output and blade rotational velocity remains constant. Given this control of the turbines and their blade angles, the components that might respond directly to changing wind velocity are only the exposed faces of the towers and nacelle. Therefore, the relatively weak relationship between measured foundation particle velocity and wind velocity is consistent with the design and operational characteristics of the turbine.

Figures 11A through 11D illustrate a comparison of foundation and mock well particle velocities measured in the horizontal plane. In general, the x axes were oriented to form a direct line between the foundation and nearby mock well with an azimuth ranging between west to west-northwest. The y axis was oriented at 90 degrees to the x axis at each location. For evaluation of mock well responses, data from the uniaxial accelerometers mounted to the casing top were selected since these produced the best signal to noise ratios, would represent values greater than those measured within the bedrock (because of the effects of soil conditions and casing lengths) and, therefore, would be less likely to produce equivocal comparisons. For both the foundation and mock wells, the data illustrated in Figures 11A through 11D indicate that ground vibrations tend to be somewhat stronger in the x direction, consistent with prevailing wind velocity and direction trends (see Figure 7 in November 2018 report). Comparisons of Figures 11A and 11B to 11C and 11D also illustrate the attenuation of particle velocity magnitudes at the mock wells as compared to the data obtained for the foundations.

While the environmental and directional aspects of ground borne vibrations that may be associated with the wind turbines are of scientific interest, the magnitudes of the ground vibrations at the mock wells and beyond are inconsequential for typical human activities and the performance of residential or agricultural groundwater wells.

4.3 Constructive and Destructive Interference of Ground Vibrations

When multiple waveforms combine, they can interfere with each other leading to different interference patterns. These interference patterns between waves can produce constructive, destructive or mixed interference. Constructive interference occurs when two wave forms of the same frequency (or wavelength) arrive at the same time exactly in phase (the maximum and minimum amplitudes of one wave line up exactly with those of the other wave); then the influence of one wave will add to the other. In contrast, when two waves of identical wavelength arrive at the same time but exactly out of phase, where the peak amplitude of one wave aligns with the minimum amplitude of the other wave, they produce destructive interference. This type of interference pattern will diminish the amplitude of both waves creating a wave amplitude that is smaller than either of the source waves individually, and in special cases, if the wavelength and amplitude are identical except for being exactly of opposite phase, these waves can completely cancel each other. However, local site conditions can greatly influence the characteristics of propagated waves through rock and soils (e.g., duration, amplitude, frequency content, propagation direction). The magnitude of this influence will depend on the properties of the subsurface materials (e.g., shear modulus, Poisson’s ratio, soil anisotropy, layering, soil thickness, rock fractures and discontinuities, etc.), site topography and on the characteristics of the vibration waves generated at their source, making simple constructive or destructive interference patterns rare. Vibrations originating from processes such as wind loads acting on a wind turbine structure and its associated turbine nacelles and blades, and operation of the rotating turbine and other internal components can produce waveforms with different characteristics (different amplitudes and wavelength). Thus, when these dissimilar waves combine, they can produce mixed interference patterns where the final waveform is a mix of both constructive and destructive interference and complex frequency and amplitude signals.

As illustrated by the example persistence diagrams provided in this report (November 2018 and subsequent addenda), the waveforms suspected of being associated with the turbines and their degree of persistence at clearly definable frequencies (inverse of wavelength) and magnitudes is relatively small and complex within the full spectrum of anthropogenically-induced (e.g., traffic on local roads, farming activities, etc.) and natural background conditions. While it may be possible to simulate some transient constructive or destructive interference under idealized computer simulation conditions where all turbines and towers respond identically to identical wind velocities and directions with these towers supported on a continuous and homogeneous ground model, it is Golder’s opinion that such idealized conditions are not suited to discretely defining the degree of constructive and destructive interference given the comparatively weak (small amplitude) vibration magnitudes and complex signals measured in the field for this project. Given the long durations of monitoring, the variety of distances from turbines to accelerometers, the variety of wind directions and velocities experienced by the turbines and the approach of using the maximum particle velocity values derived from the accelerometer data as the basis for reporting, any constructive, destructive or other complexities that may have influenced the vibration characteristics are and have been incorporated into the measurements presented in this report. While initially it was considered that placing instruments near the twin turbines of T19 and T51, the distance between the mock well instruments and T19 is approximately 638 m. In this case, if simple constructive or destructive interference driven by T19 had influenced data from the T51 mock well instruments, the particle velocities measured at the mock well casing or in the rock would have likely exhibited distinctive differences in magnitude-distance attenuation as compared to data from T23, T41 or T42. However, no clear differences in instrument responses could be discerned from the available data. Given that the particle velocity and distance attenuation relationships developed by this work were based on an envelope of the largest values measured at all the instrument locations, regardless of whether T19 and T51 were operating independently or concurrently at different measuring events, the potential for constructive and destructive interference to have influenced these values is of no practical importance – the effects have already been included in the data. Further, as indicated in prior reports prepared for this project, beyond a relatively short distance from the turbines, the ground vibration magnitudes that may be associated with the wind turbines are of such small magnitude that they are of no consequence to human activities and water wells.

4.4 Anomalous Data at Turbine Locations

During the course of monitoring and data reduction, a few instances of unusually large particle velocities were measured at the turbine foundation locations. Based on a review of all data available, it is Golder’s conclusion that these assessed particle velocities are associated with data artifacts. Data artifacts in this case are parts of the recorded accelerometer signal that arise from sources other than the source of interest (e.g., vibration magnitudes associated with wind forces and turbine operation). As such, artifacts are a form of noise relative to the signal of interest and, in this case, could include:

- Random high-amplitude fluctuations (or constant zero signal) in a single channel due to sensor malfunction;
- Brief signal jumps due to transient sources such as: construction or maintenance vehicles or heavy farming equipment operating nearby the turbine towers, turbine related maintenance (e.g., turbine braking); and
- Low signal-to-noise ratio at frequencies of less or equal to 1Hz.

Except for 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 that could lead to properly identify all the sources of signal artifacts. As discussed in the initial report on the long-term vibration monitoring program (Section 6.2 of the November 2018 report), the data analysis approach used herein limited the potential influence of various filtering algorithms and signal power suppression that might otherwise be used to address FFT spectra noise and could exclude or ‘repair’ artifacts in the recorded signals.

After examining the data, it is clear that the few instances of data artifacts, or anomalous data, at the turbine foundation bases is not a true measure of repetitive, or persistent, structure foundations associated with turbine operation. Further, these anomalous data have no ground vibration counterparts at monitoring locations at various distances from the foundations (e.g., in-ground, in-rock, or mock-well casings). Therefore, for the purposes of evaluating propagation of ground-borne vibrations and attenuation of vibration (ground particle velocity) magnitude related to wind turbine operation, these few anomalous data are of no practical relevance.

4.5 Summary

Long-term vibration monitoring data collected during operations at the North Kent Wind 1 facility for the time period between February 2020 to April 2021 demonstrates:

- The largest vibration magnitudes (as measured by particle velocities) associated with wind forces and turbine operation measured in the turbine tower were on the order of 11 mm/s.
- The largest vibration magnitudes measured on the turbine foundation structure, including all potential sources of vibrations, were on the order of 0.1 to 5 mm/s, though the 95th percentile values were about 1/5th to 1/10th of these values or smaller and, while further evaluation of the potential sources of the largest values is the subject of additional study, it is believed that these measurements are associated with local transient sources, influenced by low frequency artifacts in the signals and FFT analysis processes.
- The largest vibration magnitudes in the bedrock within approximately 20 m of the turbine centre were approximately 0.5 mm/s in the rock and 0.6 mm/s in the soil, diminishing to about 1/13th to 1/50th of these values at a distance of about 60 m from the turbine centre.
- The largest vibration magnitudes at the top of the mock well casings were on the order of 4.5×10^{-2} mm/s (i.e., 45 μm/s) and typically about 10 times the magnitude of those for accelerometers grouted into the bedrock at these same mock well locations.
- The largest vertical vibration magnitudes in the bedrock at the closest mock well, about 146 m from the turbine, was about 4.5×10^{-3} mm/s, and about 1/10th to 1/1,000th of those measured within 20 m of the turbine.
- The largest vertical bedrock vibration magnitudes at about 512 m from the turbine were about 6.3×10^{-4} mm/s and about 1/50th to 1/10,000th of those at about 20 m from the turbine.
- 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 NPC-207.
- Attenuation of vibration magnitudes with increasing distance from the source was demonstrated by comparison of measurements on the turbine tower at T42, in the rock at T42 and at the mock well casing tops and bedrock.
- Relatively weak relationships exist between: wind velocity and ground vibration particle velocity magnitudes and wind direction; and wind direction and the directionality of ground vibration particle velocity magnitudes. These relatively weak relationships between ground vibration magnitudes and wind direction are consistent with the design and operational characteristics of the turbines.
- The specific character of constructive or destructive interference of highly complex vibration waveforms associated with multiple turbine towers could not be discerned since the ground particle velocity magnitudes at meaningful distances from the turbine locations (on the order of a few hundred meters or more) were of such small values their proportional contribution to such interference would be nominal. The data obtained during the monitoring period also captured the net result of such constructive and destructive interference, if any, since the largest ground particle velocities at different distances from the source as derived from the persistence spectra were used for our evaluation.
- The measured characteristics of vibration magnitude attenuation were consistent with the responses measured during the construction phase of this project, with the responses measured during the North Kent

Wind 1 operations between January 1, 2018 and April 1, 2021 documented in Report and Addenda No. 1, No. 2 and No.3, and with published research from other areas of the world.

- At about 500 m from the turbines, vibrations at the ground surface would be expected to be well below the threshold of human perception. As indicated in CALTRANS 2004, the threshold for human perception has been found to be higher for transient vibrations (threshold of approximately 1 mm/sec) than for continuous vibrations (threshold of about 0.15 to 0.5 mm/sec).
- Vibrations of the magnitude and frequency measured during the period of operation from January 1, 2018 to April 1, 2021 were inconsequential with respect to the performance of water wells in the region.

Data gathered as part of the long-term ground-borne vibration monitoring program at the North Kent Wind 1 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.

5.0 CONCLUSIONS

The work completed for this Report Addendum represents the completion of long-term vibration monitoring of ground-borne vibrations during operation of turbines at the North Kent Wind 1 site from January 1, 2018 through April 1, 2021. It is expected that this report will conclude the long-term vibration monitoring work at this site.

Despite challenges related to implementation of a unique and novel field monitoring program, with sensitive instrumentation installed in boreholes and remote agricultural locations (i.e., distant from power sources and communications connections), a significant body of ground-borne vibration data was gathered. The data has been evaluated for multiple wind velocity conditions with consideration given to a wide spectrum of vibration frequencies. Data gathered as part of this work is also consistent with published research from other areas of the world. While the measurements of vibrations at large distances from the wind turbines at the North Kent Wind 1 facility are of scientific interest, the vibration magnitudes are extremely small and, in Golder’s opinion, of no consequence to water wells in the area.

Signature Page

Golder Associates Ltd.

LICENSED PROFESSIONAL ENGINEER
Dec. 14/2021
M. A. SWALLOW
PROVINCE OF ONTARIO

Jesús González-Hurtado, Ph.D., E.I.T.	Mark A. Swallow, P.E., P.Eng.
Geotechnical Engineer-in-Training	*Principal and Senior Practice Leader*

JGH/SJB/MAS/cr

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IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT

Standard of Care: Golder Associates Ltd. (Golder) has prepared this report in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this report. No other warranty, expressed or implied is made.

Basis and Use of the Report: This report has been prepared for the specific site, design objective, development and purpose described to Golder by the Client. The factual data, interpretations and recommendations pertain to a specific project as described in this report and are not applicable to any other project or site location. Any change of site conditions, purpose, development plans or if the project is not initiated within eighteen months of the date of the report may alter the validity of the report. Golder cannot be responsible for use of this report, or portions thereof, unless Golder is requested to review and, if necessary, revise the report.

The information, recommendations and opinions expressed in this report are for the sole benefit of the Client. No other party may use or rely on this report or any portion thereof without Golder's express written consent. If the report was prepared to be included for a specific permit application process, then upon the reasonable request of the client, Golder may authorize in writing the use of this report by the regulatory agency as an Approved User for the specific and identified purpose of the applicable permit review process. Any other use of this report by others is prohibited and is without responsibility to Golder. The report, all plans, data, drawings and other documents as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder, who authorizes only the Client and Approved Users to make copies of the report, but only in such quantities as are reasonably necessary for the use of the report by those parties. The Client and Approved Users may not give, lend, sell, or otherwise make available the report or any portion thereof to any other party without the express written permission of Golder. The Client acknowledges that electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore the Client can not rely upon the electronic media versions of Golder's report or other work products.

The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by the Client, communications between Golder and the Client, and to any other reports prepared by Golder 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. Golder 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, Golder 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 Golder 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: Golder 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. Golder 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, Golder 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 Golder 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 Golder 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 Golder 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. Golder takes no responsibility for the effects of drainage unless specifically involved in the detailed design and construction monitoring of the system.

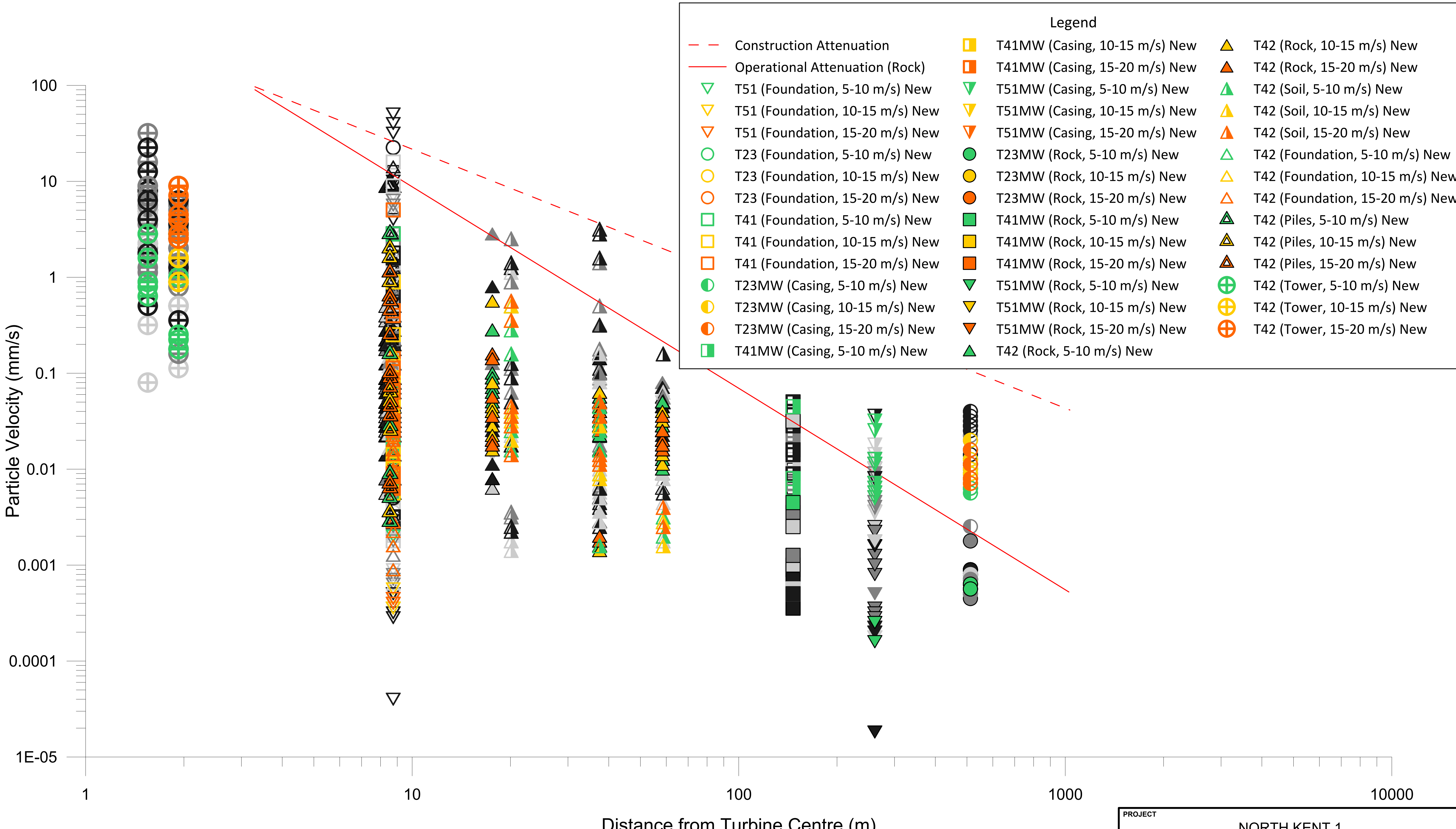
Notes:
1. Meteorological data prior to Commercial Operations Date (COD) based on digitizing limited data images provided by turbine supplier.
2. Refer to report text for periods during which data was not gathered for particular instruments.

PROJECT
NORTH KENT 1
VIBRATION MONITORING

TITLE
WIND VELOCITY
AND DATA AVAILABILITY
(FEB. 2020 TO APR. 2021)

GOLDER
MEMBER OF WSP

PROJECT No. 1668031	FILE No.
	SCALE AS SHOWN REV. 0
DRAWN JGH May 2021	FIGURE 6
CHECK	



Notes:
1. This figure must be read with accompanying report.
2. Well casing vibration measurements based on persistence spectra and exclude transient influences (e.g., traffic, farm equipment, etc.).

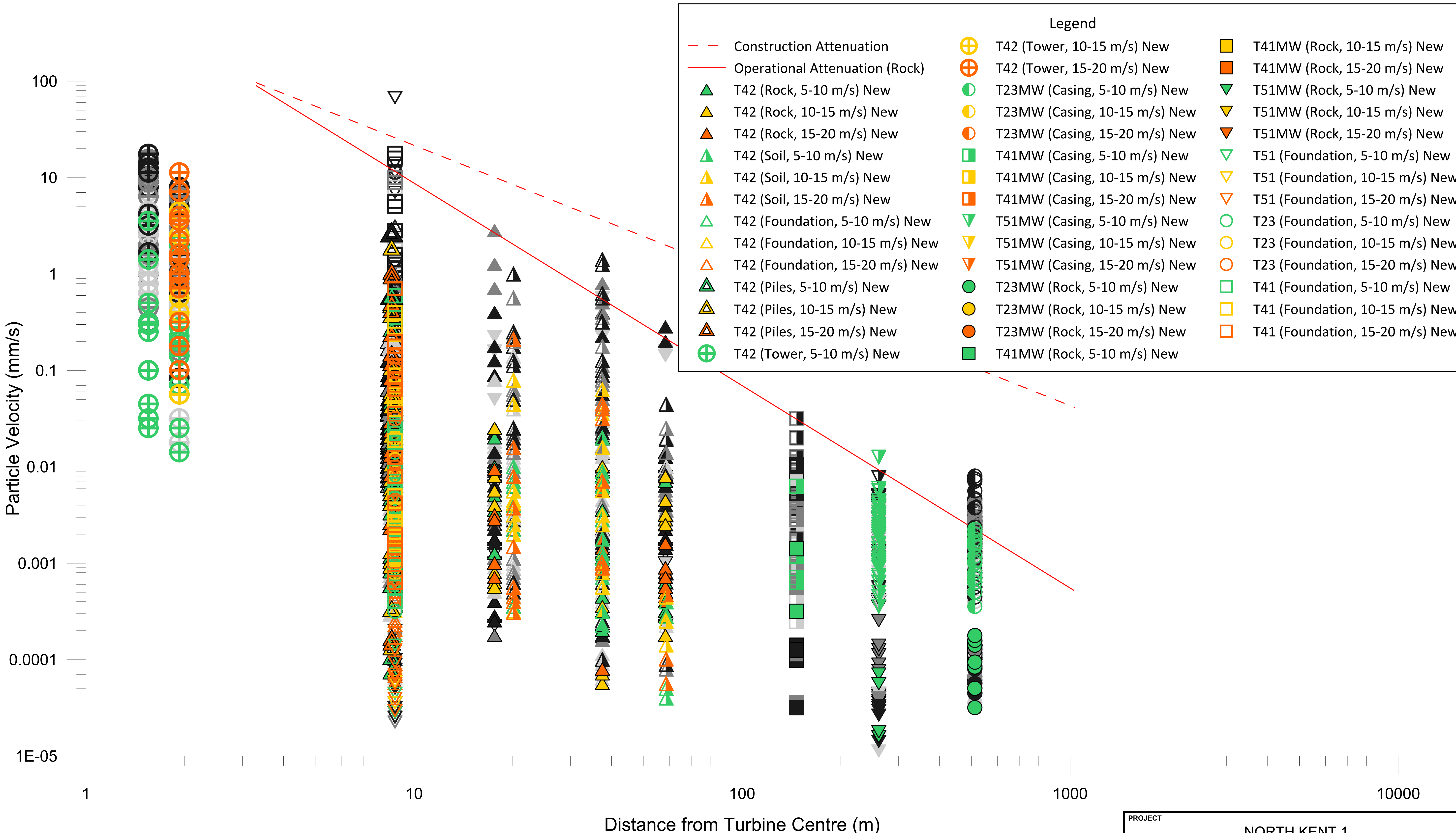
PROJECT
NORTH KENT 1
VIBRATION MONITORING

TITLE
VIBRATION VELOCITY AND ATTENUATION (1 Hz) (MAY 2021)

GOLDER
MEMBER OF WSP

PROJECT No.	1668031-4000	FILE No.	1668031-4000-R01009A (Ad#3)
		SCALE	AS SHOWN
		REV.	0
DRAWN	JGH		May 2021
CHECK			

FIGURE 9A



Notes:
1. This figure must be read with accompanying report.
2. Well casing vibration measurements based on persistence spectra and exclude transient influences (e.g., traffic, farm equipment, etc.).

PROJECT
NORTH KENT 1
VIBRATION MONITORING

TITLE
VIBRATION VELOCITY AND ATTENUATION (>1 to 5 Hz) (MAY 2021)

GOLDER MEMBER OF WSP

PROJECT No.	1668031-4000	FILE No. 1668031-4000-R01009B (Ad#3)
		SCALE AS SHOWN REV. 0
DRAWN	JGH	May 2021
CHECK	SJB	

FIGURE 9B

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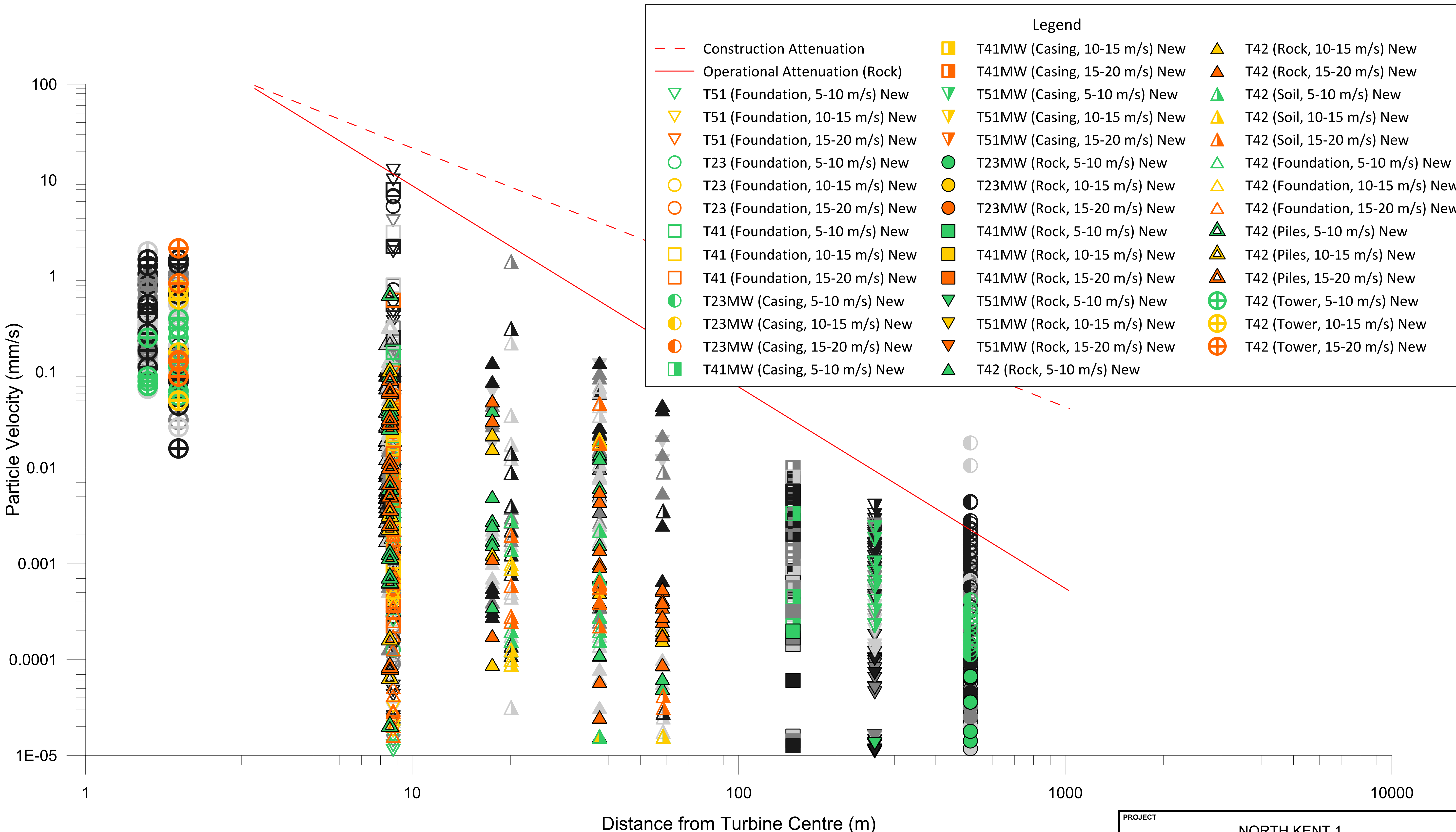

Notes:
1. This figure must be read with accompanying report.
2. Well casing vibration measurements based on persistence spectra and exclude transient influences (e.g., traffic, farm equipment, etc.).

PROJECT
NORTH KENT 1
VIBRATION MONITORING

TITLE
VIBRATION VELOCITY AND ATTENUATION (>5 to 10 Hz) (MAY 2021)

GOLDER
MEMBER OF WSP

PROJECT No.	1668031-4000	FILE No.	1668031-4000-R01009C (Ad#3)
		SCALE	AS SHOWN REV. 0
DRAWN	JGH	May 2021	
CHECK			**FIGURE 9C**

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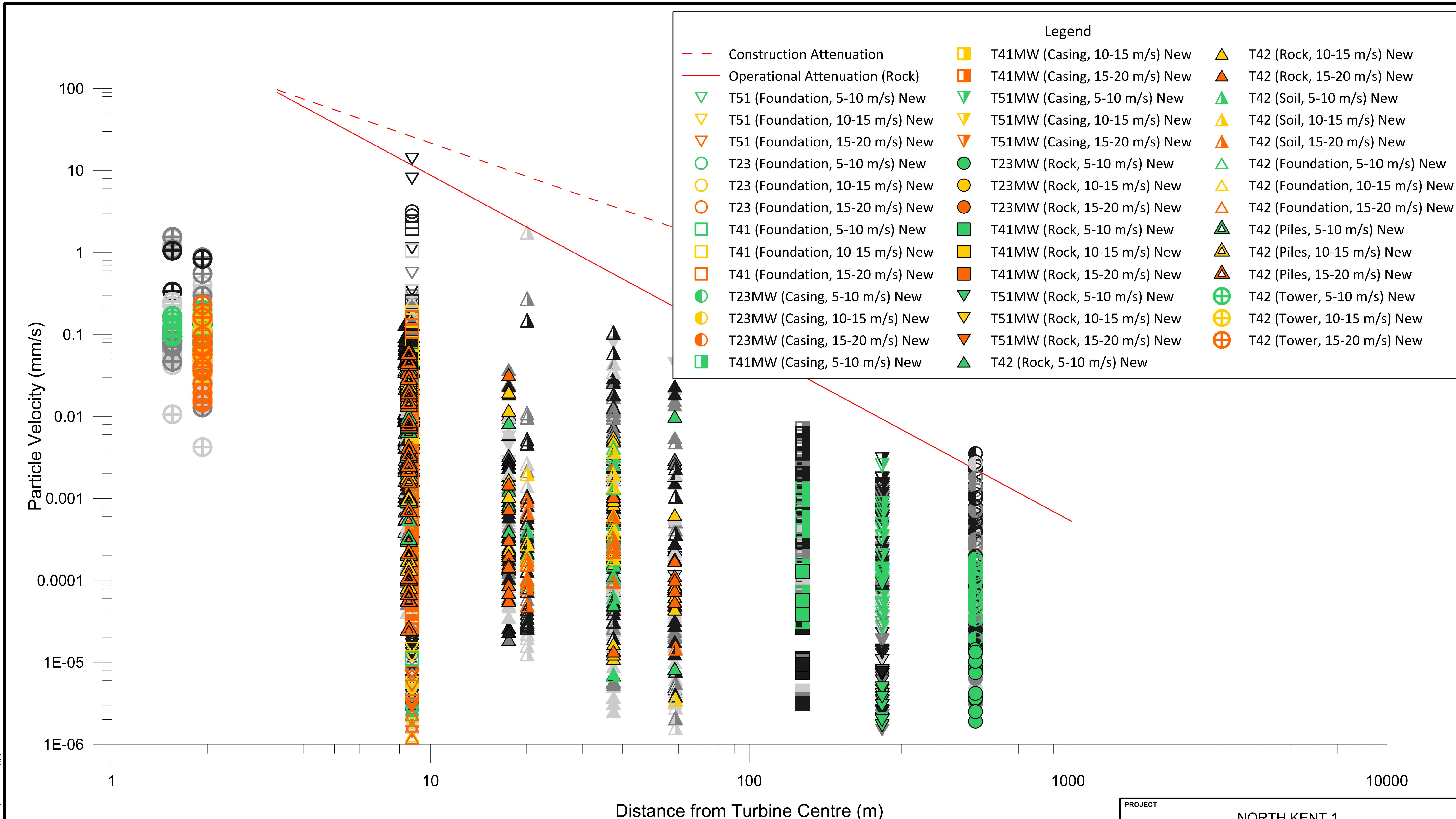

Notes:
1. This figure must be read with accompanying report.
2. Well casing vibration measurements based on persistence spectra and exclude transient influences (e.g., traffic, farm equipment, etc.).

PROJECT
NORTH KENT 1
VIBRATION MONITORING

TITLE
VIBRATION VELOCITY AND ATTENUATION (>10 Hz) (MAY 2021)

GOLDER MEMBER OF WSP

PROJECT No.	1668031-4000	FILE No.	1661031-4000-R1009D (Ad#3)
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DRAWN	JGH	May 2021	
CHECK	SJS		**FIGURE 9D**

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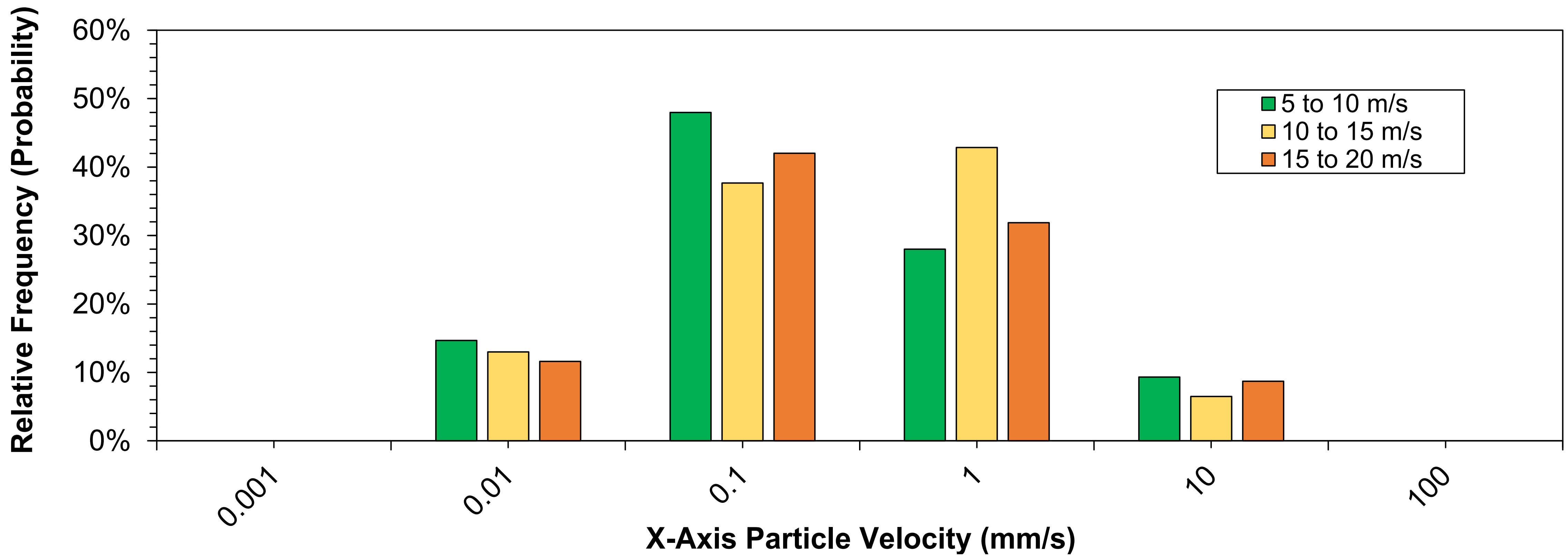
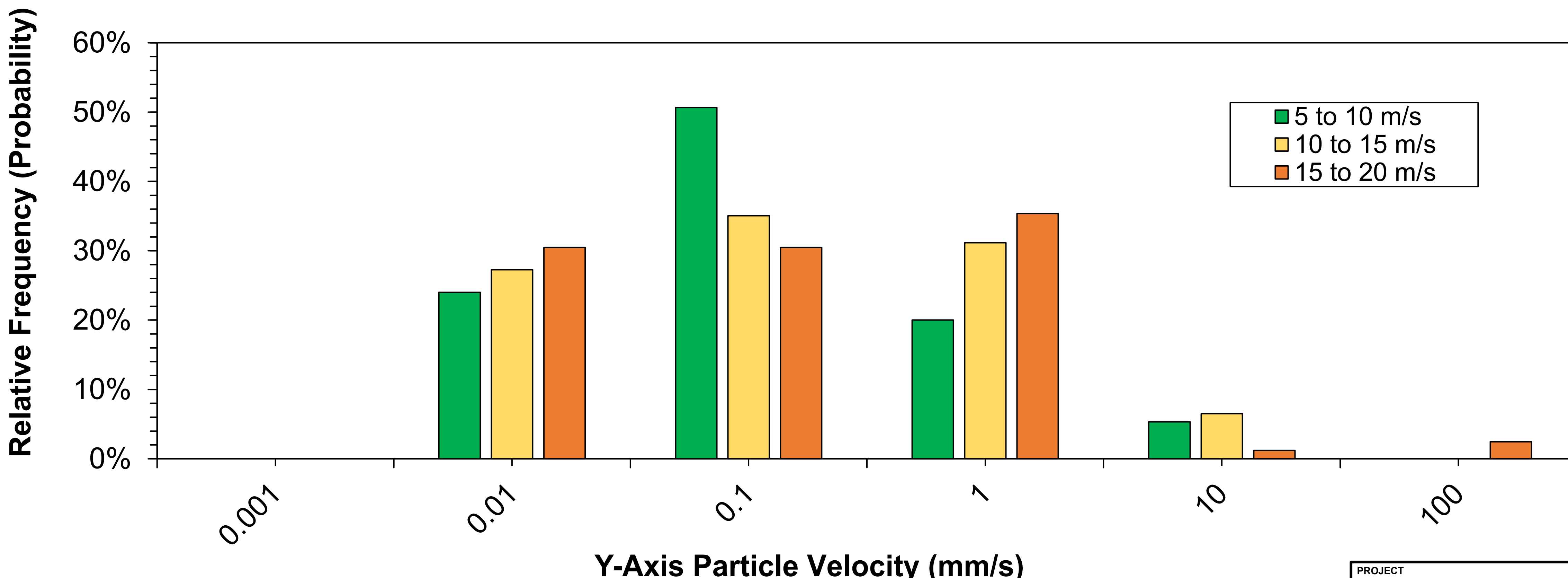


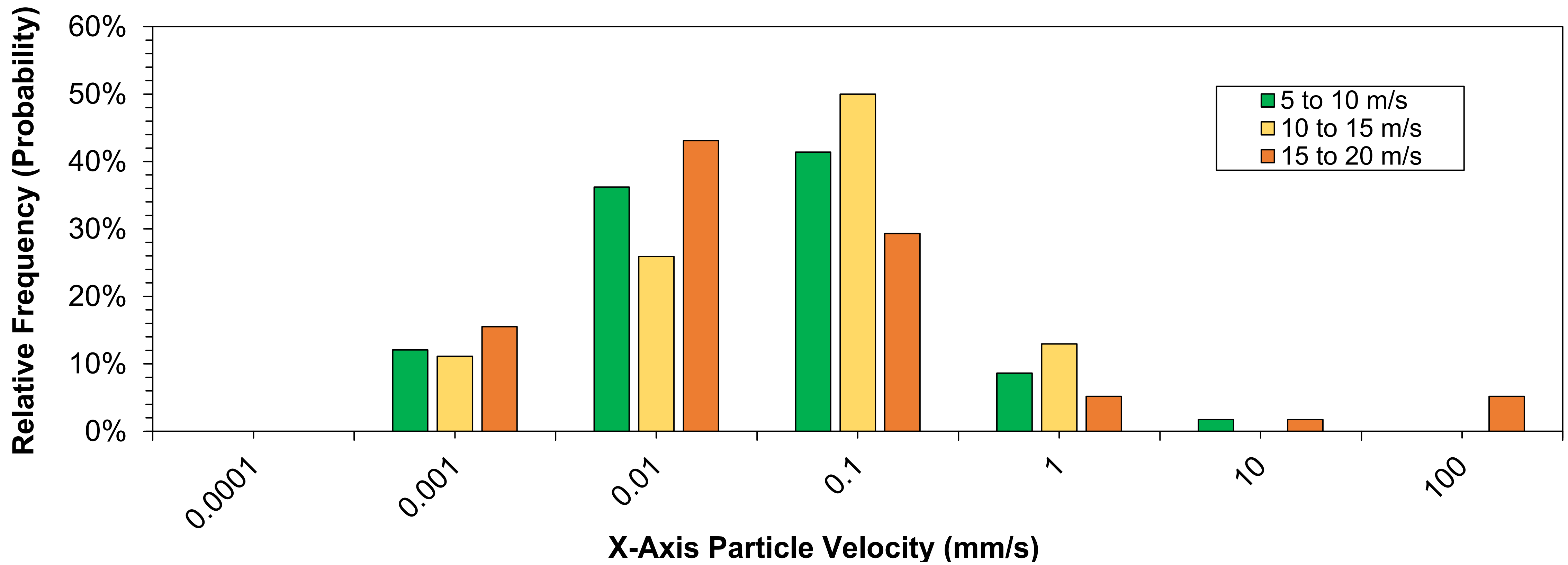


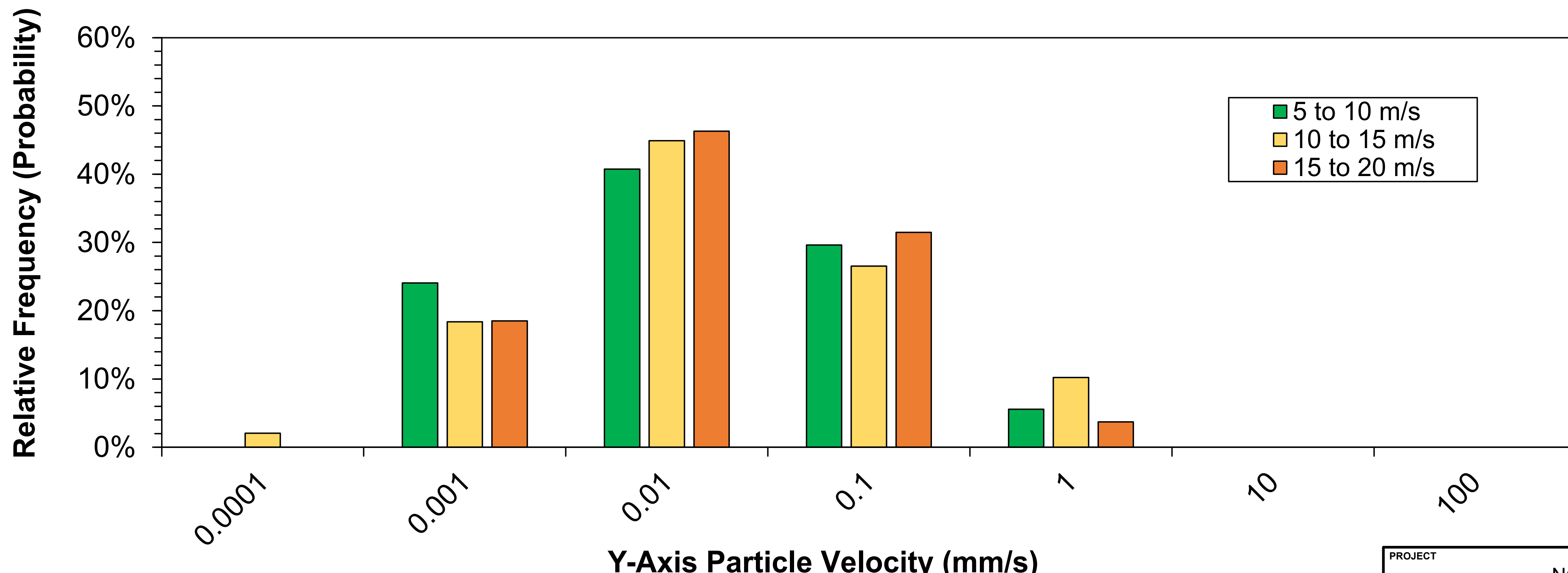
Notes:
1. This figure must be read with accompanying report.
2. Foundation vibration measurements based on persistence spectra and exclude transient influences (e.g., traffic, farm equipment, etc.).

PROJECT	NORTH KENT 1 VIBRATION MONITORING
TITLE	**RELATIVE FREQUENCY OF VIBRATION VELOCITY AT DIFFERENT WIND SPEED RANGES FOR TURBINE FOUNDATIONS AT 1 Hz (PERIOD JANUARY 2018 TO APRIL 2021)**

GOLDER
MEMBER OF WSP

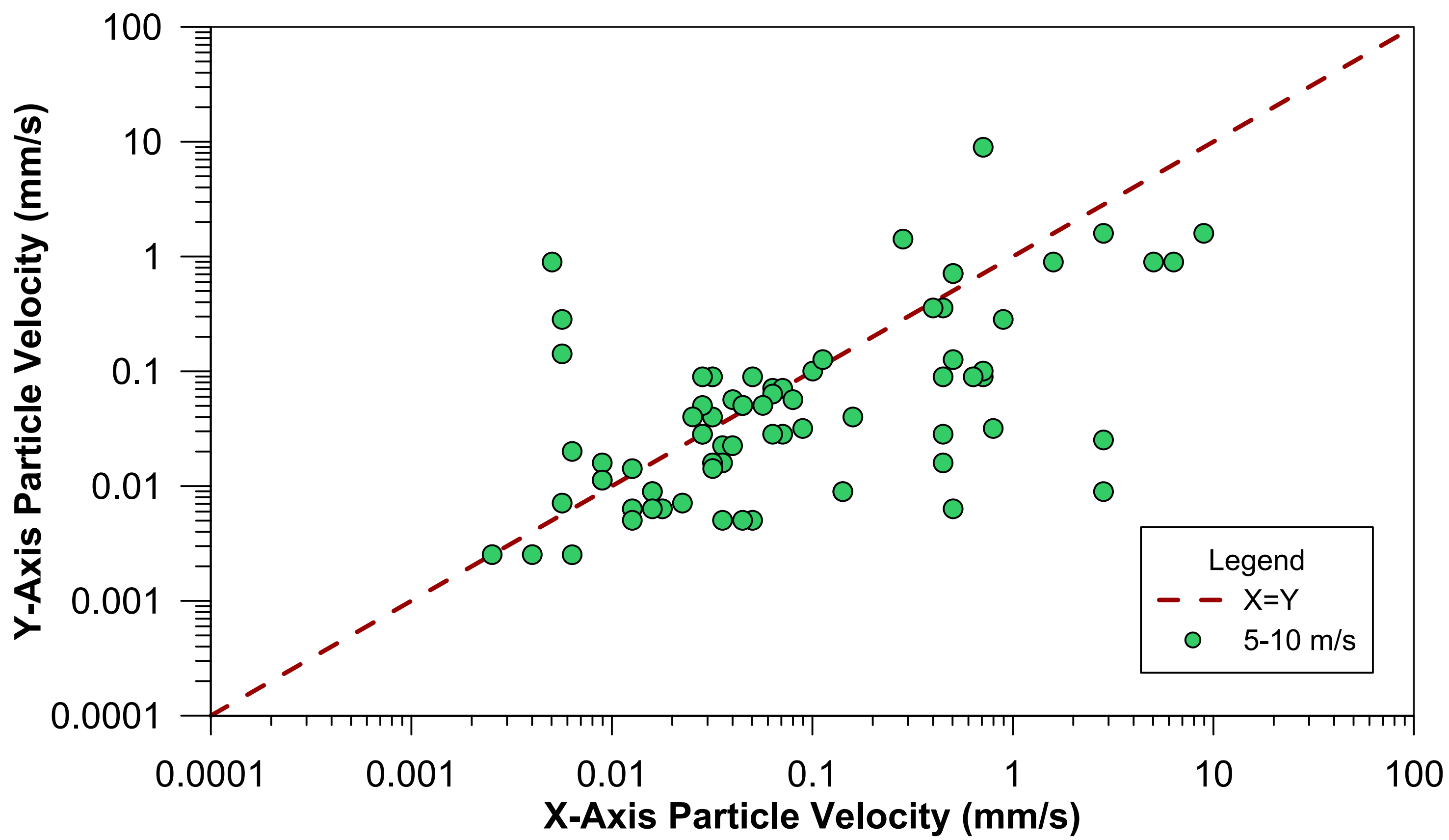
PROJECT No.	1668031-4000		FILE No.	1668031-4000-R04010A (Ad#3)
			SCALE	AS SHOWN REV. 0
DRAWN	JGH	June 2021	**FIGURE 10A**	
CHECK	SJB			

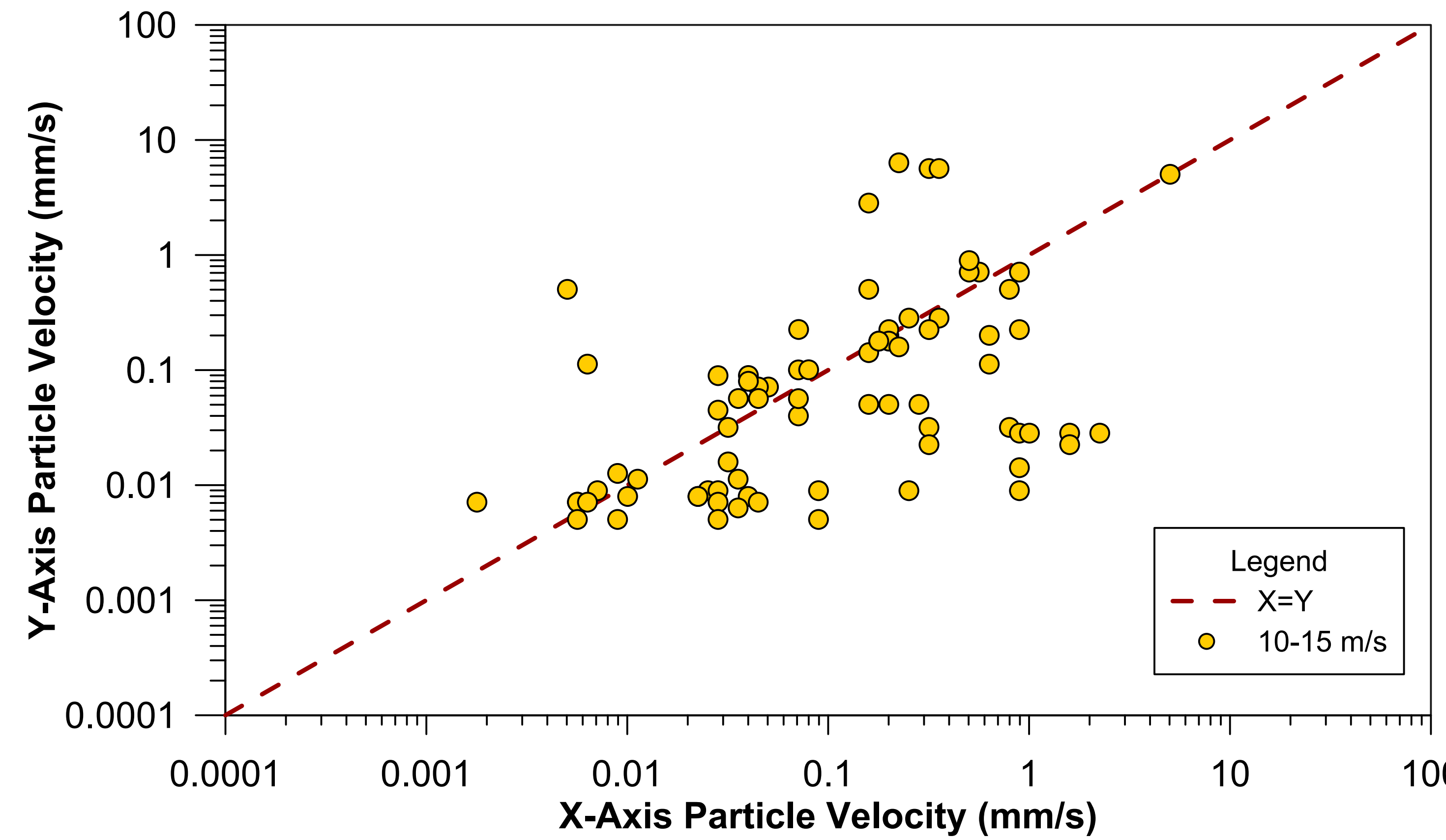


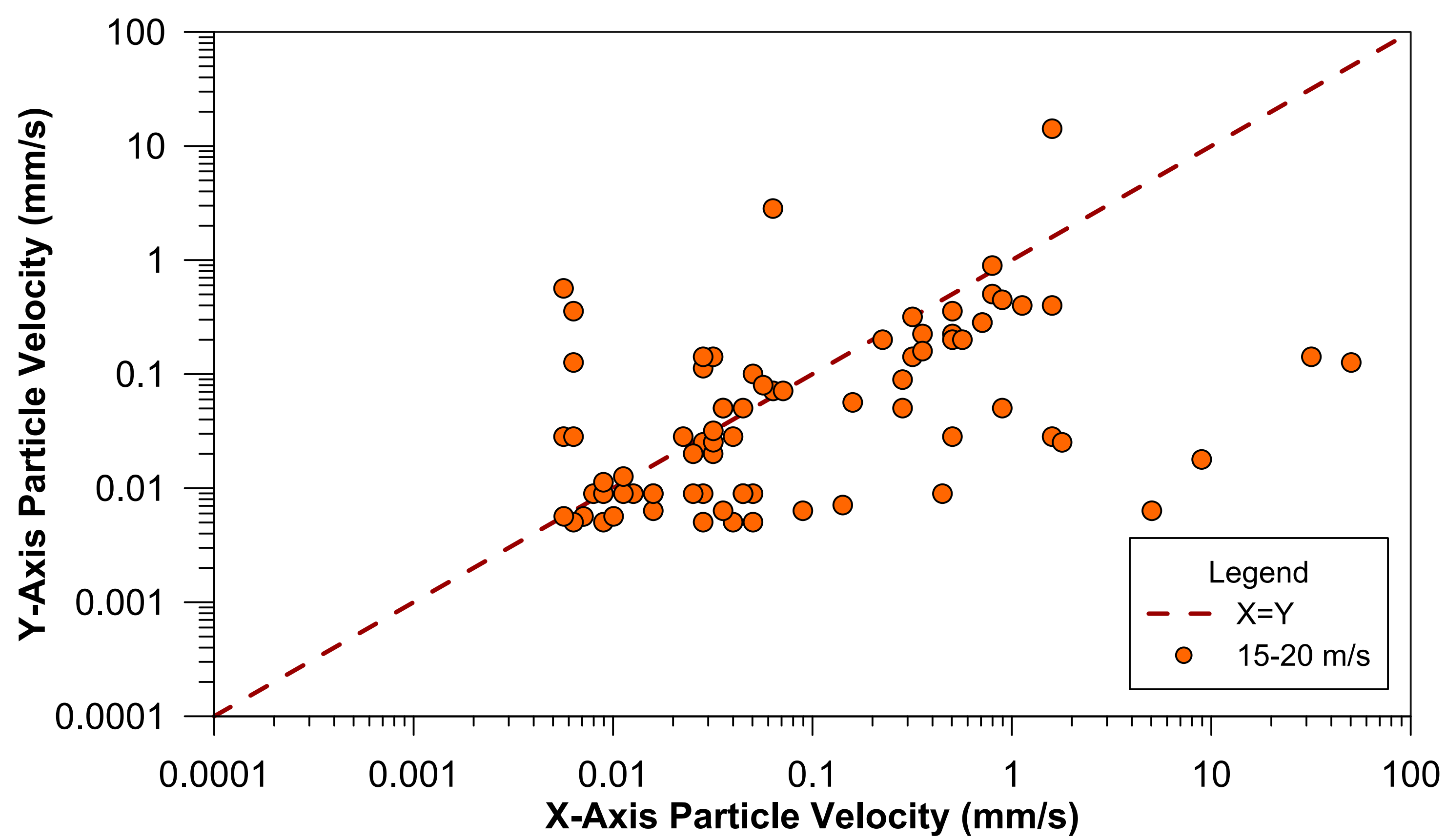


Notes:
1. This figure must be read with accompanying report.
2. Foundation vibration measurements based on persistence spectra and exclude transient influences (e.g., traffic, farm equipment, etc.).

PROJECT	NORTH KENT 1 VIBRATION MONITORING		
TITLE	RELATIVE FREQUENCY OF VIBRATION VELOCITY AT DIFFERENT WIND SPEED RANGES FOR TURBINE FOUNDATIONS AT 5 Hz (PERIOD JANUARY 2018 TO APRIL 2021)		
GOLDER MEMBER OF WSP	PROJECT No. 1668031-4000	FILE No. 1668031-4000-R04010B (Ad#3)	
		SCALE AS SHOWN	REV. 0
	DRAWN JGH June 2021	FIGURE 10B	
	CHECK SJB		







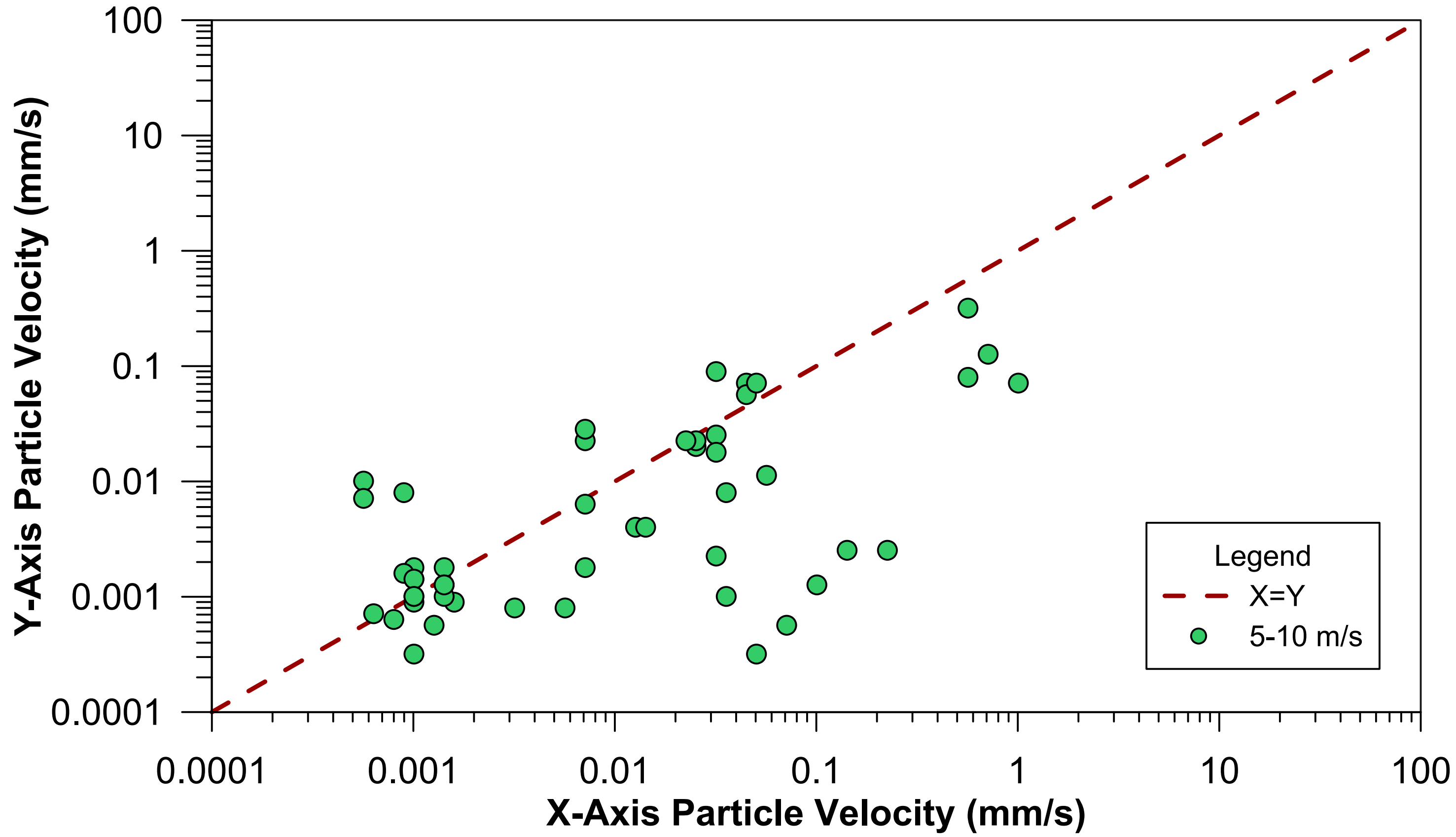
Notes:
1. This figure must be read with accompanying report.
2. Foundation vibration measurements based on persistence spectra and exclude transient influences (e.g., traffic, farm equipment, etc.).

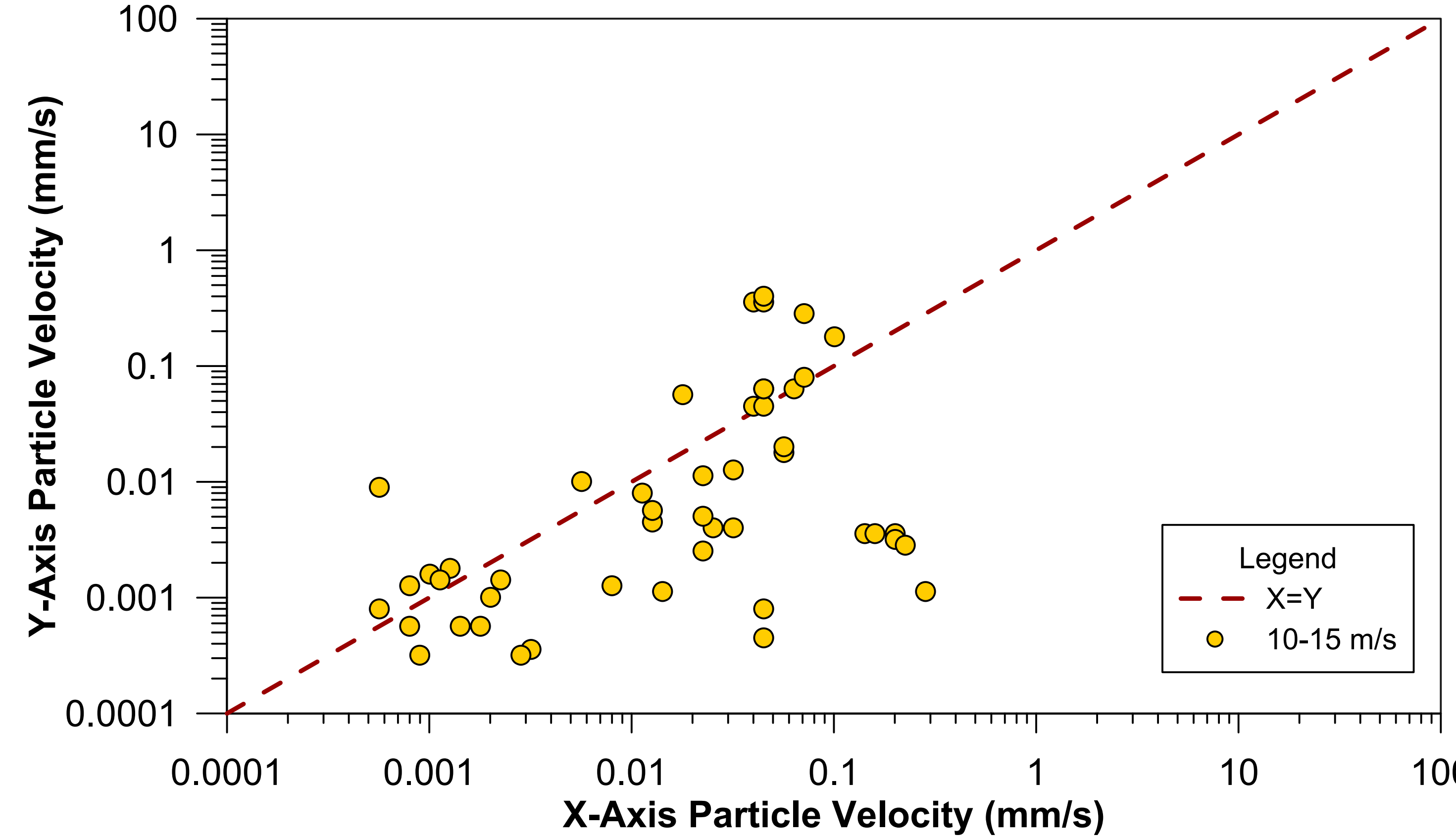
PROJECT
NORTH KENT 1
VIBRATION MONITORING

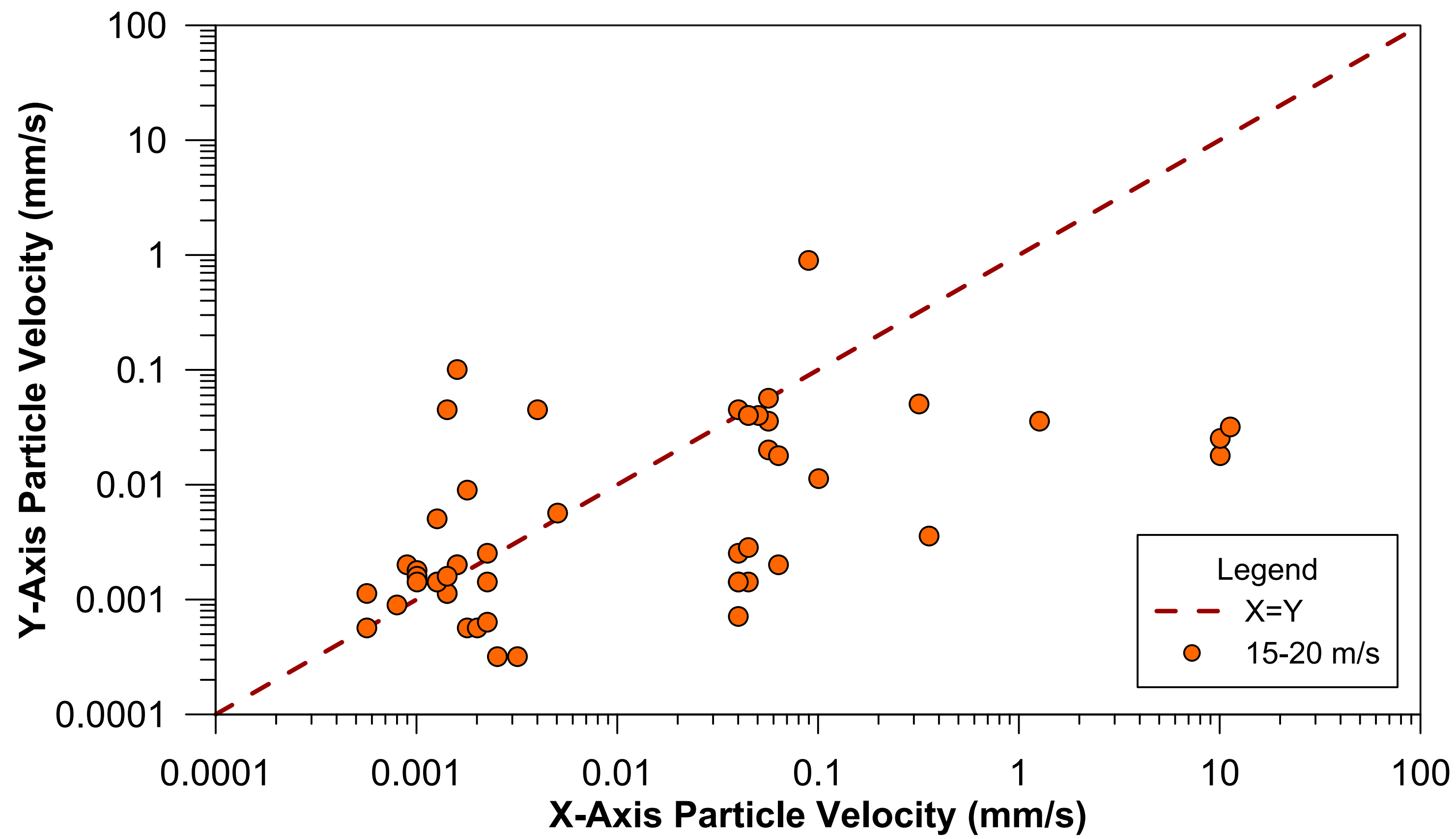
TITLE
VIBRATION VELOCITY MEASURED AT DIFFERENT WIND SPEED RANGES FOR TURBINE FOUNDATIONS AT 1 Hz (PERIOD JANUARY 2018 TO APRIL 2021)

GOLDER
MEMBER OF WSP

PROJECT No.	1668031-4000	FILE No.	1668031-4000-R04011A (Ad#3)
		SCALE	AS SHOWN	REV. 0
DRAWN	JGH	June 2021	
CHECK	SS		**FIGURE 11A**





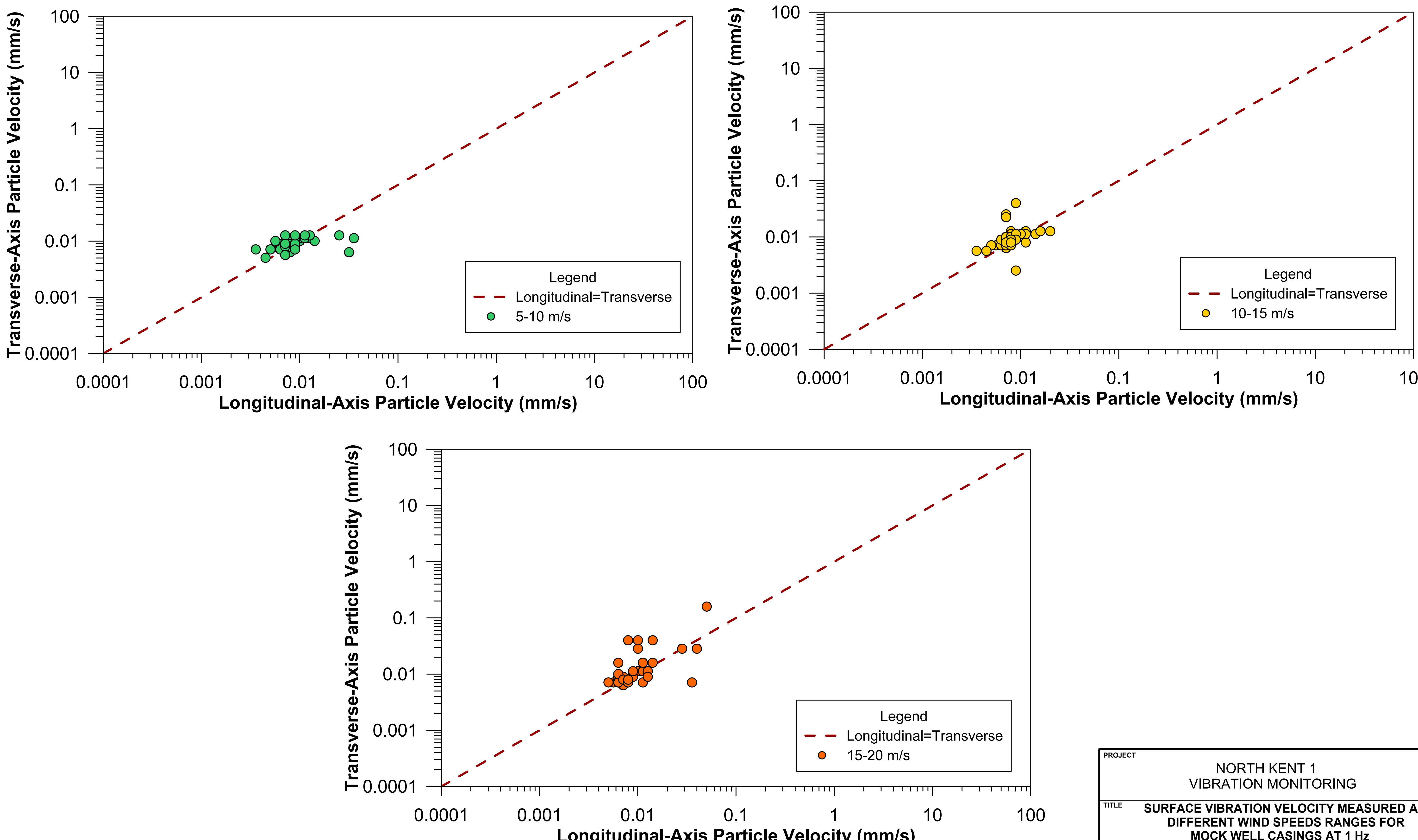


Notes:
1. This figure must be read with accompanying report.
2. Foundation vibration measurements based on persistence spectra and exclude transient influences (e.g., traffic, farm equipment, etc.).

PROJECT	NORTH KENT 1 VIBRATION MONITORING
TITLE	**VIBRATION VELOCITY MEASURED AT DIFFERENT WIND SPEED RANGES FOR TURBINE FOUNDATIONS AT 5 Hz (PERIOD JANUARY 2018 TO APRIL 2021)**

GOLDER
MEMBER OF WSP

PROJECT No.	1668031-4000		FILE No.	1668031-4000-R04011B (Ad#3)
			SCALE AS SHOWN	REV. 0
DRAWN	JGH	June 2021	**FIGURE 11B**	
CHECK	SSB			

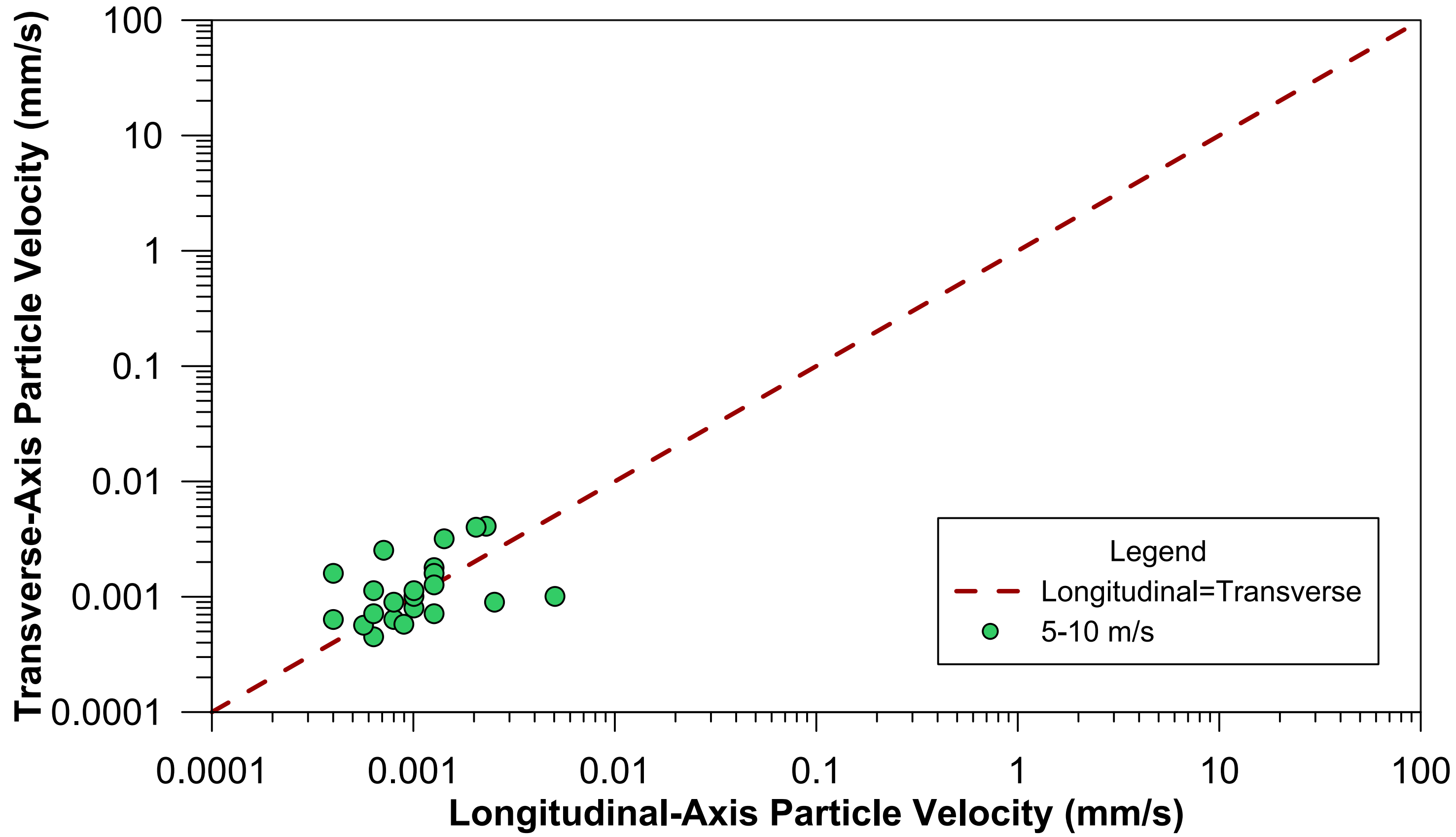


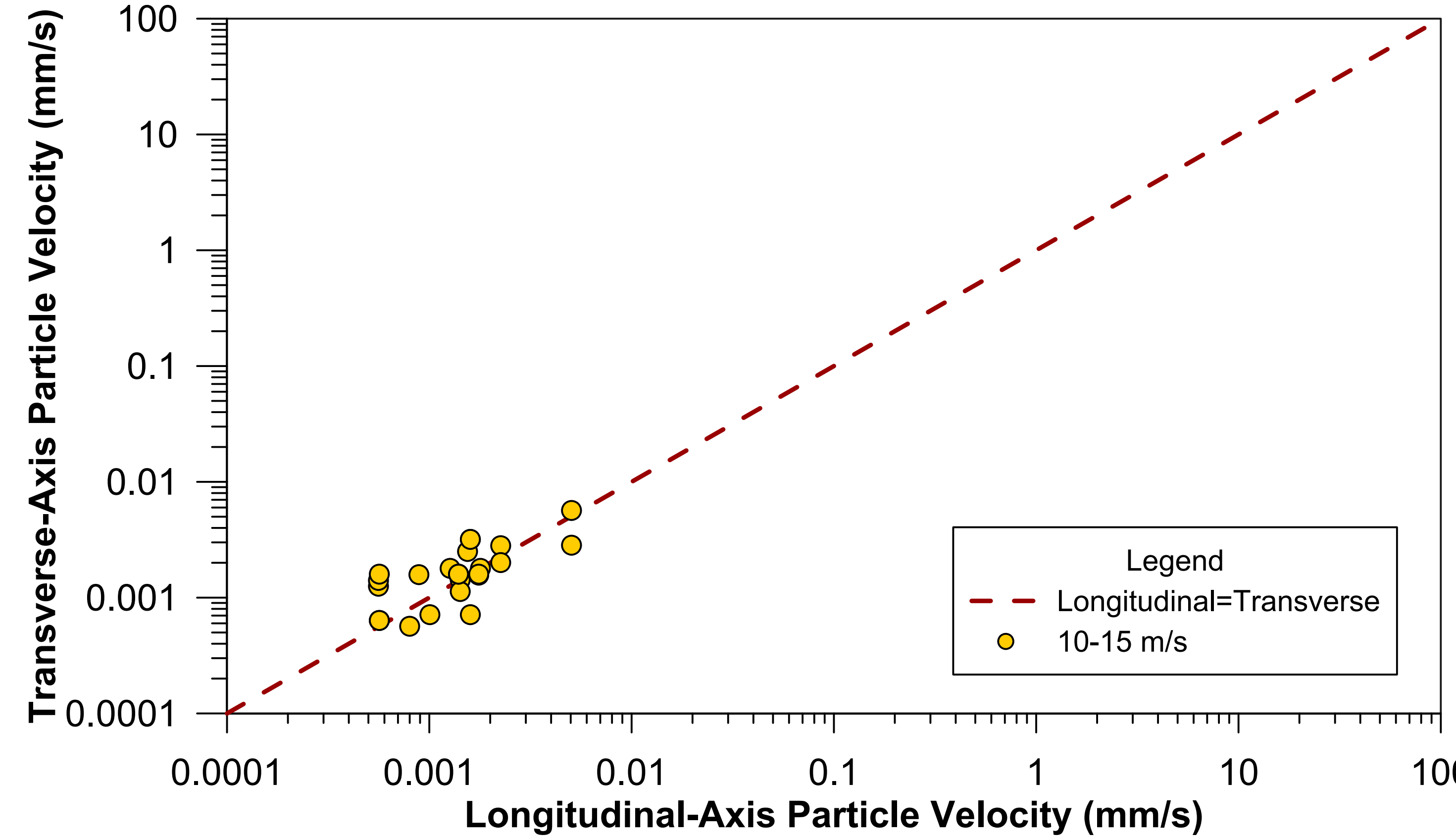
Notes:
1. This figure must be read with accompanying report.
2. Well casing vibration measurements based on persistence spectra and exclude transient influences (e.g., traffic, farm equipment, etc.).

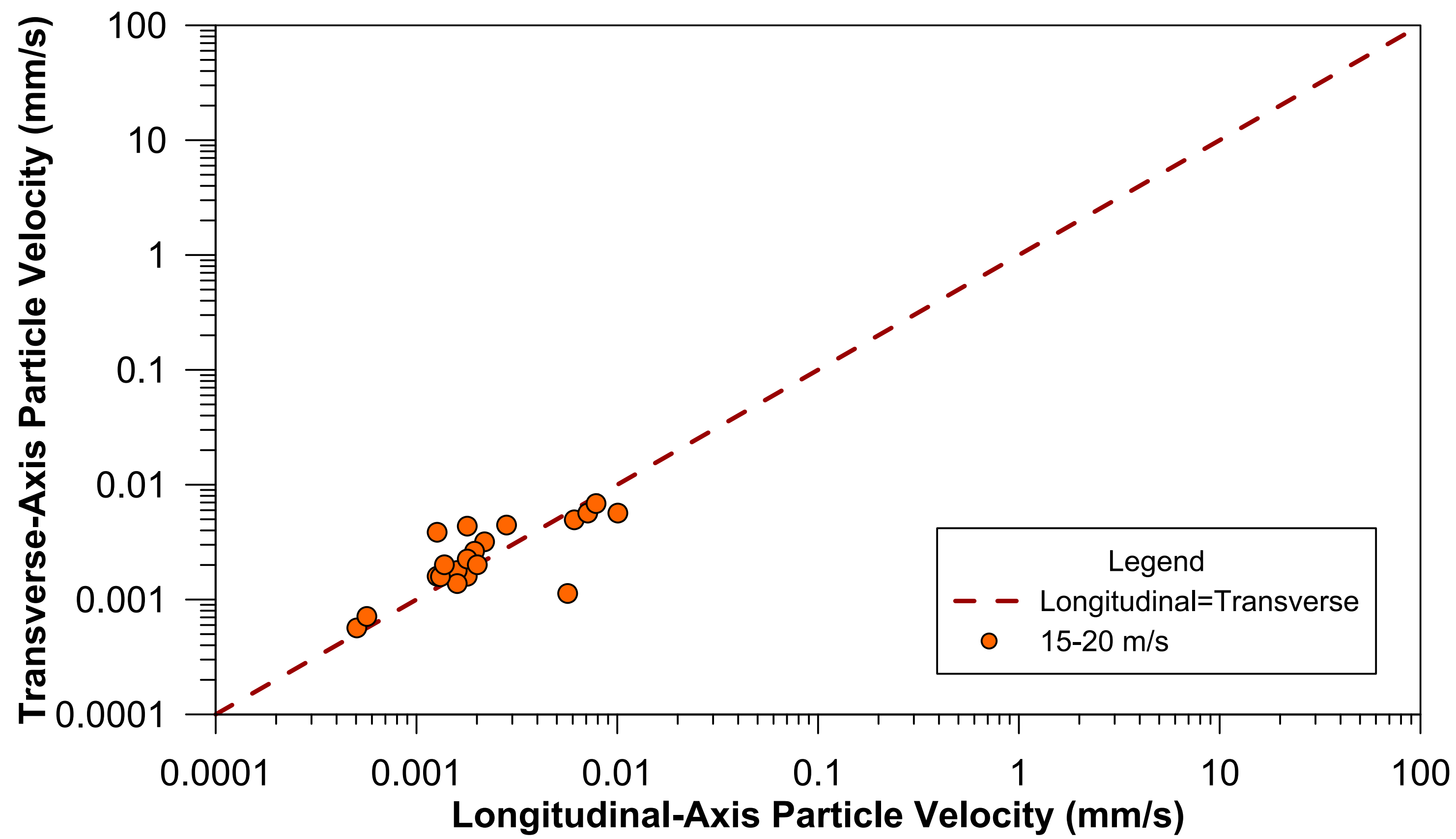
PROJECT	NORTH KENT 1 VIBRATION MONITORING
TITLE	SURFACE VIBRATION VELOCITY MEASURED AT DIFFERENT WIND SPEEDS RANGES FOR MOCK WELL CASINGS AT 1 Hz (PERIOD JANUARY 2018 TO APRIL 2021)

GOLDER
MEMBER OF WSP

PROJECT No.	1668031-4000	FILE No.	1668031-4000-R04011C (Ad#3)
		SCALE	AS SHOWN
		REV.	0
DRAWN	JGH	June 2021	
CHECK			FIGURE 11C







Notes:
1. This figure must be read with accompanying report.
2. Well casing vibration measurements based on persistence spectra and exclude transient influences (e.g., traffic, farm equipment, etc.).

PROJECT
NORTH KENT 1
VIBRATION MONITORING

TITLE
SURFACE VIBRATION VELOCITY MEASURED AT DIFFERENT WIND SPEEDS RANGES FOR MOCK WELL CASINGS AT 5 Hz
(PERIOD JANUARY 2018 TO APRIL 2021)

GOLDER
MEMBER OF WSP

PROJECT No. 1668031-4000		FILE No. 1668031-4000-R04011D (Add#3)	
		SCALE AS SHOWN	REV. 0
DRAWN	JGH	June 2021	FIGURE 11D
CHECK	SJS		

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